Subcutaneous versus Intraarticular Indwelling Closed Suction Drainage after TKA

A Randomized Controlled Trial

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Abstract

Background TKA can involve substantial bleeding, and the issue regarding whether vacuum drainage should be used during TKA continues to be debated as both methods have disadvantages.

Questions/purposes We therefore asked whether subcutaneous indwelling vacuum drainage is advantageous over intraarticular indwelling vacuum drainage in terms of blood drainage, bleeding-related complications, and functional outcomes in primary TKA.

Patients and methods We randomized 111 patients undergoing TKAs to have either a subcutaneous indwelling or an intraarticular indwelling catheter and compared the two groups for blood loss (hemoglobin decrease, transfusion requirements, hypotension episode), incidence of wound problems (requirements for dressing reinforcement,

oozing, hematoma, hemarthrosis, ecchymosis, infection), and functional outcomes (recovery of motion arc, American Knee Society, WOMAC, and SF-36 scores) at 12 months after surgery.

Results The mean vacuum drainage volume was less in the subcutaneous indwelling group than in the intraarticular indwelling group (140 mL versus 352 mL). The groups were similar in terms of decreases in hemoglobin after 2 and 5 days (3.0 versus 3.3 g/dL and 3.3 versus 3.7 g/dL, respectively), allogenic transfusion requirements (4% versus 11%), incidence of wound problems, and functional scores.

Conclusions The data suggest subcutaneous indwelling closed-suction drainage is a reasonable alternative to intraarticular indwelling closed-suction drainage and to no suction drainage.

Level of Evidence Level I, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol used for this investigation, that all investigations were conducted in conformity with the ethical principles of research, and that informed consent for participation in the study was obtained. This work was performed at Seoul National University Bundang Hospital.

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Introduction

Substantial bleeding may occur at intraarticular and subcutaneous sites after TKA [11, 17, 24, 32, 40, 43], and this can result in blood transfusion, which has been associated with many complications [5, 6]. In addition, excessive bleeding may lead to intraarticular or subcutaneous hematoma formation, which can impair wound healing, restrict mobilization, and increase the risk of deep infection [18, 22, 31]. Vacuum drainage is commonly used after TKA with the intent of preventing intraarticular or subcutaneous hematoma formation and thus decreasing the likelihood of delayed recovery of motion arc, prolonged drainage, and wound infection [7, 18, 22, 29, 30, 44].

There are two schools of thought regarding the use of vacuum drainage after TKA: to use indwelling vacuum drainage in the intraarticular space [18, 22, 29, 44] or to not use any form of vacuum drainage [1, 3, 10, 15, 20, 23, 28, 30, 35, 36]. Intraarticular placement of a vacuum drain can reduce undesirable blood accumulation and thus prevent intraarticular or subcutaneous hematoma formation [18, 22, 29, 30]. However, it can increase blood loss and induce circulatory instability owing to acute blood drainage through the drainage system, which increases the likelihood of postoperative blood transfusion [15, 20, 28–30, 35]. However, the nonuse of an indwelling vacuum drain, owing to a tamponade effect, can reduce total blood loss but also can increase bleeding into dressings and cause wound complications [18, 22, 29, 30]. Therefore, both approaches have limitations, and the issue of vacuum drainage after TKA remains a matter of debate. Nonetheless, many arthroplasty surgeons routinely place an intraarticular indwelling vacuum drain [2, 7, 8, 12, 13, 16, 21, 23, 25–27, 33, 34, 37, 38, 41–43, 45, 47].

We speculated subcutaneous indwelling closed-suction drainage might offer a beneficial alternative to intraarticular indwelling closed-suction drainage and address the shortcomings of both methods: it might provide an intraarticular tamponade effect as the joint is not drained and yet have a drainage effect subcutaneously. Subcutaneous indwelling closed-suction drainage has been used in other types of surgery including breast and thyroid [9, 39]. We have used the subcutaneous indwelling method for 3 years and have noted no particular problems with blood loss or wound complications. We are unaware of other reports for this application.

Accordingly, we compared subcutaneous indwelling closed-suction drainage and intraarticular indwelling closed-suction drainage in terms of hematologic parameters including blood drainage, bleeding-related complications, and functional outcomes in primary TKA. We hypothesized the subcutaneous indwelling method would reduce blood loss with comparable functional outcomes and wound problem incidences.

Patients and Methods

We randomly allocated 111 patients (111 knees) with advanced osteoarthritis scheduled for unilateral TKA during the 12-month period from May 2006 through April 2007 to either the subcutaneous group or intraarticular indwelling group using a computer-generated randomized table. The randomization table in permuted blocks of four and six was created by a statistician who was independent of this study. Patients and surgeon were unaware of block

sizes. The patients and an independent investigator (SWY) who collected all clinical information prospectively were kept blind to the randomization until final data analyses. We excluded patients undergoing revision or simultaneous bilateral primary TKAs, patients with a diagnosis other than primary osteoarthritis, and patients with coagulation disorders. Fifty-four patients were assigned to the subcutaneous indwelling group and 57 to the intraarticular indwelling group. We performed an a priori power analysis for Student's *t* test and for Fisher's exact test, which were to be used for the comparisons between the two groups at an alpha level of 0.05 using the PS program (<http://biostat.mc.vanderbilt.edu/wiki/Main/PowerSampleSize>) [14]. We regarded the following differences as clinically meaningful: greater than 50 mL in drained volume, 0.5 mg/dL in hemoglobin level, 10% in the incidence of bleeding-related wound problems, 10° motion arc, and 10% of maximum points in functional outcome scales. These analyses indicated sample sizes of 36, 32, 110, 32, and 18 were required for each group to achieve significance in the above clinical differences, respectively, indicating, with the exception of the incidence of wound problems, the cohort size (*n* = 111) was adequate. We observed no demographic differences in the two groups (Table 1). No patients were lost to followup. All patients were seen 12 months post-surgery to collect data for this study. Informed consent was obtained from all patients, and the Institutional Review Board at our hospital approved the study protocol. The study protocol was registered at ClinicalTrials.gov (identifier: NCT00916331).

Surgeries were performed by one surgeon (TKK) using the standard medial parapatellar approach, under spinal anesthesia, and using a pneumatic tourniquet. All knees were implanted with the same prosthesis (Genesis[®] II posterior-stabilized type; Smith & Nephew, Memphis, TN), and all prostheses were fixed with cement. After cement application, the tourniquet was released to allow arterial bleeders to be electrocoagulated. In the intraarticular indwelling group, a vacuum drainage system

Table 1. Demographic data for subcutaneous and intraarticular closed suction drainage groups

Variable	Subcutaneous indwelling (n = 54)	Intraarticular indwelling (n = 57)	p Value
Age (years)*	73.5 (5.5)	71.9 (5.9)	0.146
Gender (female)	52 (96.3%)	53 (93.0%)	0.679
Body weight (kg)*	62.6 (10.3)	61.7 (7.9)	0.594
Body height (cm)*	152.2 (6.6)	151.8 (5.7)	0.748
Body mass index (kg/m ²)*	27.0 (3.8)	26.7 (2.5)	0.655

* Data are presented as means, with SDs in parentheses.

Fig. 1A–B Placement of the (A) subcutaneous and (B) intraarticular closed-suction drainage systems is shown. The black arrow indicates the indwelling drain.

(Varobac; Sewoon Medical Co, Ltd, Cheonan, Korea) was placed in the intraarticular space (the medial gutter) before joint capsule closure (Fig. 1). The joint capsule was closed using an interrupted suture technique using Number 1 Vicryl® sutures (Ethicon, Inc, Somerville, NJ). In the subcutaneous indwelling group, a vacuum drainage system was placed in the subcutaneous space (below the medial skin flap) after joint capsule closure (Fig. 1). We closed the subcutaneous layer with an interrupted suture technique using Number 2 Vicryl® sutures. The skin was closed using a metal stapler, and an elastic compression dressing then was applied. In the subcutaneous indwelling group, vacuum drains were kept open constantly whereas, in the intraarticular indwelling group, they were opened after 2 hours of clamping. All drains were removed in both groups 24 hours postoperatively during first dressing changes; wound dressings subsequently were changed every other day. However, when a dressing was saturated, it was changed or reinforced regardless of the schedule.

The same blood transfusion, prophylactic antibiotic, and thromboprophylaxis guidelines were used for all patients. Allogenic blood transfusion was performed if hemoglobin decreased to less than 7.0 mg/dL or if anemic symptoms developed, such as a decrease in blood pressure to less than 100 mmHg, tachycardia greater than 100 beats/minute, or a low urine output less than 30 mL/hour, even after volume replacement with 500 mL normal saline in patients with a hemoglobin level between 7.0 and 8.0 mg/dL [29, 32]. Allogenic transfusion was not performed when the hemoglobin level was greater than 8.0 mg/dL. All patients were given 1 g first-generation cephalosporin 30 minutes before skin incision and were covered for 24 hours with three additional doses. All patients were given low-molecular-

weight heparin (enoxaparin 40 mg) subcutaneously daily from Postoperative Days 1 to 7.

All patients underwent the same postoperative rehabilitation protocol. Patients learned how to perform quadriceps-strengthening exercises and how to use a walking aid at a physiotherapy unit preoperatively and were encouraged to perform quadriceps-strengthening exercises postoperatively in the ward during the first postoperative day. One day after surgery, patients were allowed to walk to the toilet using a walking aid and received a 50-minute continuous passive motion (CPM) session with a ROM of 0° to 30°. CPM sessions were continued for 2 weeks postoperatively, and ROMs were increased gradually as tolerated. Patients began to dangle their legs and perform active ROM exercises from the second postoperative day and underwent a daily physiotherapy session at our rehabilitation center from the third to the fourteenth postoperative days. Patients typically were discharged 2 weeks after surgery unless they wanted to go home earlier or had medical conditions develop that required an additional hospital stay.

All patients were evaluated to collect data relating to hematologic parameters including blood drainage, wound problems, and functional outcomes at 12 months after surgery. Total drainage volumes were monitored over 24-hour periods. Hemoglobin levels were checked at 2 days, 5 days, 2 weeks, 6 weeks, and 3 months postoperatively, and hemoglobin decreases versus preoperative levels were checked on the second and fifth postoperative days. In addition, hemoglobin recovery was calculated at 2 weeks, 6 weeks, and 3 months postoperatively versus the fifth postoperative day, when hemoglobin levels typically were lowest. Furthermore, incidents of postoperative hypotension, which we presumed were associated with

rapid blood loss via indwelling drainage, were recorded. A hypotension episode was defined as a systolic blood pressure less than 90 mm Hg or as 30 or more points lower than a previous systolic blood pressure. When wound dressings were changed, we noted the presence of any bleeding-related wound problems, including oozing persisting beyond 2 days after surgery, subcutaneous hematoma (requiring aspiration or surgical drainage), hemarthrosis (requiring aspiration or surgical drainage), ecchymosis (larger than 3 cm in diameter), and wound infection (requiring additional treatments such as antibiotics coverage or surgical debridement). The decisions to perform aspirations or surgical debridement were made at the discretion of the operating surgeon (TKK) considering clinical scenarios. If a dressing had been reinforced or changed because it was saturated, this was noted. In addition, patients were evaluated preoperatively and 12 months postoperatively for knee motion arc (flexion contracture and maximum flexion), and the following scoring systems were applied: the American Knee Society (AKS) knee and function scoring system [19], the WOMAC scoring system [4], and the SF-36 scoring system [46]. The same clinical research assistant measured the knee motion arc to the nearest 5° using a standard clinical goniometer, with the patient in the supine position.

The two study groups were compared with respect to blood volumes collected via indwelled drains, changes in hemoglobin levels at 2 and 5 days and at 2, 6, and 12 weeks postoperatively, requirements for allogenic blood transfusion, and bleeding-related wound problems (dressing reinforcement, oozing, subcutaneous hematoma, hemarthrosis, ecchymosis, infection), and functional outcomes (motion arc, AKS knee and function scores, WOMAC scores, SF-36 scores). The Kolmogorov-Smirnov test was used to determine whether continuous variables were normally distributed. Fisher's exact test or the Yates chi square test was used to analyze categorical variables. Student's *t* test was used to analyze continuous variables for normally distributed data, and the Mann-Whitney *U* test

was used for nonnormally distributed variables (preoperative and postoperative maximum flexion, preoperative and postoperative AKS scores, and preoperative and postoperative WOMAC scores). We used analysis of covariance (ANCOVA) to adjust for the effects of preoperative differences on continuous outcome variables. In addition, to evaluate the confounding effects by differences in operation time, we compared mean operation time and found no difference ($p = 0.420$, Student's *t* test) between the subcutaneous and intraarticular indwelling groups (87 versus 89 minutes). Statistical analysis was performed using SPSS® for Windows® (Version 12.0; SPSS Inc, Chicago, IL).

Results

There was no difference between patients in the subcutaneous drain group and intraarticular drain group regarding hematologic parameters except drained volume via vacuum drainage (Table 2). Mean drained volume via vacuum drainage was smaller ($p < 0.001$) for patients in the subcutaneous indwelling group than for those in the intraarticular indwelling group (140 mL versus 352 mL). However, there was no difference between patients in the subcutaneous and intraarticular indwelling groups at 2 days (3.0 g/dL versus 3.3 g/dL, $p = 0.079$) and 5 days (3.3 g/dL versus 3.7 g/dL, $p = 0.094$) postoperatively. Allogenic transfusion requirements between patients in the subcutaneous indwelling and intraarticular indwelling groups (4% versus 11%) were similar ($p = 0.272$). One patient in each group experienced a hypotension episode postoperatively, but both recovered after volume replacements without any residual medical problems. No group differences were observed in terms of hemoglobin recovery at 2, 6, and 12 weeks postoperatively from levels on the fifth postoperative day.

The two groups were comparable in terms of rates of wound problem incidences and functional outcomes

Table 2. Comparisons of hematologic data for subcutaneous and intraarticular groups

Variable	Subcutaneous indwelling (n = 54)	Intraarticular indwelling (n = 57)	p Value
Hemovac drainage (mL)*	139.8 (118.4) (0–495)	352.1 (204.3) (20–880)	< 0.001
Allogenic blood transfusion†	3.7% (2)	10.5% (6)	0.272
Hypotension episode†	1.9% (1)	1.8% (1)	1.000
Hemoglobin drop after 2 days (g/dL)*	3.0 (1.1)	3.3 (0.9)	0.079
Hemoglobin drop after 5 days (g/dL)*	3.3 (1.3)	3.7 (1.2)	0.094
Hemoglobin recovery after 2 weeks (g/dL)*	1.7 (1.0)	1.6 (1.0)	0.776
Hemoglobin recovery after 6 weeks (g/dL)*	3.6 (1.1)	3.4 (1.2)	0.437
Hemoglobin recovery after 12 weeks (g/dL)*	4.2 (1.1)	4.1 (1.2)	0.727

* Data are presented as means, with SDs in parentheses; †data are presented as percentages, with numbers of patients in parentheses.

Table 3. Comparisons of incidences of bleeding-related wound problems for subcutaneous and intraarticular groups

Complication	Subcutaneous indwelling (n = 54)	Intraarticular indwelling (n = 57)	p Value
Dressing reinforcement	0% (0)	0% (0)	1.000
Oozing	3.7% (2)	3.5% (2)	1.000
Subcutaneous hematoma	1.9% (1)	1.8% (1)	1.000
Ecchymosis	9.3% (5)	10.5% (6)	0.823
Hemarthrosis	1.9% (1)	5.3% (3)	0.619
Infection	0% (0)	0% (0)	1.000

Data are presented as percentages of knees with a complication, with numbers of knees in parentheses.

Table 4. Comparisons of functional outcomes for subcutaneous and intraarticular groups

Variable	Subcutaneous indwelling (n = 54)	Intraarticular indwelling (n = 57)	p Value
Preoperative status			
Flexion contracture (°)	12.5 (9.7)	14.6 (7.0)	0.053
Maximum flexion (°)	137.2 (17.0)	138.4 (18.0)	0.165
AKS knee score	46.8 (9.7)	43.9 (10.8)	0.200
AKS function score	63.6 (10.1)	58.9 (12.0)	0.275
WOMAC pain	10.0 (3.8)	10.3 (3.7)	0.698
WOMAC stiffness	4.3 (2.3)	4.4 (1.9)	0.700
WOMAC function	36.0 (12.0)	35.5 (12.2)	0.864
SF-36 PCS	41.0 (12.0)	40.1 (9.9)	0.368
SF-36 MCS	31.6 (7.5)	30.9 (6.3)	0.760
Postoperative outcome			
Flexion contracture (°)	0.2 (1.0)	0.0 (0.0)	0.923
Maximum flexion (°)	132.6 (15.5)	131.2 (11.6)	0.745
AKS knee score	93.6 (5.7)	93.3 (6.6)	0.711
AKS function score	90.7 (14.1)	90.0 (13.5)	0.727
WOMAC pain	3.0 (3.6)	3.5 (3.9)	0.415
WOMAC stiffness	1.9 (1.8)	1.8 (1.6)	0.463
WOMAC function	15.9 (10.1)	18.5 (11.6)	0.917
SF-36 PCS	46.3 (11.7)	47.1 (10.4)	0.511
SF-36 MCS	43.4 (8.2)	39.2 (11.1)	0.104

Data are presented as means, with SDs in parentheses; AKS = American Knee Society; PCS = Physical Component Summary, MCS = Mental Component Summary.

(Table 3). No patient in either group underwent additional surgery for any reason. We observed no group differences in functional outcomes (Table 4). There was no group difference in postoperative flexion contracture even after adjusting for preoperative flexion contracture ($p = 0.910$).

Discussion

The use of vacuum drainage in TKA to manage bleeding continues to be debated (Table 5) [1, 3, 10, 15, 18, 20, 22, 23, 28–30, 35, 36, 44]. Many surgeons place vacuum drainage to avoid bleeding-related complications, such as hemarthrosis, which allegedly is associated with increased infection, delayed rehabilitation, and wound-healing problems. However, this modality has the disadvantage of increasing blood loss [7, 18, 22, 29, 30, 44]. In contrast, some surgeons favor not placing an indwelling vacuum drain to avoid increased blood loss [1, 3, 10, 15, 20, 23, 28, 30, 35, 36], although this strategy increases the risk of wound problems and the need for more frequent dressing reinforcement [18, 22, 29, 30]. We hypothesized that subcutaneous closed-suction drainage would be a potentially efficacious alternative to either intraarticular closed-suction drainage or no drain because it could exploit the advantages of both methods, namely, the drainage and the joint tamponade effects. We asked whether the subcutaneous indwelling method would reduce blood loss with comparable functional outcomes and wound problem incidences in comparison to the intraarticular indwelling method.

The findings of this study should be viewed after considering the following limitations. First, we did not include a group without closed-suction drainage, and therefore, we cannot conclude from this study whether intraarticular or subcutaneous closed drainage offers advantages or disadvantages in comparison to no drain. Furthermore, despite the lack of definitive proof regarding the advantages of vacuum drainage [1, 3, 10, 15, 20, 23, 28, 30, 35, 36], many surgeons continue to use vacuum drainage after TKA to reduce the possibility of wound problems and the need for dressing reinforcement [7, 18, 22, 29, 30]. Our data showed that a subcutaneous closed suction drain resulted in outcomes equivalent to those of an intraarticular closed suction drain but, having no control group without a drain, could not address the value of either drainage method versus no drain. Second, we clamped our intraarticular drains for 2 hours after surgery and then kept drains open until 24 hours after surgery (at which time the drains were removed). Several studies have determined optimal drain clamping times, but recommendations varied and included no clamping [21], clamping for 1 hour [37, 47], 10-minute clamp releases every 2 hours [33], clamping for 4 hours [41, 43], and clamping for 20 hours [38]. We cannot comment on the effects of clamping time on the intraarticular indwelling method, but mean drained volume in our study (352 mL) compares with those (253–843 mL) reported previously [21, 33, 37, 38, 41, 43, 47]. Third, as mentioned above, our cohort size was sufficient to detect differences in drained volumes, hemoglobin level, and

Table 5. Summary of previous studies comparing no closed suction drainage with closed suction drainage after TKA

Study (year)	Study design	Blood loss	Wound problems	Functional outcome	Recommended option
Adalberth et al. [1] (1998)	Prospective randomized trials, 30 with no drain vs 30 with autotransfusion drainage vs 30 with closed suction drainage	No difference in Hb decrease and allogenic transfusions	No difference in knee swelling	No difference in ROM	No use
Beer et al. [3] (1991)*	Prospective comparisons of 38 bilateral TKAs (drains in right vs no drains in left knees)	Not included	No differences in the incidence of swelling or persistent drainage	No differences in quadriceps function, ROM	No use
Crevoisier et al. [10] (1998)*	Prospective randomized trials, 16 with vs 16 without drains	No difference in blood transfusion requirement	No differences in wound healing, wound hematoma	No differences in ROM, hospital stay	No use
Esler et al. [15] (2003)	Prospective, randomized trials, 50 with vs 50 without drains	No difference in Hb decrease (2.9 vs 2.8 g/dL, $p = 0.6$), but higher transfusion in drained knees (62% vs 38%)	No differences in incidence of ecchymosis, pyrexia, but one deep infection in undrained group	Delayed straight leg raising in drained knees (4.4 vs 3.4 days, $p = 0.02$), more manipulation in undrained knees (4 vs 0)	No use
Jenny et al. [20] (2001)	Prospective, randomized trials, 30 with vs 30 without drains	More blood transfusion in drained knees (34 vs 29 units, $p = 0.03$)	No difference in complications or reoperations	No differences in pain, flexion	No use
Kumar et al. [23] (2007)	Retrospective review, 44 with vs 48 without drains	No difference (Hb decrease, 2.6 vs 2.8 g/dL; no hypotension or cardiac complications)	No differences in wound problems and requirements for dressing reinforcement	No difference (hospital stay)	No use
Niskanen et al. [28] (2000)*	Prospective, randomized trials, 20 with vs 19 without drains	More blood transfusion in drained knees (2.3 vs 1.4 units, $p > 0.05$ with power analysis)	No difference in ecchymosis or thrombosis, but higher incidence of dressing reinforcement in undrained knees (52.6% vs 25%, $p = 0.07$)	Not included	No use
Parker et al. [30] (2004)*	Meta-analysis (13 studies), 137–513 with vs 130–505 without drains	Greater in drained knees (transfusion requirement, 49.6% vs 30.7%, relative risk = 1.43 [95% CI, 1.19–1.72])	No differences in wound infection, hematoma, and reoperation, but higher dressing reinforcement in undrained knees	Not included	No use
Reilly et al. [35] (1986)	Retrospective review, 170 with vs 129 without drains	Greater Hb decrease (3.1 vs 2.6 g/dL, $p < 0.01$) and greater transfusion rate (39% vs 16%, $p < 0.01$) in drained knees	No differences in the incidence of wound problems	No difference in ROM	No use
Ritter et al. [36] (1994)*	Prospective, randomized trials, 137 with vs 138 without drains	No differences in Hb decrease and transfused volume	No difference in the incidence of wound problems	No difference in ROM	No use
Holt et al. [18] (1997)	Prospective randomized trials, 136 (drained vs undrained)	No difference in blood loss	Greater incidences of dressing reinforcement (40% vs 0%) and ecchymosis in undrained knees	Not included	Use

Table 5. continued

Study (year)	Study design	Blood loss	Wound problems	Functional outcome	Recommended option
Kim et al. [22] (1998)	Prospective randomized trials, 69 patients with simultaneous bilateral TKAs (drained vs undrained)	Not included	Greater incidences of wound drainage, dressing reinforcement, ecchymosis, erythema, two infections only in undrained knees	No differences in quadriceps strength, ROM	Use
Ovadia et al. [27] (1997)*	Prospective, randomized trials, 32 with vs 26 without drains	Higher transfusion in drained knees (50% vs 15.4%, $p = 0.005$), but no difference in Hb decrease	Greater incidence of wound discharge in undrained knees (38.4% vs 12.5%, $p = 0.02$)	No difference	Use
Sundaram and Parkinson [44] (2007)	Retrospective review, 100 with vs 100 without drains	No difference (Hb decrease, 3.3 vs 3.3 g/dL; transfusion, 9% vs 7%, $p = 0.79$)	Not included	Not included	Use
Current study	Prospective, randomized trials, 54 subcutaneous indwelling vs 57 intraarticular indwelling	Reduced blood drainage, but similar Hb decreases and allogenic blood transfusions	No difference in the incidence wound problems	No differences in motion arc, AKS, WOMAC, SF-36 scores	Subcutaneous indwelling

* Only the data relating to TKA were extracted to present in this table from the original studies also involving THA; Hb = hemoglobin; CI = confidence interval; AKS = American Knee Society.

functional outcomes, but not differences in allogenic transfusion requirements, hypotension episodes, and wound problems. Finally, we did not measure intraoperative blood loss. We believed the amount of intraoperative blood loss would be negligible because all surgical procedures were performed with a pneumatic tourniquet inflated except when checking the presence of arterial bleeders before capsule closure.

Our findings suggest, compared with intraarticular closed-suction drainage, subcutaneous closed-suction drainage involves equivalent blood loss with comparable wound problems and functional outcomes. The mean drained volume was lower in the subcutaneous indwelling group, but hemoglobin decreases at 2 and 5 days postoperatively were similar (Table 2). No difference was found in allogenic transfusion requirements. Furthermore, although we had expected faster hemoglobin recovery in the subcutaneous indwelling group, because some components required for hematopoiesis could be recruited from extravasated blood [40], no group differences were found in terms of hemoglobin recovery variables. Our finding of similar blood loss in the subcutaneous indwelling group indicates whether the subcutaneous indwelling method exploits the joint tamponade effect of the no suction drainage method to a clinically meaningful extent remains to be answered. Nonetheless, the observation of smaller blood drainage in the subcutaneous group suggests, after TKA, more free blood is available for drain removal

intraarticularly than is available subcutaneously. Subsequently, this finding of small blood drainage in the subcutaneous indwelling group indicates clinical values of a subcutaneous indwelling autotransfusion drain would be limited.

Our observations also suggest the two approaches have similar incidences of wound problems and similar functional outcomes. There were no differences in any of the parameters representing wound problems and functional outcomes (Tables 3, 4). We cannot draw a solid conclusion regarding wound complications because of the insufficient power, but our experience during the past 3 years using this method has supported its safety in terms of wound complications. Several studies have concluded closed-suction drainage offers advantages over no drainage in terms of wound problems and dressing reinforcement requirements (Table 5) [18, 22, 29, 30]. Nonetheless, our study indicates removal of either intraarticular or subcutaneous blood by a postoperative drain does not create a clinical difference regarding transfusion rate, motion arc, or functional outcomes.

Our data suggest subcutaneous indwelling closed-suction drainage is similar to that for intraarticular indwelling closed-suction drainage with equivalent blood loss and no adverse effects on functional outcomes. Based on our findings, we propose subcutaneous closed suction drainage offers a reasonable alternative to intraarticular closed suction drainage after TKA.

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References

- Adalberth G, Bystrom S, Kolstad K, Mallmin H, Milbrink J. Postoperative drainage of knee arthroplasty is not necessary: a randomized study of 90 patients. *Acta Orthop Scand*. 1998;69:475–478.
- Amin A, Watson A, Mangwani J, Nawabi D, Ahluwalia R, Loeffler M. A prospective randomised controlled trial of autologous retransfusion in total knee replacement. *J Bone Joint Surg Br*. 2008;90:451–454.
- Beer KJ, Lombardi AV Jr, Mallory TH, Vaughn BK. The efficacy of suction drains after routine total joint arthroplasty. *J Bone Joint Surg Am*. 1991;73:584–587.
- Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol*. 1988;15:1833–1840.
- Bong MR, Patel V, Chang E, Issack PS, Hebert R, Di Cesare PE. Risks associated with blood transfusion after total knee arthroplasty. *J Arthroplasty*. 2004;19:281–287.
- Borghi B, Casati A: Incidence and risk factors for allogenic blood transfusion during major joint replacement using an integrated autotransfusion regimen. The Rizzoli Study Group on Orthopaedic Anaesthesia. *Eur J Anaesthesiol*. 2000;17:411–417.
- Canty SJ, Shepard GJ, Ryan WG, Banks AJ. Do we practice evidence based medicine with regard to drain usage in knee arthroplasty? Results of a questionnaire of BASK members. *Knee*. 2003;10:385–387.
- Cheung KW, Chiu KH. Effect of drain pressure in total knee arthroplasty. *J Orthop Surg (Hong Kong)*. 2006;14:163–166.
- Chintamani, Singhal V, Singh J, Bansal A, Saxena S. Half versus full vacuum suction drainage after modified radical mastectomy for breast cancer: a prospective randomized clinical trial [ISRCTN24484328]. *BMC Cancer*. 2005;5:11.
- Crevoisier XM, Reber P, Noesberger B. Is suction drainage necessary after total joint arthroplasty? A prospective study. *Arch Orthop Trauma Surg*. 1998;117:121–124.
- Cushner FD, Scott WN, Scuderi G, Hill K, Insall JN. Blood loss and transfusion rates in bilateral total knee arthroplasty. *J Knee Surg*. 2005;18:102–107.
- Dramis A, Plewes J. Autologous blood transfusion after primary unilateral total knee replacement surgery. *Acta Orthop Belg*. 2006;72:15–17.
- Drinkwater CJ, Neil MJ. Optimal timing of wound drain removal following total joint arthroplasty. *J Arthroplasty*. 1995;10:185–189.
- Dupont WD, Plummer WD Jr. Power and sample size calculations: a review and computer program. *Control Clin Trials*. 1990;11:116–128.
- Esler CN, Blakeway C, Fiddian NJ. The use of a closed-suction drain in total knee arthroplasty: a prospective, randomised study. *J Bone Joint Surg Br*. 2003;85:215–217.
- Gordon AC, Pulido P, Copp SN, Ezzet KA, Walker RH, Colwell CW Jr. The use of reinfusion drains after total knee arthroplasty in patients treated with low molecular weight heparin for thromboembolic prophylaxis. *HSS J*. 2005;1:19–24.
- Hinarejos P, Corrales M, Matamalas A, Bisbe E, Caceres E. Computer-assisted surgery can reduce blood loss after total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2009;17:356–360.
- Holt BT, Parks NL, Engh GA, Lawrence JM. Comparison of closed-suction drainage and no drainage after primary total knee arthroplasty. *Orthopedics*. 1997;20:1121–1124; discussion 1124–1125.
- Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. *Clin Orthop Relat Res*. 1989;248:13–14.
- Jenny JY, Boeri C, Lafare S. No drainage does not increase complication risk after total knee prosthesis implantation: a prospective, comparative, randomized study. *Knee Surg Sports Traumatol Arthrosc*. 2001;9:299–301.
- Kiely N, Hockings M, Gambhir A. Does temporary clamping of drains following knee arthroplasty reduce blood loss? A randomised controlled trial. *Knee*. 2001;8:325–327.
- Kim YH, Cho SH, Kim RS. Drainage versus nondrainage in simultaneous bilateral total knee arthroplasties. *Clin Orthop Relat Res*. 1998;347:188–193.
- Kumar S, Penematsa S, Parekh S. Are drains required following a routine primary total joint arthroplasty? *Int Orthop*. 2007;31:593–596.
- Lee GC, Hawes T, Cushner FD, Scott WN. Current trends in blood conservation in total knee arthroplasty. *Clin Orthop Relat Res*. 2005;440:170–174.
- Leeman MF, Costa ML, Costello E, Edwards D. Timing of retransfusion drain removal following total knee replacement. *Ann R Coll Surg Engl*. 2006;88:134–135.
- Munoz M, Ariza D, Florez A, Campos A. Reinfusion drains reduce postoperative transfusion requirements after primary total knee replacement surgery. *Transfus Med*. 2008;18:269–271.
- Munoz M, Ariza D, Garcera MJ, Gomez A, Campos A. Benefits of postoperative shed blood reinfusion in patients undergoing unilateral total knee replacement. *Arch Orthop Trauma Surg*. 2005;125:385–389.
- Niskanen RO, Korkala OL, Haapala J, Kuokkanen HO, Kaukonen JP, Salo SA. Drainage is of no use in primary uncomplicated cemented hip and knee arthroplasty for osteoarthritis: a prospective randomized study. *J Arthroplasty*. 2000;15:567–569.
- Ovadia D, Luger E, Bickels J, Menachem A, Dekel S. Efficacy of closed wound drainage after total joint arthroplasty: a prospective randomized study. *J Arthroplasty*. 1997;12:317–321.
- Parker MJ, Roberts CP, Hay D. Closed suction drainage for hip and knee arthroplasty: a meta-analysis. *J Bone Joint Surg Am*. 2004;86:1146–1152.
- Patel VP, Walsh M, Sehgal B, Preston C, DeWal H, Di Cesare PE. Factors associated with prolonged wound drainage after primary total hip and knee arthroplasty. *J Bone Joint Surg Am*. 2007;89:33–38.
- Pierson JL, Hannon TJ, Earles DR. A blood-conservation algorithm to reduce blood transfusions after total hip and knee arthroplasty. *J Bone Joint Surg Am*. 2004;86:1512–1518.
- Prasad N, Padmanabhan V, Mullaji A. Comparison between two methods of drain clamping after total knee arthroplasty. *Arch Orthop Trauma Surg*. 2005;125:381–384.
- Raleigh E, Hing CB, Hanusiewicz AS, Fletcher SA, Price R. Drain clamping in knee arthroplasty: a randomized controlled trial. *ANZ J Surg*. 2007;77:333–335.
- Reilly TJ, Gradisar IA Jr, Pakan W, Reilly M. The use of postoperative suction drainage in total knee arthroplasty. *Clin Orthop Relat Res*. 1986;208:238–242.
- Ritter MA, Keating EM, Faris PM. Closed wound drainage in total hip or total knee replacement: a prospective, randomized study. *J Bone Joint Surg Am*. 1994;76:35–38.

37. Roy N, Smith M, Anwar M, Elsworth C. Delayed release of drain in total knee replacement reduces blood loss: a prospective randomised study. *Acta Orthop Belg.* 2006;72:34–38.
38. Ryu J, Sakamoto A, Honda T, Saito S. The postoperative drain-clamping method for hemostasis in total knee arthroplasty: reducing postoperative bleeding in total knee arthroplasty. *Bull Hosp Jt Dis.* 1997;56:251–254.
39. Samraj K, Gurusamy KS. Wound drains following thyroid surgery. *Cochrane Database Syst Rev.* 2007;CD006099.
40. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty: correct management of blood loss should take hidden loss into account. *J Bone Joint Surg Br.* 2004;86:561–565.
41. Shen PC, Jou IM, Lin YT, Lai KA, Yang CY, Chern TC. Comparison between 4-hour clamping drainage and nonclamping drainage after total knee arthroplasty. *J Arthroplasty.* 2005;20:909–913.
42. Strumper D, Weber EW, Gielen-Wijffels S, Van Drumpt R, Bulstra S, Slappendel R, Durieux ME, Marcus MA. Clinical efficacy of postoperative autologous transfusion of filtered shed blood in hip and knee arthroplasty. *Transfusion.* 2004;44:1567–1571.
43. Stucinskas J, Tarasevicius S, Cebatorius A, Robertsson O, Smailys A, Wingstrand H. Conventional drainage versus four hour clamping drainage after total knee arthroplasty in severe osteoarthritis: a prospective, randomised trial. *Int Orthop.* 2009;33:1275–1278.
44. Sundaram RO, Parkinson RW. Closed suction drains do not increase the blood transfusion rates in patients undergoing total knee arthroplasty. *Int Orthop.* 2007;31:613–616.
45. Tsumara N, Yoshiya S, Chin T, Shiba R, Kohso K, Doita M. A prospective comparison of clamping the drain or post-operative salvage of blood in reducing blood loss after total knee arthroplasty. *J Bone Joint Surg Br.* 2006;88:49–53.
46. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36): I. Conceptual framework and item selection. *Med Care.* 1992;30:473–483.
47. Yamada K, Imaizumi T, Uemura M, Takada N, Kim Y. Comparison between 1-hour and 24-hour drain clamping using diluted epinephrine solution after total knee arthroplasty. *J Arthroplasty.* 2001;16:458–462.