



# Is Intraoperative Use of QuikClot Combat Gauze Effective for Hemostasis after Total Knee Arthroplasty?

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**Background:** To assess the hemostatic effect of QuikClot Combat Gauze (QCG) compared to that of standard gauze during cruciate-retaining total knee arthroplasty (TKA).

**Methods:** Sixty knees underwent TKA using a pneumatic tourniquet in this prospective randomized study. After implantation of the femoral and tibial components and hardening of the bone cement, the tourniquet was deflated and QCG (group 1) or standard gauze (group 2) was packed into the joint cavity for 5 minutes for hemostasis. Perioperative bleeding volume and blood transfusion volume were compared between two groups.

**Results:** The mean intraoperative bleeding volume was  $64.7 \pm 12.7$  mL in group 1 and  $63.9 \pm 9.2$  mL in group 2 ( $p = 0.808$ ). The mean postoperative blood drainage was  $349.0 \pm 170.6$  mL in group 1 and  $270.1 \pm 136.3$  mL in group 2 ( $p = 0.057$ ). The average postoperative blood transfusion volume was  $323.7 \pm 325.9$  mL in group 1 and  $403.6 \pm 274.8$  mL in group 2 ( $p = 0.314$ ).

**Conclusions:** QCG was not significantly effective for reducing perioperative bleeding volume or the blood transfusion rate compared with standard gauze during TKA.

**Keywords:** *Knee, Replacement, Arthroplasty, Hemostasis, QuikClot Combat Gauze*

Total knee arthroplasty (TKA) is one of the most commonly performed orthopedic procedures. The number of people undergoing joint replacement surgery has been steadily increasing with time due to population ageing and the increase in life expectancy. Replacement arthroplasty accounts for a significant proportion of all perioperative blood transfusions. Perioperative anemia and red blood cell (RBC) transfusions are associated with increased medical costs, extended hospital stay, transmission of pathogens, delayed recovery and higher rates of postoperative morbidity and mortality.<sup>1-3)</sup> Antifibrinolytic therapy has been introduced to reduce blood loss during the periop-

erative period in patients undergoing TKA.<sup>4,5)</sup> However, antifibrinolytic agents are expected to have no significant effect on primary hemostasis or coagulation and have little effect on blood loss during surgery.<sup>6)</sup> Moreover, use of antifibrinolytic agents may increase the risk of myocardial infarction, about which there are debates though.<sup>7)</sup>

QuikClot Combat Gauze (QCG; Z-Medica, Wallingford, CT, USA) is among the hemostatic agents that the US Military Committee on Tactical Combat Casualty Care recommends as the first-line hemostatic dressing for treating a compressible hemorrhage not amenable to a tourniquet (CareCoTCC; Tactical combat casualty care guidelines; 2015 update. [February 2015]; [http://www.naemt.org/education/TCCC/guidelines\\_curriculum](http://www.naemt.org/education/TCCC/guidelines_curriculum)). QCG is a kaolin-impregnated rayon/polyester hemostatic dressing that promotes clotting by activating factors XII and XI of the intrinsic coagulation pathway (Z-Medica; QuikClot Combat Gauze [November 30, 2013]; <http://www.z-medica.com/healthcare/Home.aspx>). Several ani-

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mal studies have reported that QCG is effective in controlling massive hemorrhage.<sup>8-10</sup> QCG has been used in general and obstetric surgery for several years. However, this kaolin-impregnated dressing material is not widely used in orthopedic surgeries.

The purpose of this prospective study was to assess the hemostatic effect of QCG compared to that of standard gauze during cruciate-retaining type TKA. The hypothesis was that the hemostatic effect of QCG would not be superior to that of standard gauze.

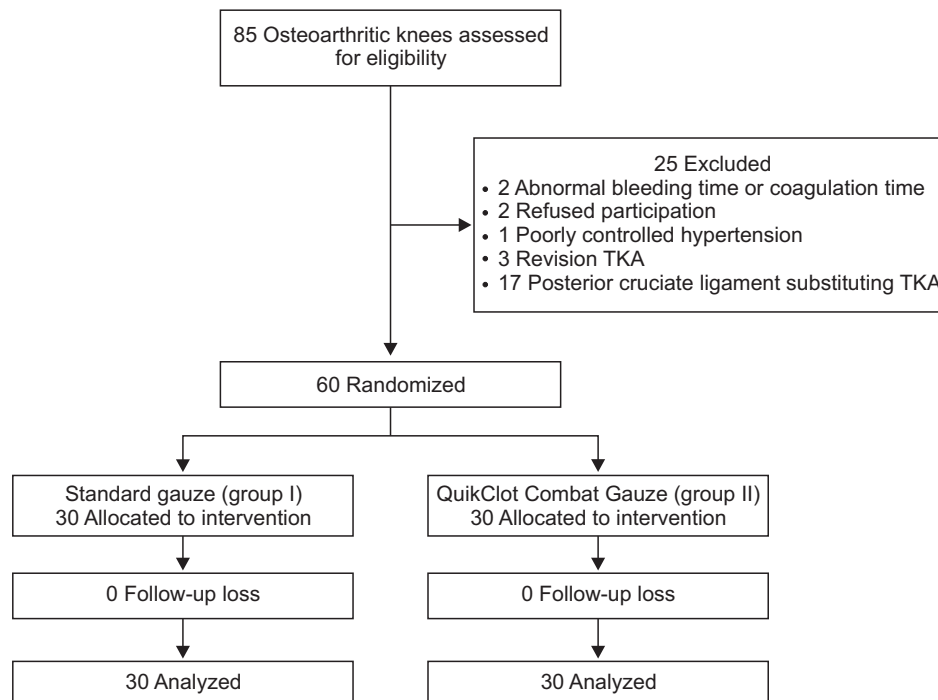
## METHODS

This prospective randomized controlled study was performed with the approval of the ethics committee of Kangwon National University Hospital (No. 2015-04-005-002). Eighty-nine knees underwent TKA between July 2015 and January 2016. The inclusion criterion was subjects with osteoarthritis who had normotensive blood pressure regardless of whether they were taking drugs for hypertension. Indications for surgery were grade 4 osteoarthritis of the knee according to the Kellgren and Lawrence grading system.<sup>11</sup> The exclusion criteria were subjects with hematologic disease, who showed abnormal bleeding test or coagulation test results preoperatively, anemia, poorly controlled hypertension, posterior cruciate ligament substituting type TKA (PS-TKA), revision TKA, and refusal

to participate in the study. Subjects who were taking anti-thrombotic or anti-fibrinolytic drugs had stopped the medication for 7 days before surgery and restarted after the Hemovac drain was removed. The subjects with normal laboratory results prior to surgery were included and those with abnormal results were excluded. Eighty-five osteoarthritic knees underwent TKA during the study period. Two subjects (2 knees) had abnormal preoperative laboratory test results, one had uncontrolled hypertension, 1 subject (2 knees) refused to participate in the study, and three knees required revision TKA. Thus, 77 knees were enrolled before surgery, and informed consent was obtained from all subjects after the purpose and procedures of this study were explained. However, 17 knees were additionally excluded during surgery as they underwent PS-TKA (Fig. 1).

## Surgical Procedure

TKA was performed with the cruciate-retaining type Vanguard Complete Knee system (Biomet, Warsaw, IN, USA). All operations were performed using a uniform approach and technique by a single experienced surgeon. Surgeries were usually performed under spinal anesthesia, and a tourniquet with the pressure of 300 mmHg was applied in all cases. An anterior midline skin incision and a medial parapatellar arthrotomy were performed. Intramedullary instrumentation was used for the distal femoral cut with a



**Fig. 1.** The Consolidated Standards Of Reporting Trials (CONSORT) flow diagram of this study. TKA: total knee arthroplasty.

measured resection technique. All osteophytes of the distal femur were removed medially and laterally. Extramedullary instrumentation was used to align the proximal tibial cut, and medial osteophytes were removed.

The medial collateral ligament (MCL) was subperiosteally released on the tibial side step-by-step using a curved osteotome when the knee was tight on the medial side, until the ligament was balanced properly. The posterior cruciate ligament (PCL) was released at the tibial attachment with the knee in tight flexion. All patellae were resurfaced. The opening of the distal femur made for the intramedullary instrument was plugged using resected bone before implanting the femoral component. All components were implanted with Cemex (Exactech, Gainesville, FL, USA) bone cement. If patellar tracking was abnormal, the lateral retinaculum was released with an inside-out technique to optimize patellar tracking and minimize patellar tilt. A lateral retinacular release was performed in a staged fashion, in which the lateral retinaculum was sequentially released in short increments, and patellar tracking was reassessed between each incremental release. Attempts were made to preserve the lateral geniculate artery during release, and it was cauterized if cut.

After the bone cement hardened, the polyethylene insert trial was removed, and QCG was tightly packed into the joint cavity in group 1 and standard gauze was packed in group 2. Randomization was simply performed by closed envelope. A sealed envelope which had been randomly chosen by a scrub nurse was opened in the operating room before the surgery. Elastic bandage was applied around the knee to compress the surgical wound, and the tourniquet was deflated. Elastic bandage and gauze were removed after 5 minutes. Jetting arterioles were cauterized, and the cauterized arterioles were counted before the tourniquet was re-inflated. The blood permeating the gauze was weighed. The knee joint was irrigated with normal saline, and the polyethylene bearing was inserted. Hemovac was applied into the lateral compartment of the knee joint cavity. The arthrotomy was repaired with simple interrupted sutures using No.2 Vicryl (Ethicon Inc., Somerville, NJ, USA). The tourniquet was deflated after all layers of the surgical wound were closed and a Jones dressing was applied. The Hemovac was clamped for the first 3 hours.

#### Postoperative Care

The Hemovac clamp was released 3 hours after surgery. Normal saline of 1,500 mL/day was provided intravenously to all patients. Postoperative laboratory tests were performed immediately after surgery and each day for the first 4 days after surgery. If hemoglobin was lower than

10.0 g/dL, packed RBCs (320 mL/pack) were transfused. If albumin was lower than 3.0 g/dL, the albumin was also transfused.

Intermittent pneumatic compression was applied on both calves for 3 days to prevent deep vein thrombosis. However, no medications were administered to prevent deep vein thrombosis. Quadriceps set exercises were started immediately after surgery. The Hemovac was removed 2 days after surgery. Continuous motion exercises for the knee and walking with crutches were started thereafter. Ice massage was applied for 7 days after surgery for hemostasis and swelling reduction.

The sutures were removed and laboratory testing was performed on day 14 postoperatively.

#### Assessment of Outcomes

The number of jetting arterioles was counted after removing the gauze during surgery. The volume of blood permeating the gauze was measured and was considered the intraoperative bleeding volume. The volume of postoperatively draining blood was counted until the Hemovac was removed. Blood transfusion volume was recorded. The change in hemoglobin between preoperative and postoperative day 14 was assessed. To assess the influence of soft tissue balancing on bleeding, perioperative bleeding volume was compared between subjects with complete MCL release and those without complete release, between subjects with and without PCL release, and between subjects with and without lateral retinacular release.

#### Statistical Analysis

Sample size was calculated based on the volume of draining blood. The power analyses were performed with data from a pilot study prior to this prospective randomized study. Thirty subjects in each group would have 90% power to detect a difference of 160 mL in blood loss. The blood loss difference of 160 mL did not come from any published references. The power analyses were performed with data from a pilot study involving 10 subjects in each group prior to this prospective randomized study. Statistical analyses were performed using SPSS ver. 17.0 (SPSS Inc., Chicago, IL, USA). Means and standard deviations were used to describe the continuous data, and medians and ranges were used to describe noncontinuous data. Comparisons of the values between groups were conducted using Student *t*-test, the dependent *t*-test, the Mann-Whitney *U*-test, and the chi-square test. A *p*-value less than 0.05 was considered significant.

**Table 1.** Demographics of the Subjects

Variable	Group 1 (QCG)	Group 2 (standard gauze)	<i>p</i> -value
Number	30	30	
Age (yr)	71.5 ± 5.4	71.3 ± 5.8	0.511
Sex (male:female)	5:25	5:25	1.000
Body mass index (kg/m <sup>2</sup> )	26.2 ± 3.6	28.1 ± 4.3	0.983
Preoperative hip-knee-ankle angle (°)	Varus 8.1 ± 5.2	Varus 8.6 ± 6.0	0.730
Preoperative range of motion of the knee (°)	132 ± 11	132 ± 16	0.963

Values are presented as mean ± standard deviation.  
 QCG: QuikClot Combat Gauze (Z-Medica).

**Table 2.** Comparisons of Results between Groups 1 and 2

Variable	Group 1	Group 2	<i>p</i> -value
Operation time (min)	104.3 ± 7.6	103.3 ± 7.3	0.615
No. of jetting arterioles median (range)	0 (0–3)	0 (0–4)	0.254
Intraoperative bleeding volume (mL)	64.7 ± 12.7	63.9 ± 9.2	0.808
Postoperative drainage volume (mL)	349.0 ± 170.6	270.1 ± 136.3	0.057
Preoperative hemoglobin (g/dL)	13.1 ± 1.7	13.3 ± 1.2	0.714
Preoperative albumin (g/dL)	4.2 ± 0.4	4.2 ± 0.3	0.485
Postoperative hemoglobin on postoperative day 14 (g/dL)	11.3 ± 1.3	11.0 ± 1.0	0.240
Postoperative albumin on postoperative day 14 (g/dL)	3.6 ± 0.3	3.5 ± 0.3	0.109
Volume of red blood cell transfusion (mL)	323.7 ± 325.9	403.6 ± 274.8	0.314

Values are presented as mean ± standard deviation.

## RESULTS

The demographics of the subjects are shown in Table 1. The outcomes were not statistically significantly different between two groups as seen in Table 2. The MCL was completely released during surgery in four knees in group 1 and six knees in group 2 ( $p = 0.488$ ). The PCL was released at the tibial side in 18 knees in group 1 and in 17 knees in group 2 ( $p = 0.793$ ). Lateral retinacular release was performed in three knees in group 1 and eight knees in group 2 ( $p = 0.095$ ). Total bleeding volume was  $311.6 \pm 147.7$  mL in the subjects in whom the MCL was completely released and  $318.1 \pm 165.0$  mL in those in whom the MCL was not completely released ( $p = 0.908$ ). Total bleeding volume was  $310.4 \pm 131.2$  mL in the subjects in whom the PCL was released and  $328.0 \pm 204.1$  mL in

those in whom the PCL was not released ( $p = 0.684$ ). Total bleeding volume was  $325.9 \pm 168.1$  mL in the subjects in whom the lateral retinaculum was released and  $280.3 \pm 86.6$  mL in those in whom the lateral retinaculum was not released ( $p = 0.378$ ). No complications were observed in either group.

## DISCUSSION

The most important finding of this study was that QCG was not significantly effective for reducing postoperative hemorrhage after cruciate-retaining type TKA compared with standard gauze. As TKA is becoming one of the most commonly performed orthopedic surgeries, care must be taken regarding potential perioperative complications. TKA is associated with significant perioperative blood loss

of up to 2,000 mL after surgery.<sup>12,13)</sup> A blood transfusion is often required intra- or postoperatively and transfusion rates range as high as 63%–94%.<sup>14,15)</sup> In this study, the mean drainage output volume was  $270.1 \pm 136.3$  mL in group 1 and  $349.0 \pm 170.6$  mL in group 2, and the transfusion rates were 90% in group 1 and 67% in group 2 to maintain a postoperative hemoglobin level of over 10 g/dL. Perioperative anemia and RBC transfusions are associated with increased utilization of healthcare resources, extended hospital stay, delayed recovery, and higher rates of postoperative morbidity and mortality.<sup>1,2)</sup> Various techniques have been introduced to reduce blood loss during the perioperative period, and perioperative antifibrinolytic therapy is recommended as part of a comprehensive perioperative blood management strategy.<sup>16)</sup> However, there is an issue of the risks of antifibrinolytic therapy such as a cerebrovascular accident.<sup>17)</sup> We used a pneumatic tourniquet during surgery and Hemovac drainage was clamped for the first 3 hours after surgery. We did not use antifibrinolytic therapy in this study.

The trigger hemoglobin level for blood transfusion varies. Many authors recommend blood transfusion in case of hemoglobin level below 8–10 g/dL.<sup>18,19)</sup> Tavares Cardozo et al.<sup>20)</sup> recommended blood transfusions in patients with hemoglobin less than 9 g/dL. Rosencher et al.<sup>21)</sup> reported that blood transfusion triggered after orthopedic surgery were hemoglobin levels of  $8.93 \pm 1.83$  g/dL in Europe and 21% of these occurred when the hemoglobin level was greater than 10 g/dL. Borghi and Casati<sup>22)</sup> recommended blood transfusion for a patient with hemoglobin of less than 10 g/dL if the patient had cerebrovascular or coronary artery disease. We set the trigger hemoglobin level to 10 g/dL for blood transfusion and assessed hemoglobin during the first 4 days after surgery. Zhou et al.<sup>23)</sup> reported that hemoglobin decreased during the first 4 days after arthroplasty and then gradually returned to normal levels within 6–12 weeks postoperatively. We assessed perioperative albumin level, as albumin level has been used as an index of nutritional status, which is associated with hemoglobin level.<sup>24,25)</sup>

We think that bone bleeding may significantly affect postoperative blood loss, and no evidence suggests an effect of QCG on postoperative bone bleeding. However, bone bleeding can be minimized by performing cruciate-retaining type TKA and sealing the bone cutting surface with bone cement. Additionally, the soft tissue release to balance ligaments, such as MCL, PCL, or lateral retinaculum releases, did not affect perioperative bleeding in this study.

There are several studies favoring QCG over stan-

dard gauze regarding the hemostatic effect.<sup>26-28)</sup> Abbott et al.<sup>26)</sup> reported that QCG was more effective in reducing intraoperative blood loss and limiting perioperative transfusion rate than standard gauze in their retrospective study of pediatric spinal deformity surgery. Gegel et al.<sup>28)</sup> stated that QCG produced a more robust clot that could withstand significant movement than standard gauze in their porcine study. On the other hand, our study revealed that QCG was not more effective than standard gauze for reducing intraoperative bleeding, postoperative drainage, or the perioperative blood transfusion rate. However, our study was performed during routine surgery and not under extreme conditions, such as hemodilution, acidosis, or severance of major vessels.

This study had some limitations. First, QCG was initially invented for hemostasis of major bleeding for cases in which a tourniquet cannot be applied. The entire procedures of the surgery were performed with an inflated tourniquet except during the 5 minutes of gauze application. However, the amount of postoperative bleeding after TKA is mostly significant and postoperative hemostasis has been a matter of concern. Second, no control group, which would have received no gauze packing, was used. Gauze packing for hemostasis may not be routine procedure during TKA; however, we set the control group procedure the same as that of the QCG group. Third, the hemostatic effect of standard gauze and QCG may not be certain as significant time passed after the tissue was injured before the gauze packing was performed. Vasoconstriction, platelet plug formation, and blood coagulation usually occur within several minutes after tissue injury. We released the tourniquet 40 to 50 minutes after beginning the procedure in this study, which would be sufficient for self-hemostasis although the operated limb was exsanguinated.

In conclusions, QCG was not significantly effective for reducing perioperative bleeding volume or the blood transfusion rate compared with standard gauze during cruciate-retaining TKA.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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