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Association Between Deep Vein Thrombosis and the Temperature at the Popliteal Fossa During Cement Curing in Total Knee Arthroplasty

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Abstract: The temperature at the popliteal fossa during cement curing and its relationship with deep vein thrombosis (DVT) in total knee arthroplasty (TKA) has not been investigated. Fifty-six consecutive patients who underwent primary TKA were recruited. The temperatures at the popliteal fossa were measured during bone cement exothermic polymerization. Postoperative operated leg ascending venographies were performed 5 days after TKA for screening of DVT. The maximum temperatures were 32.5°C ± 1.0°C at the popliteal fossa during cement curing. No significant difference was found of the maximum temperatures in the popliteal fossa between the non-DVT and DVT groups. The present study indicated that the heat resulting from polymerization of the cement may not be a possible cause of damage to the veins surrounding the knee, and it may have no relationship with DVT. **Keywords:** temperature, popliteal fossa, total knee arthroplasty.

Cements are commonly used to fix prosthetic components in joint surgery. The cements set in short periods by a complex polymerization of initially liquid monomer compounds into solid structures with accompanying significant heat release. Two main problems arise from this form of fixation: the first is the potential damage caused by exothermic reaction, and the second is incomplete reaction leaving active monomer compounds, which can potentially be slowly released into the patient [1].

The temperatures at the bone-cement interface during bone cement exothermic polymerization have been widely investigated. In vivo studies have found maximum temperatures ranging from 40°C to 48°C in the bone-cement interface of a 3 to 5-mm-thick cement layer [2,3]. In vitro studies found the maximum temperatures ranging from 36°C to 53°C, depending on the mixing technique [4]. Finally, theoretical prediction of the maximum temperature in the bone-cement interface of 3-mm-thick cement region lie between 35°C and 43°C [5,6]. Potential thermal damage and bone necrosis has been proposed. Fukushima et al [7] adopted an initial temperature of 32°C and a cement layer of 3 mm to their simulation and analyzed heat conduction. The maximum temperature into the cement layer was 65°C and 56°C at the bone-cement interface 200 seconds after the start of heat generation. Bone necrosis was observed approximately 2 mm from the bone-cement interface. To thin the cement layer, the maximum temperature and bone necrotic area are reduced. Because bone necrosis would contribute to the loosening of the tibial components, Fukushima et al [7] suggested that the cement layer should been made as thin as possible and cool the bone before cementing to prevent thermal bone necrosis.

It has also been suspected that the heat resulting from polymerization of the cement could be a possible cause of damage to the vein surround the cement and plays a role in deep vein thrombosis (DVT) [8]. However, to our knowledge, there was no study that reported the temperatures at the popliteal fossa during bone cement exothermic polymerization in total knee arthroplasty (TKA). Whether the heat resulting from polymerization of the cement plays a role in DVT remains unclear. In the present study, we measured the temperatures at the popliteal fossa during bone cement exothermic polymerization in TKA and investigated the relationship between the temperatures and DVT.

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Patients and Methods

Patients and Surgical Procedure

Fifty-six (19 male and 37 female) consecutive patients with a mean age of 59.8 years (range, 55-70 years) were included for this study from February 2008 to December 2008. The diagnoses of the patients before TKA were knee osteoarthritis in 50 patients, rheumatoid arthritis in 5 patients, and traumatic arthritis in 1 patient. The indications for TKA were to relieve pain caused by severe arthritis in most of the patients; or in patients with moderate arthritis and variable levels of pain, when the progression of deformity begins to threaten the expected outcome of an anticipated arthroplasty, deformity was the principal indication for arthroplasty. No patient had cardiocerebral vascular disease or type 2 diabetes. All the patients underwent primary TKA. Bilateral and revision operations were excluded because they were at special risk for DVT [9]. All operations were performed by one surgeon (Jiang Q). Anterior midline incisions and medial parapatellar retinacular approach were used in this series of patients. Posterior cruciate ligament was resected, and posterior cruciate ligament–substituting prosthesis was used. Genesis II prosthesis (Smith & Nephew, Memphis, Tenn) was used in 40 patients, and TC-Dynamic prosthesis (Plus-Fosun Ortho Co, Beijing, China) was used in 16 other patients. Polymethylmethacrylate bone cement (VersaBond; Smith & Nephew) was adopted in the present study. The maximum temperature of this bone cement after hand mixing during curing was 67.7°C in vitro (the temperature was measured after the ASTM F451-95 Standard Specification for Acrylic Bone Cement). Tourniquet was used after the tibial and femoral osteotomy during surgery, and it lasted for about 30 minutes until the prosthesis components were tightly fixed. Patients received low-molecular-weight heparin (5000 IU/d) 1 day before the operation and 5 days after the operation for prophylaxis of venous thromboembolism. Postoperative operated leg ascending venographies were performed 5 days after TKAs in all the patients.

Temperature Measurements

The temperature measurements were performed with thermocouples thermometer (accuracy ± 0.1°C; temperature range, 0°C-200°C, Tse Company, Nanjing, China). The thermocouples were connected to a data acquisition system that can register values of temperature every 20 seconds. One preliminary test was performed before this study to measure the temperature at 3 different sites in the popliteal fossa during cement curing. Three probes were placed just anterior to the posterior capsule in the popliteal fossa. The first one was behind the distal femur, the second one was behind the proximal tibia, and the third one was just placed in the gap between the femur and tibia. The results showed that there was no significant difference in the temperature rising at 3 different sites. Therefore, in the present study, the probes were placed just anterior to the posterior capsule and in the gaps between the femur and tibia when measuring the temperature at the popliteal fossa during cement curing. The other thermocouple was inserted into the suprapatellar bursa (Fig. 1). The temperatures were recorded before the fixation of prosthesis and after the fixation of prosthesis during cement curing. The time point of the prosthesis insertion was defined as "time 0" and then the temperatures were recorded every 20 seconds until it did not rise. The operating room temperature was set at 22°C to 24°C.

Statistical Analysis

The patients were divided into 2 groups according to the venography results: one was DVT group and the other was non-DVT group. *T* test was used to analyze the difference of the maximum temperatures in the popliteal fossa between these 2 groups (version 11.5;

Fig. 1. Temperature measurement in TKA. The position of the thermocouple tips: one was bent and embedded in the popliteal fossa (hollow arrowhead) and the other was inserted in the suprapatellar bursa (red arrowhead).

Fig. 2. (A) The thrombus was in the venous plexus of gastrocnemius muscle (calf vein). (B) The thrombus was in the anterior and posterior tibial vein.

SPSS Inc, Chicago, Ill). Statistical significance was set at $P < .05$.

Results

The temperatures in suprapatellar bursa did not seem to rise during cement curing; it was 29.0°C ± 0.9°C. The initial temperatures of the popliteal fossa were 29.4°C ± 0.8°C as the initial temperatures of suprapatellar bursa. About 3°C rise in temperature were found at the popliteal fossa during cement curing, and the maximum temperatures were 32.5°C ± 1.0°C, which was lower than normal body temperature.

Postoperative operated leg ascending venography (gold standard of DVT research) and clinical assessment were performed 5 days after TKA in all the patients. Fourteen (26%) of 56 patients had fresh thrombi: 12 in the venous plexus of gastrocnemius muscle and 2 in the anterior and posterior tibial veins (Fig. 2). There were more asymptomatic DVT (71.4%; 10/14) than symptomatic DVT, and some patients without DVT (9.5%; 4/42) presented some DVT symptoms.

The patients were divided into 2 groups according to the ascending venography: one was non-DVT group and the other was DVT group. The details of the non-DVT and DVT groups were listed in Table 1. The D-dimer was slightly higher in DVT group than the non-DVT group preoperatively and postoperatively (the fifth day), but there was no significant difference between 2 groups. The D-dimer was higher than 0.05 mg/L in both groups postoperatively, which may due to the operation itself. The mean temperatures and the maximum temperatures in the popliteal fossa were comparable between the non-DVT group and the DVT group ($P > .05$) (Table 2). The incidences of DVT in patients with different prosthesis were similar with each other.

Table 1. Details of the DVT and Non-DVT Groups

	Non-DVT (42)	DVT (14)	*P*
Age (y)	67.8 ± 5.6	68.1 ± 6.3	.82
Sex			
Male	9 (21.4%)	4 (28.5%)	–
Female	33 (78.6%)	10 (71.5%)	–
Diagnosis			
Osteoarthritis	38 (90.4%)	12 (85.7%)	–
Rheumatic arthritis	3 (7.1%)	2 (14.3%)	–
Traumatic arthritis	1 (2.3%)	0	–
The D-dimer (preoperative) (mg/L)	0.12 ± 0.18	0.32 ± 0.28	.16
The D-dimer (postoperation) (mg/L)	0.98 ± 1.07	1.12 ± 1.15	.79

Discussion

Our study indicated that the temperatures at the popliteal fossa does rise during bone cement exothermic polymerization in TKA. However, the heat generated by bone cement exothermic reaction had little effect on the temperature change at the popliteal fossa. The temperature at the popliteal fossa rose only about 3° during bone cement exothermic polymerization, and the peak temperature (32.5°C ± 1.0°C) was still lower than the normal body temperature (about 37°C). The popliteal vein was close to the posterior capsule; the initial temperature of the popliteal vein was unknown, but it was impossible for the initial temperature of the popliteal vein to be higher than the body temperature because the operating room temperature was set at 22°C to 24°C, and the initial temperature of the posterior capsule in the popliteal fossa was 29.4°C ± 0.8°C. It was also impossible for the temperature of the popliteal vein to be higher than the body temperature during cement

Table 2. Temperatures in the Popliteal Fossas During Cement Curing in the DVT and Non-DVT Groups

	Non-DVT (42)	DVT (14)	*P*
Initial temperatures (°C)	29.4 ± 0.7	29.4 ± 0.9	$P > .05$
Mean temperatures (°C)	32.0 ± 0.7	31.2 ± 0.6	$P > .05$
Max temperatures (°C)	32.6 ± 1.0	32.4 ± 1.1	$P > .05$

curing because the peak temperature of the posterior capsule in the popliteal fossa was 32.5°C ± 1.0°C. Therefore, our study eliminated the suspect that the heat resulting from polymerization of the cement could be a possible cause of damage to the veins surrounding the knee, especially the popliteal fossa vein. Furthermore, the ascending venography showed that most of the thrombi were in the venous plexus of gastrocnemius muscle and some were in the anterior and posterior tibial veins. None of the DVT was in the popliteal fossa veins in our series, which further suggested that there is no relationship between DVT and the heat generated by the bone cement during exothermic polymerization.

Other people investigated whether bone cement itself could be thrombogenic. However, the results were controversial. Cenni et al [10] showed that all the cements induced the secretion of transforming growth factor-b1; platelet activation induced by the cements could contribute to the pathogenesis of deep venous thrombosis, which often occurs after prosthetic implant and is caused also by other factors, including surgical trauma and venous stasis. Dahl et al [11] pointed out that methylmethacrylate (MMA) in concentrations found in central venous blood in vivo, alone or together with thrombin, directly or indirectly exert effects that contribute to activation of coagulation. However, Blinc et al [12] concluded that the surface of fresh or aged bone cement is not thrombogenic in vitro.

Actually, randomized study comparing cemented with uncemented replacements using DVT as the main outcome measure would confirm whether cement increases the risk of DVT. Some earlier clinical reports have suggested that cemented total hip arthroplasties has an increased risk for DVT over uncemented total hip arthroplasties [13-15], but a more recent prospective, randomized trial has indicated that this may not be the case [16]. There are fewer reports on TKA, but prospective studies suggest that cementing does not increase the postoperative incidence of DVT [17,18], at least in Asian patients who are thought to have a lower risk of thrombosis. One study [19] even showed that the total prevalence of DVT was significantly greater after uncemented (81%) than after cemented TKA (55%). This author concluded that the use of cement does not appear to lead to an increased incidence.

Our study together with other studies indicated that cement maybe not a risk factor for DVT. Hence, it is worth to study other risk factors for DVT in TKA. Cold is supposed to be associated with alterations in blood coagulation and a pronounced risk for thrombosis. Moderate systemic hypothermia accelerates microvascular thrombosis, which might be mediated by increased glycoprotein IIb-IIIa activation on platelets [20]. One other study showed that the use of endovascular cooling catheters is associated with increased risk of DVT in patients with traumatic head injuries. The DVT rate was 33% if catheters were removed in 4 days or less and 75% if removed after 4 days. Therefore, Simosa et al [21] discouraged the use of endovascular cooling devices in this patient population. Our study showed that the localized temperature surrounding the knee during TKA was around 29°C, which was even lower than general endovascular therapeutic hypothermia. Whether these lower temperatures were associated with the high incidence of DVT in TKR was undetermined, which merits further study.

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