Skin protection underneath the pneumatic tourniquet during total knee arthroplasty

A randomized controlled trial of 92 patients

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Background **The use of a pneumatic tourniquet to obtain a bloodless field during a total knee arthroplasty (TKA) allows the surgeon to work with greater technical precision in a safe, clear environment. Despite the benefits of surgical tourniquets and many advances in tourniquet equipment, their use is not without risk and complications may still occur. The primary aim of this study was to determine whether there are any differences between an elastic stockinette, cast padding, and no protective material at all regarding skin injuries after a primary TKA in a bloodless field using a pneumatic tourniquet.**

Methods **92 patients were randomized to 1 of 3 groups. In the first group, the limb underneath the pneumatic tourniquet was protected by a two-layer elastic stockinette (E). In the second group, it was protected by cast padding (C), and no protective material (N) was used in the third group. The presence of major skin injuries (blisters) was recorded when the tourniquet was removed after surgery.**

Results **The two groups with skin protection had fewer skin injuries (p = 0.007). The elastic stockinette was significantly better than having no protective material and there was a trend towards better results in the elastic stockinette group than in the cast padding group.**

Interpretations **Our findings indicate that protective material underneath the tourniquet cuff reduces the risk of skin injuries, i.e. blisters. An elastic stockinette appears to be best.**

The complications of a pneumatic tourniquet to obtain a bloodless field reported in the literature include skin injuries underneath the cuff, postoperative swelling, delay of recovery of muscle power, compression neuropraxia, wound hematoma with the potential for infection, vascular injury, tissue necrosis, compartment syndrome and systemic complications (Wakai et al. 2001). Complications such as skin blisters can be a source of substantial postoperative morbidity (Koval et al. 2003).

The injuries reported are most often pressure-related, but they can also be caused by excessive tourniquet time. The pressure to which the tourniquet is inflated should be based on the patient's systolic blood pressure and the shape and size of the extremity. For conical extremities, curved cuffs are considered ideal because they require a lower cuff pressure to maintain a bloodless field than straight cuffs (Pedowitz et al. 1991, 1993).

Injuries to the skin underneath the cuff, such as indentation, redness and blistering, can still occur even when the pressure and tourniquet time are optimal (Choudhary et al. 1998). Today, there is no clear evidence that any type of skin protection underneath the tourniquet can prevent or minimize the risk of skin injuries.

The main aim of this study was to determine whether there are any differences between an elastic stockinette, cast padding, or no protective material at all regarding skin injuries after a primary TKA in a bloodless field using a pneumatic

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Figure 1. Two-layer elastic stockinette (DeltaNet; Smith and Nephew, Mölndal, Sweden).

Figure 2. Cast padding (Soffban Synthetic; Smith and Nephew, Mölndal, Sweden).

tourniquet. The secondary aim was to investigate the overall incidence of skin injuries directly after the use of a pneumatic tourniquet during TKA, and their potential to progress to clinically significant injuries requiring treatment.

Patients and methods

The study was conducted between October 2000 and March 2003. All 215 patients who underwent a primary TKA during this period were considered eligible for inclusion. 94 patients gave their informed consent to participate in the study and were randomized to 3 groups using opaque sealed envelopes. In the first group (E), the limb underneath the pneumatic tourniquet was protected by a two-layer elastic stockinette (DeltaNet; Smith and Nephew, Mölndal, Sweden) (Figure 1); in the second group (C), protection was by cast padding (Soffban Synthetic; Smith and Nephew) (Figure 2). No protective material was used in the third group (N). 2 patients were excluded, 1 because of cancellation of surgery and 1 because of missing data, which left 92 patients in the study population. The indication for surgery was osteoarthritis in 82 patients and rheumatoid arthritis in 10. The study was conducted according to the Helsinki Declaration and the protocol was approved by the local ethics committee.

Based on the circumference and shape of the patient's thigh, the operating nurse (OR) could choose between a 140-mm-wide contoured thigh cuff (conical) and a standard 100-mm-wide cylindrical cuff (Zimmer Sweden AB, Göteborg, Sweden). The recommended cuff pressure for the contoured cuff was 70–100 mmHg, and for the cylindrical cuff, 100–150 mm Hg, above the patient's systolic blood pressure. However, ultimately, it was the attending surgeon who determined the cuff pressure. Precautions were taken to minimize the risk of fluid collection under the cuff. The systolic blood pressure at the start of surgery, the chosen tourniquet pressure, and the time duration of the bloodless field were recorded. Directly after the surgery when the tourniquet was removed, the OR nurse inspected the patient's skin under the cuff and recorded the presence or absence of blisters. Superficial injuries such as indentation and redness were not regarded as major skin injuries.

In order to evaluate the clinical importance of blisters registered directly after surgery, the incidence of these blisters was compared with the incidence of clinically significant skin injuries after the use of a tourniquet cuff in primary TKA in our clinical audit. Clinically significant skin injuries registered in the audit are defined as an injury requiring any form of treatment, e.g. repeated dressing, wound care or surgical intervention. All patients operated upon in our institution since 1997 have been registered in this audit, in which complications during the first 6 weeks after surgery are registered and validated. The follow-up rate is 99.5%. Between 1997 and 2003, nearly 40,000 patients were registered and of them, 728 underwent TKA in a bloodless field (personal communication).

Statistics

We used SPSS 12.0.1 for Windows. The Kruskal-Wallis test and the Mann-Whitney U-test were

Background data on all patients included. Group E: elastic stockinette; group C: cast padding; group N: no protection. There were no significant differences between groups

	Total n = 92	Group E n = 33	Group C n = 29	Group N n = 30
Women	60	22	20	18
No co-morbidities	46	14	15	17
Osteoarthritis	82	29	27	26
Cylindrical cuff	50	16	17 [a]	17
Age [b]	71 (11)	69 (12)	74 (10)	69 (10)
Thigh circumference, cm [b]	54 (7)	53 (6) [a]	55 (7)	54 (8)
Systolic blood pressure, mmHg [b]	141 (26)	142 (23)	142 (27)	140 (30)
Bloodless field pressure, mmHg [b]	257 (17)	255 (20)	256 (16)	259 (16)
Bloodless field time, minutes [b]	96 (22)	96 (23)	93 (23)	99 (21)

[a] 1 missing value.
[b] mean (SD).

used for scale and ordinal variables in independent groups. Nominal variables were tested by the Chi-square test or Fisher's exact test. All tests were two-sided. The results were considered significant at $p < 0.05$.

Results

There were no differences in baseline data between the 3 groups (Table).

In total, 10 patients (7 in the N group and 3 in the C group) developed skin blisters beneath the pneumatic tourniquet during TKA, giving an overall incidence of 11%. The two groups with skin protection had fewer skin injuries ($p = 0.007$). The elastic stockinette was significantly better than no protective material ($p = 0.004$) and there was a trend towards better results in the elastic stockinette group than in the cast padding group ($p = 0.09$). The difference between cast padding and no protective material was not significant ($p = 0.3$). There was no reported case of fluid collection under the cuff.

8/41 patients with conical tourniquet cuffs developed blisters, as compared to 2/50 patients with cylindrical cuffs ($p = 0.04$). The mean cuff pressure in patients with conical cuffs was 255 (SD 21) mmHg as compared to 259 (SD 14) mmHg in patients with cylindrical cuffs ($p = 0.6$), and the mean difference between the patient systolic blood pressure and the cuff pressure was 115 (SD 24) mmHg and 118 (SD 26) mmHg, respectively ($p = 0.5$). There was no significant difference in thigh circumference between patients with conical cuffs and patients with cylindrical cuffs: 55 cm and 53 cm, respectively.

Patients who developed blisters had a longer duration of the bloodless field than those without blisters: 112 (SD 29) min and 94 (SD 21) min, respectively ($p = 0.04$). There were no significant differences in cuff pressure, 255 (SD 11) mmHg and 257 (SD 18) mmHg, thigh circumference, 55 (SD 9) cm and 54 (SD 7) cm, or age, 72 (SD 12) years and 71 (SD 11) years, between patients who developed blisters and those who did not.

Discussion

The best results were obtained with an elastic stockinette, which is in agreement with 2 previous studies. McEwen and Inkpen (2002) compared 5 cuff and padding configurations in healthy volunteers and found that an elastic stockinette produced significantly fewer and less severe pinches and wrinkles than all other padding types tested, including cast padding. However, their results were based on testing in healthy volunteers with a tourniquet cuff pressure of 200 mmHg for only 1 min. Din and Geddes (2004) compared skin protection methods in 82 patients undergoing primary TKA and 68 patients undergoing arthroscopy, and found that some type of protection underneath the cuff

reduced the incidence of skin injuries. The incidence of blisters was lower than in our study (4% compared to 11%), probably because of the lower mean age and shorter duration of surgery in the arthroscopy group.

These blisters rarely seem to require any treatment or progress to more serious skin injuries. In our local quality audit, during the years 1997–2003 the incidence of skin injuries requiring any form of treatment registered during the first 6 weeks postoperatively was 1.5% (11/728) (personal communication). This figure is higher than that found in the retrospective questionnaire study of Rudolph et al. (1990), who found an incidence of skin injuries under the cuff of 0.1% after surgery on the lower limb and of 0.04% after surgery on the upper limb. The higher incidence in our audit can be partly explained by its prospective character.

We found a higher incidence of skin blisters in patients in whom the conical cuff was used than in patients in whom the cylindrical cuff was used, which is in contrast to what might be expected. A conical cuff is wider and often fits better on a curved thigh, and therefore requires a lower bloodless field pressure (Pedowitz et al. 1993). One explanation of our finding may be that the mean difference between the patient's systolic blood pressure and the cuff pressure was almost identical in patients with conical cuffs and those with cylindrical cuffs, around 115–120 mmHg. This is not in line with the recommendation of the manufacturers, who recommend 70–100 mmHg above the systolic blood pressure for the conical cuff and 100–150 mmHg for the cylindrical cuff. This may indicate that the theoretical advantages of the conical cuffs prevail only when a reduced cuff pressure is used. Furthermore, the finding of equal cuff pressures between cuff types in our study also indicates a lack of knowledge in this regard among our surgeons. In fact, using the conical cuff with pressures recommended for cylindrical cuffs actually seemed to increase the complication rate. Besides the effect on skin injuries, previous studies have demonstrated the importance of using the lowest possible cuff pressure in order to reduce other potential tourniquet complications (Wakai et al. 2001). This finding of unnecessarily high cuff pressures in patients with conical cuffs may have had an influence on the outcome. However, a larger fraction of patients in the elastic stockinette group (0.5) had a conical cuff than in the cast padding group (0.4), and the figure in the group in which no protection was used was 0.4. This skewed distribution of cuff types between the randomization groups may, in fact, further strengthen the conclusion that the elastic stockinette is the protective method of choice.

A bloodless field time of 120 min is considered to be safe (Wakai et al. 2001). We found that a longer tourniquet time increases the risk of blisters.

Our study has some limitations. The lack of previous studies on the incidence of skin injuries directly after tourniquet application in TKA made it impossible for us to perform an adequate power analysis. The study turned out to be slightly underpowered. Moreover, a longer follow-up time would have been preferable to detect the percentage of blisters registered directly after removal of the tourniquet that progress to more serious injuries requiring treatment. On the other hand, the figures regarding incidence from our audit are most probably valid. Finally, in order to evaluate the influence of other factors besides randomization, a logistic regression would have been appropriate. However, owing to the limited number of patients included and the absence of complications in the elastic stockinette group, a logistic regression was not feasible.

Contributions of authors

CO was involved in the study design, data analysis and drafting of the manuscript. JT was mainly involved in data analysis and drafting of the manuscript. PH was mainly involved in the study design and drafting of the manuscript. SP was mainly involved in drafting of the manuscript. CC was mainly involved in data analysis and drafting of the manuscript.

Choudhary S, Koshy C, Ahmed J, Evans J. Friction burns to thigh caused by tourniquet. Br J Plast Surg 1998; 51 (2): 142-3.

Din R, Geddes T. Skin protection beneath the tourniquet. A prospective randomized trial. ANZ J Surg 2004; 74 (9): 721-2.

Koval K J, Egol K A, Polatsch D B, Baskies M A, Homman J P, Hiebert R N. Tape blisters following hip surgery. A prospective, randomized study of two types of tape. J Bone Joint Surg (Am) 2003; 85 (10): 1884-7.

McEwen J A, Inkpen K. Safety preventing skin injuries. The Surgical Technologist 2002; 34: 6-14.

Pedowitz R A, Gershuni D H, Schmidt A H, Friden J, Rydevik B L, Hargens A R. Muscle injury induced beneath and distal to a pneumatic tourniquet: a quantitative animal study of effects of tourniquet pressure and duration. J Hand Surg (Am) 1991; 16 (4): 610-21.

Pedowitz R A, Gershuni D H, Botte M J, Kuiper S, Rydevik B L, Hargens A R. The use of lower tourniquet inflation pressures in extremity surgery facilitated by curved and wide tourniquets and an integrated cuff inflation system. Clin Orthop 1993; (287): 237-44.

Rudolph H, Gartner J, Studtmann V. Skin lesions following the use of a tourniquet. Unfallchirurgie 1990; 16 (5): 244-51.

Wakai A, Winter D C, Street J T, Redmond P H. Pneumatic tourniquets in extremity surgery. J Am Acad Orthop Surg 2001; 9 (5): 345-51.