Lower Tourniquet Cuff Pressure Reduces Postoperative Wound Complications After Total Knee Arthroplasty

A Randomized Controlled Study of 164 Patients

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Background: Measurement of limb occlusion pressure before surgery might lead to the use of a lower tourniquet cuff pressure during surgery and thereby reduce the risk of postoperative pain and complications. The primary aim of this study was to investigate whether the limb-occlusion-pressure method reduces the tourniquet cuff pressure used during total knee arthroplasty and if this leads to less postoperative pain compared with that experienced by patients on whom this method is not used. The secondary aim was to investigate whether there were any differences regarding the quality of the bloodless field, range of motion, and postoperative wound complications.

Methods: One hundred and sixty-four patients scheduled to be treated with a total knee arthroplasty were randomized to a control group or to undergo the intervention under study (the limb-occlusion-pressure [LOP] group). In the control group, the tourniquet cuff pressure was based on the patient's systolic blood pressure and a margin decided by the surgeon (the routine method). In the LOP group, the tourniquet cuff pressure was based on the measurement of the limb occlusion pressure. The primary outcome measure was postoperative pain, and the secondary outcome measures were the quality of the bloodless field, knee motion, and wound-related complications at discharge and two months after surgery.

Results: The tourniquet cuff pressure was significantly lower in the LOP group than in the control group ($p < 0.001$). We could not demonstrate any differences between the groups regarding postoperative pain or complications, although the number of postoperative complications was relatively high in both groups. However, at discharge forty of the forty-seven patients with a wound complication had had a cuff pressure above 225 mm Hg and at the two-month follow-up evaluation fourteen of the sixteen patients with a wound complication had had a cuff pressure above 225 mm Hg.

Conclusions: The limb-occlusion-pressure method reduces the cuff pressure without reducing the quality of the bloodless field, but there were no differences in outcomes between the groups. An important secondary finding was that patients with a cuff pressure of ≤225 mm Hg had no postoperative infections and a lower rate of wound complications.

Level of Evidence: Therapeutic Level I. See Instructions for Authors for a complete description of levels of evidence.

The use of a pneumatic tourniquet during a total knee arthroplasty improves visualization by preventing intraoperative bleeding. However, some studies have demonstrated lower rates of postoperative complications and better initial recovery of knee movement when the knee arthroplasty was performed without use of a pneumatic tourniquet[1-3]. When a tourniquet is used, the cuff pressure should be minimized to reduce the risk of tourniquet-related postoperative complications[2,4]. Setting the thigh tourniquet cuff pressure on the basis of the systolic blood pressure plus a margin of 100 mm Hg has been reported to reduce the cuff pressure and early postoperative pain[5]. According to another study, limb occlusion pressure and systolic blood pressure were not correlated well enough for the systolic blood pressure alone to be used to determine the optimal cuff

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pressure[6]. Wide conical cuffs require a lower cuff pressure[7,8] and are less painful[7], although the authors of most published studies did not report whether a straight or a wider conical cuff had been used.

Measuring the limb occlusion pressure just before surgery by means of an automated photoplethysmographic sensor connected to a tourniquet apparatus takes into account such variables as the type and width of the cuff, the tightness of cuff application, the fit of the cuff to the limb, and the properties of the patient's soft tissues and vessels[6] and therefore has been suggested to result in a more optimal cuff pressure. However, automated measurement of limb occlusion pressure has been investigated in only a few clinical studies[6,9,10].

The primary aim of this study was to investigate whether the limb-occlusion-pressure method reduces the tourniquet cuff pressure used during surgery and if this leads to less postoperative pain. The secondary aim was to investigate whether there were any differences between the group treated with this method and a control group regarding the quality of the bloodless field, range of knee motion, and postoperative wound complications. We hypothesized that there would be no differences between the limb-occlusion-pressure measurement method and the control method.

Materials and Methods

This prospective randomized controlled clinical trial was performed from October 2008 to July 2010. Patients scheduled to be treated with a primary total knee arthroplasty, who were seventy-five years of age or younger, and who were classified as American Society of Anesthesiologists (ASA) 1, 2, or 3 were considered eligible for inclusion[11,12]. Patients who were unable to read and understand Swedish, had a systolic blood pressure of >200 mm Hg, or had a thigh girth of >78 cm were excluded.

All patients gave their informed consent to participate and were randomized preoperatively to a control or intervention (limb-occlusion-pressure [LOP]) group with use of opaque sealed envelopes.

The study was conducted according to the principles of the Helsinki Declaration and was approved by the Ethics Committee of Karolinska Institutet (Ref. No. 2007/757-31/1-4), Stockholm. It was registered at ClinicalTrials.gov (NCT01442298).

The standard method at our department was used for the patients in the control group. The tourniquet cuff pressure was based on the patient's systolic blood pressure and a margin that was decided by the surgeon. In the LOP group, the tourniquet cuff pressure was decided by measuring the limb occlusion pressure with use of an automated photoplethysmographic sensor connected to an ATS 3000 tourniquet apparatus (Zimmer Sweden, Sävedalen, Sweden). The recommended tourniquet pressure was defined as the limb occlusion pressure plus a safety margin of 50 mm Hg for those with a limb occlusion pressure of ≤130 mm Hg, 75 mm Hg for those with a pressure between 131 and 190 mm Hg, and 100 mm Hg for those with a pressure of >190 mm Hg. These recommended margins were higher than those reported earlier[4,6], but were the preadjustable margins indicated by the manufacturer (Zimmer Sweden).

The limb underneath the tourniquet cuff was protected by a two-layer elastic stockinette[13]. The operating room nurse applied a standard 140-mm-wide contour thigh cuff for all but seven patients (three in the control group and four in the LOP group), for whom the operating room nurse selected a 100-mm-wide cylindrical cuff because of difficulties in positioning the contour cuff due to a short lower limb or a very straight thigh.

The operating room nurse chose the tourniquet cuff and measured the limb occlusion pressure. Before starting the surgery, the surgeon determined the tourniquet cuff pressure according to the standard method. The operating room personnel applied this pressure if the patient had been randomized to the control group. If the patient had been randomized to the LOP group, they applied the pressure suggested by the limb-occlusion-pressure method. The surgeon was blinded to the randomization and was not told which tourniquet pressure was applied.The surgery was performed according to the routine at our department.

The surgeon used a midline skin incision with a medial parapatellar capsular incision of the joint, and all patients received a cemented NexGen Cruciate Retaining total knee arthroplasty (Zimmer Sweden).

All patients received perioperative antibiotics (cloxacillin, 2 g × 3) and low-molecular-weight heparin (dalteparin). All patients also received a local infiltration analgesic (300 mg of ropivacaine/0.5 mg of epinephrine/30 mg of ketorolac) at the end of the surgery by infiltration into the fascia, muscles, and subcutaneous tissue, regardless of whether they had had spinal or general anesthesia. In 147 patients, a catheter was also inserted into the knee joint for pain treatment with a local anesthetic (150 mg of ropivacain/30 mg of ketorolac). It was used during the day after the surgery and was then withdrawn[14].

After the surgery was completed, the surgeon was asked to rate the quality of the bloodless field on a visual analog scale (VAS), with 1 indicating the worst possible rating and 10, the most optimal. The surgeon was also asked to rate whether any technical difficulties had been encountered due to the quality of the bloodless field (1 indicating no difficulties and 10, extreme difficulties).

The skin underneath the tourniquet was inspected immediately after the surgery and on day four, when a ward nurse also performed a wound check. The functional assessment was done on the third postoperative day by an independent physiotherapist and included measurement of knee motion (with the patient lying down and sitting up) and a straight-leg lifting test (with a 1-kg weight). Furthermore, the patients filled out the modified Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire daily during their hospital stay. The WOMAC is a self-administered, well-validated health status instrument with three domains: pain, physical function, and stiffness[15,16].

All patients were followed at two months postoperatively (with inspection of the wound, measurement of knee motion, and completion of the WOMAC questionnaire). The medical records were scanned for complications such as nerve injury and deep venous thrombosis. The orthopaedic surgeon in charge and all staff at the department, except the operating room personnel who measured the limb occlusion pressure, were blinded to the allocation group during the hospital stay and at the follow-up evaluations.

Power Analysis

The sample size was calculated to detect a difference of 5 points (standard deviation [SD], 10 points) in the WOMAC pain score between the control and LOP groups on day four. A total of sixty-four patients in each group (128 patients in the series) were required to detect this difference with an 80% power at the 5% significance level, two-tailed. As we anticipated a drop-out rate of about 25%, the recruitment goal was determined to be 164 patients. When we were planning for this study, we knew of no earlier randomized study with cuff pressure as the outcome, so our sample size was calculated for detecting differences in postoperative pain.

Statistical Methods

Categorical variables were presented as absolute and relative frequencies and tested for differences between randomization groups with the chi-square test. Continuous variables were presented throughout as the mean and SD and tested with the Mann-Whitney U test. The nonparametric test was used because it was deemed more appropriate for the subjective scale variables, and for the remaining continuous variables the assumption of normality was not satisfied. Cuff pressure was partly analyzed as a continuous variable and partly as a categorical variable, whereby the cutoffs of 225 and 260 mm Hg were chosen on the basis of their clinical relevance. The results were regarded as significant if p was < 0.05 (two-tailed).

All analyses were performed according to the intention-to-treat principle.

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The authors did not receive any external funding or grants in support of their research for this work.

Results

Three patients were excluded after inclusion: one because of a change to a unicompartmental knee arthroplasty, one because of a change to a high-flex prosthesis, and one who was scheduled

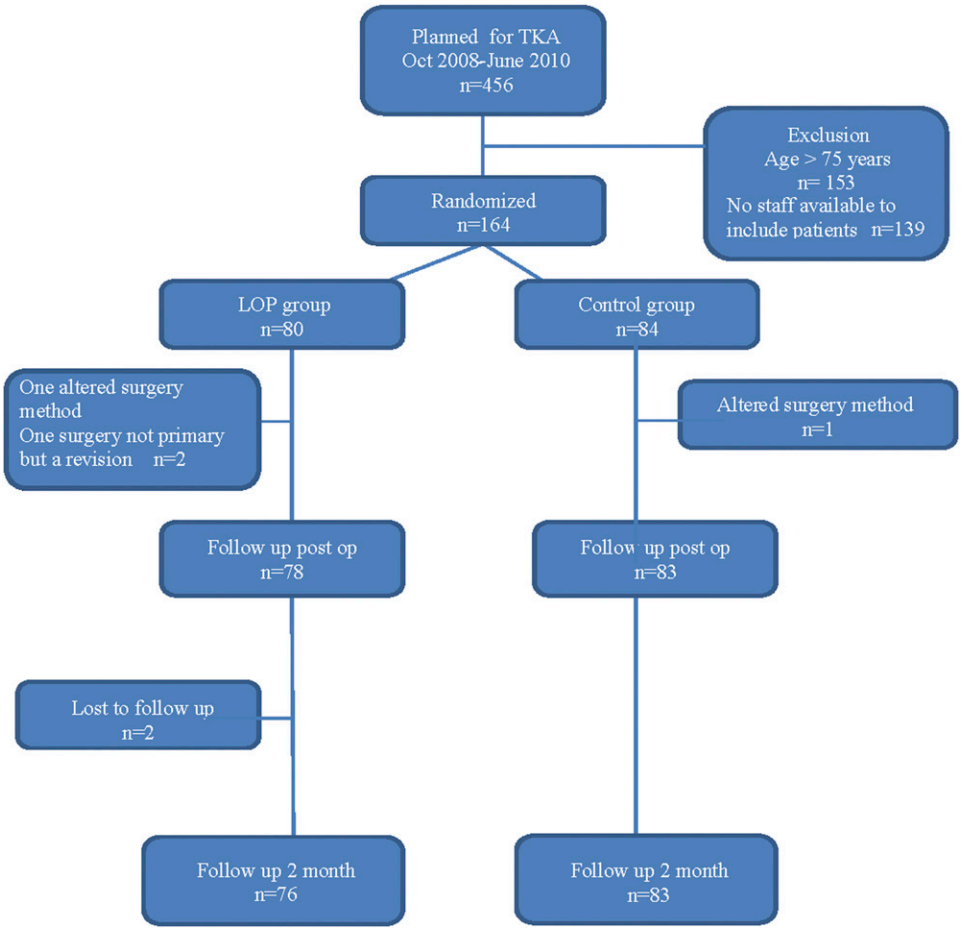

Fig. 1
CONSORT (Consolidated Standards of Reporting Trials) diagram. TKA = total knee arthroplasty.

for revision surgery and thus had been incorrectly included in the study. In total, 161 patients—eighty-three in the control group and seventy-eight in the LOP group—were included in the analysis. Two patients were lost to follow-up at two months (Fig. 1).

There were no differences between the LOP group and the control group regarding sex, age, ASA class, body mass index (BMI), preoperative systolic blood pressure, or the bloodless-field time during surgery (see Appendix). Systolic blood pressure, measured on the arm routinely at the start of surgery, was a mean (and SD) of 122 ± 20 mm Hg in the LOP group compared with 119 ± 19 mm Hg in the control group (difference not significant). The mean limb occlusion pressure (measured on the thigh in the LOP group) was 169 ± 34 mm Hg.

As shown in Table I, a tourniquet cuff pressure of ≤225 mm Hg was found more often in the LOP group than in the control group ($p < 0.001$). The mean tourniquet cuff pressure was also generally lower in the patients in the LOP group, but this difference was not significant ($p = 0.362$). No significant difference between the groups could be detected regarding the quality of the bloodless field or the technical difficulties as judged by the surgeon (Table I). There were incidents of break-through bleeding in three cases. In one of these cases, the tourniquet was deflated after only three minutes and the surgery was performed without a bloodless field.

Ratings of postoperative pain on the self-administered WOMAC questionnaire during hospitalization did not differ between the randomization groups, but the patients in the LOP group reported significantly less stiffness in the knee on day four ($p = 0.020$) (see Appendix). The range of motion of the knee on postoperative day three and the ability to do a straight-leg lift did not differ between the groups (see Appendix).

Three patients (out of 131 available) had blisters underneath the tourniquet cuff immediately after surgery, but there was no difference between the LOP group and the control group ($p = 0.227$). All three patients had had a cuff pressure of ≥260 mm Hg.

On day four, eight patients (out of the 111 available) had developed blisters or other pressure-related injuries underneath the tourniquet cuff and sixty-five patients reported that they had pain in the quadriceps muscle underneath the tourniquet cuff (no differences between the groups, $p = 0.400$).

At the time of discharge, forty-seven patients (30% of the 158 available) had developed a surgical wound complication such as blisters, oozing from the wound, or signs of infection. As shown in Table II, forty of these forty-seven patients had had a cuff pressure of >225 mm Hg during surgery. None of the patients with a cuff pressure of ≤225 mm Hg had any signs of wound secretion or infection, but seven patients had blisters

TABLE I Cuff Pressures and Ratings by the Surgeon Regarding the Quality of the Bloodless Field and Technical Difficulties

	Control Group (N = 83)	LOP Group (N = 78)	P Value
Cuff pressure *(no. [%] of patients)*			<0.001
≤225 mm Hg	7 (8)	26 (33)	
226-259 mm Hg	45 (54)	22 (28)	
≥260 mm Hg	31 (37)	30 (38)	
Mean cuff pressure (±SD) *(mm Hg)*	252 ± 17*	246 ± 45†	0.362
Mean preanesthetic systolic blood pressure (±SD) *(mm Hg)*	154 ± 18	155 ± 21	0.426
Mean preoperative systolic blood pressure/limb occlusion pressure (±SD) *(mm Hg)*	119 ± 19‡	169 ± 34§	
Mean VAS score (±SD) for quality of bloodless field	9.4 ± 1.3	8.7 ± 2.4	0.364
Mean VAS score (±SD) for technical difficulties	1.4 ± 1.3	2.04 ± 2.3	0.307

*Chosen by the surgeon. †Recommended by the apparatus. ‡Preoperative systolic blood pressure measured on the arm, immediately before the tourniquet was applied and the skin incision was made, for determination of the cuff pressure by the surgeon. §Limb occlusion pressure measured on the thigh by the limb-occlusion-pressure apparatus.

TABLE II Results of Wound Check on Postoperative Day Four, According to Group and Cuff Pressure, for the 158 Patients Available*

	Control Group			LOP Group		
	≤225 mm Hg (N = 7)	226-259 mm Hg (N = 45)	≥260 mm Hg (N = 31)	≤225 mm Hg (N = 24)	226-259 mm Hg (N = 22)	≥260 mm Hg (N = 29)
No wound complication	5	31	24	19	15	17
Blisters	2	8	4	5	5	10
Oozing from the wound	0	5	3	0	1	1
Signs of infection	0	1	0	0	1	1

*The values are given as the number of patients. P = 0.149 for the difference between the LOP and the control groups.

TABLE III Results of Wound Check at Two-Month Follow-up Visit for the 156 Patients Available*

	Control Group			LOP Group		
	≤225 mm Hg (N = 7)	226-259 mm Hg (N = 44)	≥260 mm Hg (N = 30)	≤225 mm Hg (N = 25)	226-259 mm Hg (N = 21)	≥260 mm Hg (N = 29)
No wound complications	7	39	27	23	19	25
Blisters	0	0	0	0	0	0
Delayed wound-healing	0	3	1	2	1	2
Wound infection	0	2	2	0	1	2

*The values are given as the number of patients. P = 0.869 for the difference between the LOP and the control groups.

around the knee. There were no significant differences between the LOP and the control groups (p = 0.149).

At the time of follow-up two months after surgery, seven patients (4%) had a postoperative wound infection and nine patients (6%) were recorded as having delayed wound-healing. Four of these patients had developed a deep wound infection after they were discharged from the ward and had been rehospitalized and reoperated on. Of the sixteen patients with a surgical wound complication at the two-month follow-up visit, fourteen had had a cuff pressure of >225 mm Hg. Two patients who had had a cuff pressure of ≤225 mm Hg had delayed wound-healing (Table III). There were no differences between the LOP group and the control group (p = 0.869).

Six of the seven patients who had a postoperative wound infection and all four patients who had a deep wound infection were men. We found no difference in cuff pressures between men and women, but men had significantly longer bloodless-field times (mean, eighty-nine minutes compared with seventy-three minutes for women; p = 0.027).

Two patients had a deep venous thrombosis, and one patient had a nerve injury. There were no differences between the LOP group and the control group (p = 0.752), but the patient with a nerve injury had had a cuff pressure >260 mm Hg.

At the two-month follow-up visit, knee motion, assessed by a blinded orthopaedic surgeon, did not differ between the groups. No difference in any of the three domains of the self-administered WOMAC questionnaire was detected between the LOP group and the control group (data not shown).

Discussion

This study shows that the limb-occlusion-pressure measuring technique reduces the tourniquet cuff pressures in patients undergoing a total knee arthroplasty, but we could not demonstrate any differences in postoperative pain between our LOP and control groups.

The generally lower cuff pressure in the LOP group provided a good-quality bloodless field but did not have any impact on the risk of developing a postoperative wound complication or on the range of motion, although the patients in the LOP group reported less stiffness of the knee on postoperative day four.

An important secondary finding was that, regardless of the randomization group, patients with a cuff pressure of ≤225 mm Hg had no postoperative infections and a lower rate of wound complications at discharge and at the two-month follow-up evaluation.

In contrast to the reports by Reilly et al.[9] and Younger et al.[6,10], we could not demonstrate any significant differences in the mean cuff pressures between the LOP group and the control group. The chosen cuff pressure depends on such factors as the experience of the surgeon as well as on local traditions. The surgeons in our study generally used a rather low cuff pressure, with a mean of 252 mm Hg in the control group, compared with surgeons in other published studies, in which cuff pressures of 300 to 350 mm Hg have been reported[2,4,6,17,18]. However, the limb-occlusion-pressure method led to more individual cuff pressures among our patients, since the pressures ranged from 150 to 300 mm Hg (SD, ±45) in the LOP group compared with 200 to 300 mm Hg (SD, ±17) in the control group. The mean measured limb occlusion pressure in our study was 169 mm Hg, which is higher than the mean of 142 mm Hg in the study by Younger et al.[6]. Our tourniquet apparatus also had a higher preadjustable margin from the manufacturer than earlier described[6,9,10], which resulted in higher recommended tourniquet pressures and therefore also higher mean values—246 mm Hg in our study compared with 202 mm Hg in the study by Younger et al. and 198 mm Hg in the study by Reilly et al. Nevertheless, the limb-occlusion-pressure measuring technique led to lower margins: 77 mm Hg in the LOP group compared with 133 mm Hg in the control group.

All of our patients received local infiltration analgesia at the end of surgery, and most of them received it the next day as well. This was a rather new routine at our department and was effective for treatment of postoperative pain. The fact that postoperative pain treatment was good in all patients could be one of the reasons why we could not demonstrate any differences in postoperative pain between groups. Another reason could be that the WOMAC questionnaire might not be sensitive enough to capture relatively small differences in postoperative pain ratings.

We could not demonstrate any differences in knee motion between the groups. All patients achieved good knee flexion as early as on day three: the mean was 78° in the control group and 77° in the LOP group, compared with 47° on day three after total knee arthroplasty done with a tourniquet in the study by Li et al.[3]. Earlier studies comparing knee or ankle surgery with and without a tourniquet have shown significantly better knee flexion after surgery without a tourniquet[3,17,19]. The authors suggested that the swelling of the limb after use of a tourniquet might be an explanation. Tourniquet release is known to be associated with an immediate 10% increase in limb girth[20], which was reported to increase up to 50% over the first postoperative day[17].

There was a rather large number of wound complications in our study. One reason could be that we did not exclude patients with diabetes, as has been done in other studies[1,3,17,19]. In our study, even patients classified as ASA 3, and some later classified as ASA 4, were included. However, no patient in our study who had a cuff pressure of ≤225 mm Hg developed a postoperative wound infection. This finding is in accordance with the report by Clarke et al.[2], who studied the pattern of postoperative wound hypoxia seven days after knee surgery and found that a tourniquet cuff pressure of about 225 mm Hg yielded a significantly better return of the oxygen levels compared with cuff pressures of 350 mm Hg.

Butt et al.[21] demonstrated a significant association between increased tourniquet time and wound oozing after total knee arthroplasty. They had a mean tourniquet time of eighty-three minutes with a range of thirty-eight to 125 minutes. In our study, the mean tourniquet time was eighty-seven minutes. Six of the seven patients who had a postoperative wound infection in our study were men. We found no other differences between men and women other than a significantly longer bloodless-field time for men. In this study, we focused on cuff pressures and complications; however, the duration of the bloodless field is probably another important factor that requires further investigation.

The strength of this study is that it was a randomized controlled trial of a "nonselected" study population, with few exclusion criteria. A limitation might be that we used the WOMAC questionnaire as the primary outcome measure

since it may not be reliable enough to capture the small differences regarding postoperative pain. Another limitation of our study is that very few of our patients had a BMI of >35 kg/m^2 and therefore our results may not be valid for that patient group.

In conclusion, the generally lower tourniquet cuff pressure in the LOP group did not decrease the postoperative pain or other outcomes in our patients. However, patients who had undergone total knee arthroplasty in a bloodless field with a cuff pressure of ≤225 mm Hg had a lower rate of wound complications such as delayed healing and infections.

The limb-occlusion-pressure measuring technique can help the surgeon to choose more individual, often lower, cuff pressures. However, if the surgeon carefully chooses an optimal and not too high cuff pressure and considers the type and width of the cuff, the circumference of the limb, and the patient's individual vessel characteristics, both methods appear to yield a good outcome in terms of postoperative complications.

Appendix

eA Tables showing demographic baseline data and the duration of the bloodless field as well as the results of the WOMAC, range of motion, and straight-leg lifting are available with the online version of this article as a data supplement at jbjs.org. ■

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References

1. Abdel-Salam A, Eyres KS. Effects of tourniquet during total knee arthroplasty. A prospective randomised study. J Bone Joint Surg Br. 1995 Mar;77(2):250-3.
2. Clarke MT, Longstaff L, Edwards D, Rushton N. Tourniquet-induced wound hypoxia after total knee replacement. J Bone Joint Surg Br. 2001 Jan;83(1):40-4.
3. Li B, Wen Y, Wu H, Qian Q, Lin X, Zhao H. The effect of tourniquet use on hidden blood loss in total knee arthroplasty. Int Orthop. 2009 Oct;33(5):1263-8. Epub 2008 Aug 27.
4. Noordin S, McEwen JA, Kragh JF Jr, Eisen A, Masri BA. Surgical tourniquets in orthopaedics. J Bone Joint Surg Am. 2009 Dec;91(12):2958-67.
5. Worland RL, Arredondo J, Angles F, Lopez-Jimenez F, Jessup DE. Thigh pain following tourniquet application in simultaneous bilateral total knee replacement arthroplasty. J Arthroplasty. 1997 Dec;12(8):848-52.
6. Younger AS, McEwen JA, Inkpen K. Wide contoured thigh cuffs and automated limb occlusion measurement allow lower tourniquet pressures. Clin Orthop Relat Res. 2004 Nov;(428):286-93.
7. Estebe JP, Le Naoures A, Chemaly L, Ecoffey C. Tourniquet pain in a volunteer study: effect of changes in cuff width and pressure. Anaesthesia. 2000 Jan;55(1):21-6.
8. Pedowitz RA, Gershuni DH, Botte MJ, Kuiper S, Rydevik BL, Hargens AR. The use of lower tourniquet inflation pressures in extremity surgery facilitated by curved and wide tourniquets and an integrated cuff inflation system. Clin Orthop Relat Res. 1993 Feb;(287):237-44.
9. Reilly CW, McEwen JA, Leveille L, Perdios A, Mulpuri K. Minimizing tourniquet pressure in pediatric anterior cruciate ligament reconstructive surgery: a blinded, prospective randomized controlled trial. J Pediatr Orthop. 2009 Apr-May;29(3):275-80.
10. Younger AS, Manzary M, Wing KJ, Stothers K. Automated cuff occlusion pressure effect on quality of operative fields in foot and ankle surgery: a randomized prospective study. Foot Ankle Int. 2011 Mar;32(3):239-43.
11. American Society of Anesthesiologists. ASA Physical Status Classification System. http://www.asahq.org/home/for-members/clinical-information/asa-physical-status-classification-system. Accessed 2012 Sep 4.
12. Dripps RD, Lamont A, Eckenhoff JE. The role of anesthesia in surgical mortality. JAMA. 1961 Oct 21;178:261-6.
13. Olivecrona C, Tidermark J, Hamberg P, Ponzer S, Cederfjäll C. Skin protection underneath the pneumatic tourniquet during total knee arthroplasty: a randomized controlled trial of 92 patients. Acta Orthop. 2006 Jun;77(3):519-23.
14. Kerr DR, Kohan L. Local infiltration analgesia: a technique for the control of acute postoperative pain following knee and hip surgery: a case study of 325 patients. Acta Orthop. 2008 Apr;79(2):174-83.
15. 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 Dec;15(12):1833-40.
16. Roos EM, Klässbo M, Lohmander LS. WOMAC osteoarthritis index. Reliability, validity, and responsiveness in patients with arthroscopically assessed osteoarthritis. Western Ontario and MacMaster Universities. Scand J Rheumatol. 1999;28(4):210-5.
17. Konrad G, Markmiller M, Lenich A, Mayr E, Rüter A. Tourniquets may increase postoperative swelling and pain after internal fixation of ankle fractures. Clin Orthop Relat Res. 2005 Apr;(433):189-94.
18. Tejwani NC, Immerman I, Achan P, Egol KA, McLaurin T. Tourniquet cuff pressure: the gulf between science and practice. J Trauma. 2006 Dec;61(6):1415-8.
19. Wakankar HM, Nicholl JE, Koka R, D'Arcy JC. The tourniquet in total knee arthroplasty. A prospective, randomised study. J Bone Joint Surg Br. 1999 Jan;81(1):30-3.
20. Estebe JP, Davies JM, Richebe P. The pneumatic tourniquet: mechanical, ischaemia-reperfusion and systemic effects. Eur J Anaesthesiol. 2011 Jun;28(6):404-11.
21. Butt U, Ahmad R, Aspros D, Bannister GC. Factors affecting wound ooze in total knee replacement. Ann R Coll Surg Engl. 2011 Jan;93(1):54-6. Epub 2010 Sep 10.