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A comparison of arthroscopy combined with continuous irrigation, arthroscopic debridement alone, and open arthrotomy for the treatment of septic arthritis of the native knee

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Abstract

Background The optimal surgical treatment for septic arthritis of the knee remains debatable, with few studies comparing different arthroscopic techniques. Furthermore, no study has simultaneously compared arthroscopy combined with continuous irrigation, arthroscopic debridement alone, and open arthrotomy. This study compared the efficacy and success rates of these three surgical methods and analyzed the risk factors for failure following initial surgery.

Methods Data were collected from patients who underwent surgery for native knee septic arthritis at the 900th Hospital of Joint Logistic Support Force in China between 2013 and 2023. A retrospective comparison of demographics, comorbidities, auxiliary examination results, causes, microorganisms, and efficacy outcomes was made among the three surgical groups.

Results A total of 65 patients (65 knees) were included in the study. All three groups had similar baseline characteristics. Postoperative C-reactive protein levels recovered faster in the continuous irrigation group than in the open group ($p < 0.001$). Both arthroscopic procedures showed a lower rate of hemoglobin decrease compared with open arthrotomy ($p = 0.005$ for the continuous irrigation group vs. open group; $p = 0.023$ for the debridement alone group vs. open group). The initial surgical success rate was higher in the continuous irrigation group (93.3%) than in the open group (65.2%) ($p = 0.025$). After adjusting for confounding factors through multivariate analysis, this advantage remained, with the risk of initial surgical failure in the open group being 11.31 times that in the continuous irrigation group (odds ratio = 11.31, 95% confidence interval: 1.7–75.24, $p = 0.012$). No significant differences were observed in postoperative range of motion, pain, or functional scores among the three groups.

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Conclusion No significant long-term functional differences were observed among the three surgical methods used to treat septic arthritis of the knee. The continuous irrigation group had an advantage in the early postoperative normalization of CRP levels and a higher initial surgical success rate than the open group.

Clinical trial number Not applicable.

Keywords Septic arthritis, Knee, Arthroscopy, Continuous irrigation, Arthrotomy, Native

Background

Septic arthritis is a rare orthopedic emergency, with an annual incidence of approximately 5–10 cases per 100,000 people, and its incidence is currently increasing [1, 2]. The disease progresses rapidly, and without timely treatment, it can lead to joint dysfunction, sepsis, or death in severe cases, with a mortality rate of approximately 10% [3]. The knee joint is the most commonly affected [4]. Some reports indicate that even with antibiotic treatment, the in-hospital mortality rate for septic arthritis remains between 7% and 15% [5]. Among patients undergoing arthroscopic lavage, the 90-day mortality rate is 7%, and adverse outcomes exceed 1% within 1 year [6]. Early and aggressive surgical intervention for knee septic arthritis can significantly reduce adverse outcomes and mortality rates [7–10].

Surgery primarily removes infectious materials, reduces bacterial load, and preserves joint function. Surgical treatments for septic arthritis of the knee can be categorized into traditional open surgery and arthroscopic surgery. Arthroscopic surgery is a minimally invasive procedure that enables direct visualization and irrigation of the joint [11–13]. In most studies, arthroscopic surgery refers to arthroscopic debridement and a single irrigation during the procedure. To our knowledge, few studies have compared different arthroscopic procedures for the treatment of knee septic arthritis [14]. This retrospective analysis study compared the efficacy and success rates following initial surgery among continuous irrigation after arthroscopy, arthroscopic debridement alone, and open arthrotomy as well as identifies the risk factors for initial surgical failure. This study hypothesized that arthroscopy combined with continuous irrigation would be superior to arthroscopic debridement alone and open surgery.

Methods

Data were collected from adult patients who underwent surgery for knee septic arthritis at our hospital between January 2013 and December 2023. Inclusion criteria were age ≥ 18 years, typical clinical symptoms (redness, fever, swelling, pain, effusion, and limited mobility), purulent joint fluid, elevated inflammatory markers, and pathogen diagnosis based on the Newman criteria [15], which includes (1) pathogen isolated from the joint; (2) redness, swelling, heat, and pain in the joint, with pathogens isolated from another source; (3) persistent joint pain and swelling after antibiotic treatment with cloudy synovial fluid; and (4) pathological or radiological evidence. The exclusion criteria were aseptic joint fluid, reactive arthritis, knee joint implants or prostheses, specific infections, and infections leading to femoral or tibial osteomyelitis.

Data collection

Demographic data for patients, including age, sex, body mass index (BMI), and comorbidities, were recorded. Comorbidities were assessed using the age-adjusted Charlson Comorbidity Index (aCCI). For patients suspected of septic arthritis, we routinely performed joint aspiration, with samples sent for bacterial culture, synovial fluid white blood cell (WBC) count, and the proportion of polymorphonuclear (PMN) cells. Laboratory tests included erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), WBC count, and neutrophil count. Systemic reactions, such as fever or shock were also recorded. Etiology data, microbiological results, and preoperative antibiotic use were collected. Additionally, the time from symptom onset to surgery, length of hospital stay, and infection severity graded according to the Gächter classification [16] were recorded. The degree of knee osteoarthritis was graded according to the Kellgren and Lawrence classification [17]. Postoperative functional outcomes were evaluated using range of motion, visual analog scale, and Lysholm score. The initial surgery failure rate was noted, and hemoglobin reduction was determined by comparing values after drain removal to preoperative values. For the arthroscopy group, the presence and duration of continuous irrigation, and volume of irrigation fluid were recorded.

Surgical procedure

The type of surgery and the necessity to operate were determined by the primary orthopedic surgeon. Five senior orthopedic surgeons performed the surgeries, with the same surgeons performing all arthroscopic procedures.

Operative technique

Open arthrotomy

Surgery was typically performed under epidural anesthesia. Sterile preparation and draping were performed using povidone-iodine solution. Before the skin incision,

the suprapatellar bursa was aspirated using a syringe to collect synovial fluid for testing. Subsequently, a medial parapatellar incision was made and dissected layer by layer to expose the infected area. A portion of the infected tissue was resected under direct vision for testing, and the joint was repeatedly irrigated with saline to thoroughly clean the infected tissue. After confirming complete debridement, the joint was re-irrigated until the fluid was clear, and a drainage tube was placed in the joint cavity before closing the incision.

Arthroscopic debridement alone

Surgery was typically performed under subarachnoid block anesthesia with the patient positioned supine. Sterile preparation was performed using povidone-iodine, followed by routine draping. An arthroscopic sheath was inserted into the suprapatellar pouch using the anterolateral portal. The joint fluid was collected for culture testing before activating irrigation. Subsequently, an anteromedial portal was established, and a portion of the synovial membrane was collected for culture testing. A powered shaver was used to debride the purulent material from the joint cavity, with the extent of synovectomy determined based on the degree of synovial invasion. The joint was irrigated with a large volume of normal saline during surgery, and a drain was placed through the lateral portal before closing the incision.

Arthroscopy combined with continuous irrigation

The debridement procedure followed the same steps as described above. Three drainage tubes were placed before closing the incision: one for irrigation and two for drainage. Under arthroscopic guidance, a drainage tube was inserted at the superolateral aspect of the suprapatellar pouch and connected to an infusion for continuous saline irrigation. Drainage tubes were inserted through both medial and lateral portals and connected to drainage bags before closing the incision. Upon returning to the ward, measures such as adjusting the drip rate, frequently manually compressing the drainage tube, and passively moving the affected limb, were implemented to prevent necrotic tissue and sediments from obstructing the drainage tube.

Postoperative treatment

Postoperatively, the drainage tubes in the open and debridement alone groups were removed 24–72 h later. In the arthroscopy combined with continuous irrigation group, the irrigation tube was removed after 8 days (average time). The criteria for tube removal included general improvement in the patient's condition, normal body temperature, significant reduction or absence of pain, absence of local redness or swelling, clear drainage fluid, marked improvement in joint movement limited by pain, and a significant downward trend in inflammatory markers, such as ESR and CRP. The irrigation and drainage tubes were initially removed, followed by the remaining drainage tube after 24–48 h.

If microorganisms were cultured preoperatively, appropriate antibiotics were administered intravenously. For patients with negative preoperative cultures, empirical antibiotics were initiated with subsequent adjustments based on microbial sensitivity. In cases where no microorganisms were cultured, broad-spectrum antibiotics such as glycopeptides and carbapenems were administered. After discharge, antibiotic therapy was switched to oral administration, with the entire duration of antibiotic treatment lasting approximately 4–6 weeks, which was extended appropriately based on the patient's condition. Typically, antibiotics are not added to the irrigation solution because their local effect level in the joint is higher than the minimum inhibitory concentration after intravenous administration. Additionally, local administration may increase the risk of cartilage toxicity [7, 11].

Statistical analysis

The Shapiro–Wilk test was used to assess the normality of continuous variable data. Variables following a normal distribution were expressed as mean (standard deviation), and intergroup comparisons were performed using analysis of variance, post-hoc multiple comparisons were performed using the least significant difference (LSD) test. For variables that did not follow a normal distribution, the median (interquartile range) was used, and intergroup comparisons were conducted using the Kruskal–Wallis test; significance levels were adjusted using the Bonferroni correction method. Categorical variables were expressed as numbers and frequencies, and intergroup comparisons were performed using the chi-squared test. Ordinal data were compared between groups using the Kruskal–Wallis test. Power analysis was conducted for the results that showed significant differences. A multifactorial logistic regression model was used to analyze the risk factors for postoperative recurrence, and the Hosmer–Lemeshow goodness-of-fit test was employed to assess the consistency between the predicted probabilities of the model and the actual observed outcomes. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). All statistical analyses were conducted using IBM SPSS Statistics version 27.0, with statistical significance set at $p < 0.05$.

Results

Demographic characteristics and comorbidities

A total of 103 suspected cases were recorded, and 65 patients were included in the study. Of these, 30(46%) patients underwent arthroscopic debridement with continuous irrigation (group A), 12(19%) underwent

arthroscopic debridement with single intraoperative irrigation (group B), and 23(35%) underwent open surgery (group C). Table 1 summarizes the patient characteristics. The median age of the continuous irrigation, arthroscopic debridement alone, and open groups were 51.5, 50.5, and 59 years, respectively ($p = 0.045$), indicating statistically significant differences among the three groups. Pairwise comparisons revealed that this difference originated from the continuous irrigation and open groups ($p = 0.018$). After adjusting the significance level using the Bonferroni correction method, the p-value was 0.053 (> 0.05). Therefore, no statistically significant differences were observed in age, sex ratio, BMI, duration of preoperative symptoms, fever, septicemia, or comorbidities among the groups.

Results of auxiliary examinations

The results of the preoperative synovial fluid examination and inflammatory markers are shown in Table 1. The median WBC count in synovial fluid was 18,000/μL in the continuous irrigation group, 20,960/μL in the debridement alone group, and 22,800/μL in the open group ($p = 0.978$). The proportions of PMN cells were 90%, 90%, and 93%, respectively ($p = 0.494$). The percentage of positive Leventhal test results (3 + and 4+) was 88.6%. Preoperative WBC and neutrophil counts were within the normal range. Among all patients, only one had a normal ESR, while the others showed varying degrees of elevation, with relatively concentrated values. Conversely, the CRP values were not concentrated. Radiologically, a high proportion of patients had Kellgren–Lawrence grades

Table 1 Differences among the three groups

Category	Group A ($n = 30$)	Group B ($n = 12$)	Group C ($n = 23$)	p-value
Male (n, %)	23 (76.7%)	10 (83.3%)	14 (60.9%)	0.285
Age (yr)	51.50 (31)	50.50 (29)	59 (10)	0.045
BMI (kg/m^2)	24.62 ± 3.88	23.14 ± 3.66	24.69 ± 3.97	0.480
Symptom duration (days)	9 (9)	14 (12)	10 (16)	0.310
Fever (n, %)	14 (46.67%)	5 (41.67%)	7 (30.43%)	0.485
Systemic sepsis (n, %)	0	1 (8.3%)	1 (4.4%)	0.335
Comorbidities				
Smoking (n, %)	12 (40%)	4 (33.3%)	7 (30.4%)	0.760
Alcoholism (n, %)	6 (20%)	2 (16.7%)	1 (4.4%)	0.250
Diabetes (n, %)	5 (16.7%)	3 (25%)	3 (13.0%)	0.669
Hypertension (n, %)	4 (13.3%)	2 (16.7%)	6 (26.1%)	0.487
Gout (n, %)	4 (13.3%)	1 (8.3%)	3 (13.1%)	0.413
Rheumatoid arthritis (n, %)	5 (16.7%)	1 (8.3%)	8 (34.8%)	0.132
Age-adjusted Charlson Comorbidity Index	2 (3)	2 (4)	3 (2)	0.363
Knee arthrocentesis				
White blood-cell count (/μL)	18,000 (37160)	20,960 (46220)	22,800 (23320)	0.978
Polymorphonuclear cells (%)	90 (24.25)	90 (48)	93 (8.50)	0.494
Blood				
White blood-cell count (10^9/L)	8.28 (3.14)	7.74 (2.91)	8.53 (4.16)	0.399
Neutrophils (10^9/L)	6.19 (2.72)	5.84 (2.90)	6.19 (4.25)	0.570
CRP (mg/L)	96 (105.15)	91.7 (107.1)	86.7 (116.98)	0.301
ESR (mm/h)	79.57 ± 30.38	58.08 ± 30.98	69.27 ± 26.77	0.095
Gächter (n, %)				
I	3 (10%)	3 (25%)	2 (8.7%)	0.339
II	13 (43.3%)	6 (50%)	14 (60.9%)	0.449
III	14 (46.7%)	3 (25%)	5 (21.7%)	0.128
IV	0	0	2 (8.7%)	0.152
Kellgren and Lawrence (n, %)				
0	2 (6.7%)	0	1 (4.3%)	0.647
I	3 (10%)	2 (16.7%)	0	0.174
II	14 (46.7%)	6 (50%)	11 (47.8%)	0.981
III	11 (36.7%)	4 (33.3%)	10 (43.5%)	0.811
IV	0	0	1 (4.3%)	0.396

Among the continuous variables, BMI and ESR followed a normal distribution and were expressed as means ± SD. Other continuous variables were presented as median and interquartile range. Categorical variables were expressed as counts and percentages. Subsequent tables follow the same principle

BMI, body mass index; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate

Table 2 Etiology of septic arthritis

Etiology	Group A (*n* = 30)	Group B (*n* = 12)	Group C (*n* = 23)	*p*-value
Hematogenous spread	13 (43.3%)	4 (33.3%)	14 (60.9%)	0.244
Knee surgery	8 (26.7%)	3 (25.0%)	5 (21.7%)	0.918
Invasive procedure	7 (23.3%)	4 (33.3%)	2 (8.7%)	0.185
Trauma	2 (6.7%)	1 (8.3%)	1 (4.3%)	0.886
Idiopathic	0 (6.7%)	0 (6.7%)	1 (4.3%)	0.396

Table 3 Distribution of etiologic agents isolated in synovial fluid cultures of patients with knee septic arthritis

Species	Number of patients	Percentage
Negative culture	26	40%
Coagulase-negative Staphylococcus	18	27.7%
Staphylococcus aureus	14	21.5%
Pseudomonas aeruginosa	5	7.7%
Hemolytic streptococcus	2	3%
Enterobacter hormaechei	1	1.5%
Sphingobacterium multivorum	1	1.5%
Enterococcus faecalis	1	1.5%

*There were three cases of mixed infections, and 12 cases of methicillin-resistant Staphylococcus

Table 4 Univariate logistic regression analysis of etiological risk factors for culturing methicillin-resistant bacteria

Variable	Odds ratio (95% CI)	*p*-value
Hematogenous spread	0.88 (0.12 ~ 6.58)	0.897
Knee surgery	7.88 (1.11 ~ 56.12)	0.039
Invasive procedure	0.38 (0.07 ~ 2.17)	0.277
Trauma	0.000	0.999
Idiopathic	-	-

CI, confidence interval

II and III (84.6%). No statistically significant differences were observed among the groups.

Etiology and microbiological results

The etiological results are summarized in Table 2. There is no statistically significant difference in the etiology among the groups. Among the etiologies, hematogenous dissemination was the most common (47.7%), followed by a history of knee surgery (24.6%), and invasive knee procedures (20%). Other causes were relatively rare. The microbial culture results are presented in Table 3. The positive culture rate was 60% and the most common bacteria were coagulase-negative staphylococci (27.7%), followed by *Staphylococcus aureus* (21.5%). Three cases of mixed infections and 12 cases of methicillin-resistant Staphylococcus (4 methicillin-resistant *Staphylococcus aureus* and 8 methicillin-resistant coagulase-negative staphylococci) were observed. The proportion of patients who used antibiotics preoperatively was 35.3%. In our study, each etiology was independent of each other. The etiological risk factors for culturing methicillin-resistant Staphylococcus were analyzed using univariate logistic regression analysis, as presented in Table 4. A history of knee surgery had an OR of 7.88 (1.11–56.12, $p < 0.05$), indicating that patients with septic arthritis of the knee with a history of knee surgery had a 7.88 times higher risk of culturing methicillin-resistant Staphylococcus than those without a knee surgical history.

Comparison among the three groups

The efficacy comparisons among the three groups are presented in Table 5. The median time for postoperative CRP to return to normal was 8 days in the continuous irrigation group, 10 days in the debridement alone group, and 21.5 days in the open group ($p < 0.001$), with a post-hoc power analyses revealing a statistical power of 99.9%. For the comparison among the three groups). Pairwise comparisons showed significant differences between the continuous irrigation and open groups ($p < 0.001$), indicating that CRP levels normalized more quickly in the continuous irrigation group. We compared the hemoglobin decline rates before and after irrigation and found a statistically significant difference among the three groups ($p = 0.011$). Post-hoc multiple comparisons using the LSD test revealed no statistically significant difference between the two arthroscopic groups ($p = 0.964$), indicating that continuous irrigation does not lead to additional hemoglobin decline. Conversely, both arthroscopic procedures had a lower rate of hemoglobin decline compared with open surgery (continuous irrigation group vs. open

Table 5 Comparison of treatment outcomes among the three groups

Category	Group A ($n=30$)	Group B ($n=12$)	Group C ($n=23$)	p-value
Hospitalization (days)	19.5 (8)	22.5 (18)	17 (10)	0.414
Time to normalization of CRP after surgery (days)	8 (7)	10 (15)	21.5 (19)	<0.001
Hemoglobin decrease rate (%)	9.6 ± 7.88	9.49 ± 3.66	15.69 ± 8.06	0.011
Decrease in VAS score	7 (2)	6.5 (3)	6 (3)	0.065
Improvement in ROM (degrees)	12.5 (16)	15 (18)	10 (15)	0.233
Success of initial surgical procedure (n, %)	28 (93.3%)	9 (75%)	15 (65.2%)	0.036
Lysholm score at final follow-up	87 (12)	84 (19)	84 (18)	0.468

CRP, C-reactive protein; VAS, visual analog scale; ROM, range of motion

Table 6 Multivariable logistic regression: independent risk factors for failure of initial surgery in knee septic arthritis

Variable	Odds ratio (95% CI)	p-value
Open arthrotomy	11.31 (1.7 ~ 75.24)	0.012
Arthroscopic debridement alone	6.87 (0.83 ~ 56.96)	0.078
Infection classification III and above	4.39 (0.91 ~ 21.33)	0.066
Positive culture	0.62 (0.15 ~ 2.58)	0.511
Symptom duration	0.99 (0.91 ~ 1.08)	0.812

The Hosmer–Lemeshow goodness-of-fit test yielded a p-value of 0.399, which is greater than 0.05, indicating that the model fits well

CI, confidence interval

group, $p=0.005$), with post-hoc power analyses revealing a statistical power of 77%; debridement alone group vs. open group, $p=0.023$, post-hoc power analyses revealed a statistical power of 85.8%). Differences were observed in the first surgery success rates among the three groups ($p=0.036$), with the continuous irrigation group having a higher success rate (93.3%) compared with the open group (65.2%) ($p=0.025$); the post-hoc power analyses revealed a statistical power of 75.9%. No statistically significant differences were observed between the two arthroscopic groups ($p=0.131$) or between the debridement alone and open groups ($p=0.709$). In this study, the shortest follow-up time for 65 patients was 11 months. Only one patient succumbed to a cerebrovascular accident 3 months postoperatively (1.54%).

As shown in Table 6, the results of the multivariate analysis indicated that the risk of first surgery failure in the open group was 11.31 times higher than that in the continuous irrigation group (OR = 11.31, 95% CI: 1.7–75.24, $p<0.05$). Although infection grade classification III and above were statistically significant in the univariate analysis, it was non-significant in the multivariate model (OR = 4.39, 95% CI: 0.91–21.33, $p=0.066$, $p>0.05$).

Discussion

The most appropriate procedure for treating septic arthritis of the knee remains controversial, with previous studies largely comparing arthroscopic and open surgeries. Some researchers argue that arthroscopic surgery is superior to open surgery [18–21], whereas others hold the opposite view [22, 23]. Additionally, some studies have reported no significant differences between the two procedures [24–26]. A detailed review of the arthroscopic surgical techniques described in these articles indicated that "arthroscopic surgery" typically referred to arthroscopic debridement and intraoperative irrigation alone. Postoperatively, only a single drainage tube was left in place and typically removed after 24–48 h. Few studies have explored the differences among various arthroscopic procedures. We hypothesize that the differing results in studies comparing arthroscopic and open surgeries may be due to the different types of arthroscopic techniques. Therefore, we reviewed patients who underwent surgery for septic knee arthritis over a 10-year period, categorizing them into three comparison groups: arthroscopy combined with continuous irrigation, arthroscopic debridement alone, and open arthrotomy. The main finding of this study is that arthroscopy combined with continuous irrigation exhibited a higher initial surgical success rate than open surgery did in treating primary septic arthritis of the knee, which was also confirmed using multivariable analysis. Moreover, compared to open surgery, arthroscopy with continuous irrigation showed an advantage in faster normalization of CRP levels. However, with a minimum follow-up time of 11 months, no statistically significant difference was observed in final pain and functional scores among the three groups.

The initial surgical success rate was significantly higher in the continuous irrigation group (93.3%) than in the open group (65.2%). We encouraged the patients to perform functional exercises after drainage tube removal. Owing to the longer duration of tube placement in the continuous irrigation group, the initiation of exercises was delayed compared with that in the other two groups. Consequently, the expected functional advantages were

not achieved although the initial surgical success rate was high. The postoperative CRP levels in the continuous irrigation group returned to normal levels faster than those in the other two groups. While we advocate for thorough debridement, it is beneficial to appropriately preserve the synovial tissue, which has barrier and immune functions [27]. We typically adopted a more aggressive approach to synovial debridement when dealing with cases of Gächter grade III or higher [8]. Continuous irrigation promptly flushes away bacteria that escaped during surgery, as well as the toxins or proteases produced by these bacteria, thereby reducing the inflammatory response in the joints. This promotes a rapid decrease in inflammatory markers and swift control of the infection. We were concerned that continuous irrigation could lead to additional hemoglobin loss. Therefore, we compared the hemoglobin decrease rates from pre-surgery to post-drain removal among the three groups. We found no significant differences between the continuous irrigation and debridement alone groups. Notably, the hemoglobin decrease rates for both arthroscopic procedures were lower than those for the open group, which is related to the greater tissue damage and higher intraoperative blood loss associated with open surgery. Some studies suggest that the risk of blood transfusion and anemia is higher in open surgery compared with arthroscopic surgery [28, 29].

For variable selection in the multifactor logistic regression analysis model, in addition to including variables with $p < 0.05$ from the univariate analysis, we also considered variables identified in other studies as having independent effects on treatment failure. For instance, Dave et al. found that a longer time from symptom onset to surgery increased the likelihood of requiring multiple surgeries [30]. Schoenfeldt et al. also reported that patients with positive joint cultures had higher reoperation rates than those with negative cultures [23]. Aïm et al. identified Gächter stage III or IV as factors significantly associated with treatment failure [9]. A study on septic arthritis of the shoulder reported that irrigation volume was a risk factor for surgical failure [31]. Additionally, we considered potential confounding factors based on clinical reasoning, such as preoperative antibiotic use and aCCI. Ultimately, we found that open surgery was an independent risk factor for initial surgery failure, with the risk of initial surgery failure in the open group being 11.31 times higher than that in the continuous irrigation group.

Although the difference was not statistically significant, the patients in the open group appeared to be older. Younger patients tend to prefer minimally invasive arthroscopic surgery over open surgery. To address potential age differences, we compared the three groups using the aCCI to evaluate the differences in baseline conditions. The results showed no statistically significant differences in aCCI among the three groups. Ultimately, no statistically significant differences were observed among the three groups regarding demographic characteristics, comorbidities, systemic symptoms, etiology and infection grading, joint fluid and blood laboratory results, or imaging findings, indicating good homogeneity.

In this study, the male-to-female ratio was approximately 2:1, which is consistent with ratios reported in the literature [6, 32]. Male sex is considered a high-risk factor for septic arthritis of the knee, with some researchers suggesting a negative impact of this variable on treatment success [18]. In China, the normal BMI range is 18.5–23.9 kg/m^2. The mean BMI in this study was 24.37 ± 3.86 kg/m^2, suggesting that being overweight may be a potential risk factor for septic arthritis of the knee [33]. This could be due to the increased load on the knee joint from higher body weight, which indirectly increases the risk of developing the condition. In this study, the incidence of fever (40%) and symptoms related to systemic infections (sepsis, 3%) were lower than expected. Extant studies report that approximately 60% of patients with septic arthritis present with fever (> 37.5 °C) preoperatively. However, prospective studies indicated that this proportion is lower among culture-positive patients (34%) [3, 34]. This finding contradicts common clinical perceptions and suggests that patients with septic arthritis do not necessarily present with fever. The most common clinical symptoms include swelling and pain in the knee joint, often accompanied by impaired mobility. Although most studies suggest that *Staphylococcus aureus* is the most common pathogen in septic arthritis of the knee [35–38], our study found that coagulase-negative Staphylococcus had the highest detection rate, followed by *Staphylococcus aureus*. This may be related to the high proportion of patients in the study population with a history of surgery or invasive procedures (44.6%). The less typical clinical presentation caused by coagulase-negative staphylococci may also explain the lower incidence of fever and systemic symptoms mentioned earlier.

A synovial fluid WBC count > 50,000/μL is typically considered the diagnostic threshold for septic arthritis of the knee [39, 40]. However, some researchers argue that WBC counts can vary widely, with over 30% of patients having counts < 50,000/μL [41]. In our study, only 16.1% of patients had WBC counts > 50,000/μL, with a median of approximately 20,000/μL. This confirms the low sensitivity of this threshold, although its high specificity cannot be ignored. However, the percentage of PMN cells was more consistent, with approximately 90% of the patients having a PMN percentage close to 90%. Studies have shown that a PMN percentage ≥ 90% strongly suggests septic arthritis of the knee [39]. Although septic arthritis of the knee is considered an orthopedic emergency, its clinical presentation is often subacute [38]. In

our study, the median time from symptom onset to hospital presentation was 12 days. The elevation in WBC and neutrophil counts was atypical, and neutrophils did not demonstrate a superior predictive ability for the disease compared with WBCs. CRP and ESR levels were elevated in most patients, with ESR showing a more consistent elevation. Some researchers have suggested that the ESR has a sensitivity of 96% for diagnosing knee septic arthritis at a threshold of 30 mm/h [41], aligning with our findings. CRP is a more sensitive marker for monitoring the effectiveness of postoperative treatment. In our study, the median time for postoperative CRP levels to return to normal was 11.5 days, similar to that reported in other studies [42]. In contrast, monitoring the time required for the ESR to return to normal postoperatively is more challenging and can take weeks or even months.

This study has several limitations. First, this was a retrospective study, and the type of surgery performed was determined by the primary orthopedic surgeon, which may have introduced bias. Further prospective or randomized studies are needed to eliminate bias and validate these findings. In the enrolled cases, surgeons adhered to the principle that Gächter stages I–III are suitable for arthroscopic surgery, whereas Gächter stage IV typically necessitates open surgery. In this study, only one stage IV case was recorded, which was treated with open surgery. The impact of Gächter stages was accounted for in the multivariate analysis. Second, owing to the low incidence of septic knee arthritis, our 10-year data extraction resulted in an insufficient sample size, particularly for arthroscopic debridement alone, which may have reduced the statistical power. Last, as this was a single-center study, the potential for selection bias cannot be ruled out.

Conclusions

No differences in pain and function were observed among the three surgical methods used to treat septic arthritis of the knee. The continuous irrigation group had an advantage in early postoperative normalization of CRP levels and a higher initial surgical success rate than the open group. This was also confirmed using the multivariate model.

Abbreviations

aCCI	Age adjusted charlson comorbidity index
BMI	Body mass index
CI	Confidence interval
CRP	C-reactive protein
ESR	Erythrocyte sedimentation rate
OR	Odds ratio
PMN	Polymorphonuclear cells
WBC	White blood cell count

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Author contributions

JX: Data curation, data analysis, and writing. WW: Data curation, data analysis. SL: Methodology. YZ: Methodology. KL, TY, and QW were involved in data collection, case diagnosis, and confirmation of this article. FS: Visualization. XY: Project administration and funding acquisition.XH: Ideas, funding acquisition and writing - review & editing.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the ethic committee of the 900th Hospital of the Joint Logistics Team, PLA (IRB No. 2024-016). All methods were carried out in accordance with Declaration of Helsinki. All participants provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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