Original Contribution

Tourniquet use during ankle surgery leads to increased postoperative opioid use☆☆,☆☆☆

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Abstract

Study objective: Ankle surgery is often done using a tourniquet. Ischemia/reperfusion injury caused by the tourniquet may increase postoperative pain. The study objective was to investigate the amount of opioids given to patients after ankle surgery with and without tourniquet.

Design: We did a cohort study based on data from patient’s records between January 2008 and December 2011.

Setting: Information is gathered from operating room, postanesthetic care unit, and surgical ward in a university hospital.

Patients: We identified patients undergoing reconstructive ankle fracture surgery from hospital records. We excluded multiple fractures of the same extremity, major trauma, reoperations, arthrodesis of the ankle joint, and missing data on tourniquet use. We included 603 patients.

Interventions: For each patient, we registered for how long (minutes) the tourniquet was inflated.

Measurements: Main outcome was opioid use during first 24 hours postoperatively (in equipotent intravenous morphine doses). Secondary outcomes were the peak pain on a verbal rating scale, time in postanesthetic care unit, and additional antiemetic medicine. We performed multiple regression to analyze the primary outcome.

Main results: Three hundred fifty-eight patients underwent surgery with tourniquet. There was a correlation between tourniquet time and postoperative opioid use (P value = .001) after controlling for confounders. The slope of the correlation was 0.04 mg/min (95% confidence interval, 0.02-0.07), which means there is an increase in postoperative opioid use by 0.43 mg for every 10 minutes of tourniquet time.

Conclusion: We found an increase in postoperative opioid consumption correlated to tourniquet use. Possible preventive measures with antioxidant treatment to prevent ischemia/reperfusion injury should be investigated.

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1. Introduction

Postoperative pain after ankle surgery is common, and controlling pain is important for optimal recovery and patient satisfaction [1-3].

Ankle surgery is often done using a tourniquet [4-7], which gives the surgeon a bloodless field and decreases blood loss, but it also leads to a number of challenges for the anesthesiologist both during and after surgery [6]. In a systematic review, it was shown that tourniquet use increases hospital length of stay and makes the postoperative period more painful in relation to foot and ankle surgery [6].

Ischemia/reperfusion (I/R) injury is defined as cellular damage after reperfusion of previously viable ischemic tissue [8]. Ischemia/reperfusion injury involves a complex cascade of responses and local inflammation resulting in swelling and pain. Ischemia/reperfusion injury after tourniquet use occurs despite improvement of patient security [9].

The hypothesis behind this study is that tourniquet use is associated with increased postoperative pain, and the aim of our study is to determine the opioid use in patients undergoing ankle fracture surgery with and without use of tourniquet.

2. Materials and methods

Data collection was approved by the Danish Data Protection Agency (J-no. HEH-750.16-32, I-Suite no. 01788). According to Danish legislation, database studies do not require ethics committee consideration.

2.1. Database: patient selection

All ankle fracture patients undergoing open reduction and internal fixation surgery at University Hospital Herlev between January 2008 and December 2011 were identified from hospital records. Data collection was initiated in 2012 and took place throughout 2013.

Data were entered into standard hospital records by treating personnel and subsequently extracted for this study. Patient’s records include several digital and nondigital clinical records and databases used by physicians and nurses.

We also used Danish Anaesthesia Database for data collection, which is a quality assurance initiative.

Inclusion criteria were the unique Danish Social Security Number, reconstructive surgery of the ankle at Herlev University Hospital within the time span 2008-2011, and correct registration of the surgical procedure. Exclusion criteria used were multiple fractures of the same extremity and/or major trauma; operations in the same ankle within 30 days or without intercurrent injury, as they were considered reoperations; arthrodesis of the ankle joint; and missing data on tourniquet use. We defined tourniquet data as missing if anesthesia chart or surgery description included reference to tourniquet being used, but no tourniquet time could be found.

2.2. Database: data collection

Information on exposure to tourniquet was found in the anesthetic chart, which is used to document perioperative events, and it is registered in minutes of inflated tourniquet.

We defined primary outcome as opioid consumption during the first postoperative 24 hours. This was measured by extracting data on the doses of any opioid drug administered to the patient and then converting this dose into equipotent doses of intravenous morphine in milligrams.

In the electronic system used for managing medicine, it is registered what medicine is prescribed to the patient by the doctor and what medicine is given to the patient by the nurses. In our study, we extracted data on the medicine that had been administered by the nurses to the patient.

Secondary outcomes used in this study were peak pain score (PPS), time in postanesthetic care unit (PACU), and need for additional postoperative antiemetic medication.

Peak pain score is the highest registered pain score with the standard scoring system used in the PACU. The scoring system used is based on a 100-mm visual analogue scale (VAS) score and registered as 1 of 4 categories: “no pain,” 0 mm; “light pain,” 1-29 mm; “moderate pain,” 30-69 mm; and “severe pain,” 70-100 mm. The staff registers this on a scale 0-3 where 0, no pain; 1, light; 2, moderate; and 3, severe pain. Patients were scored at rest every hour.

Almost all patients received 4 mg ondansetron to prevent nausea; therefore, we defined the outcome related to nausea as a dichotomous outcome: yes/no to additional antiemetic medication as registered in the patient’s record. Time in PACU was defined as the time recorded in the anesthesia chart from arrival to discharge.

To characterize the cohort and identify possible confounders, we also gathered and analyzed demographic, anamnestic, and perioperative information. The demographic factors we analyzed were age and sex. Anamnestic factors we investigated were American Society of Anesthesiologists (ASA) score, body mass index (BMI), diabetes mellitus, smoking, pretraumatic use of prescription pain medication, and type of fracture. We registered patients as having diabetes mellitus if they had stated so in the hospital admission interview or if their medication included drugs used in diabetes treatment (ie, insulin and metformin). Smoking and pretraumatic use of prescription pain medication were determined from admission interview as well. Information on time under anesthesia and type of anesthesia (general or spinal anesthesia ± peripheral nerve blockade and miscellaneous) was also gathered for analysis.

2.3. Statistical analysis

We visually inspected all outcome data for normal distribution. We detected no severe deviations from normal distribution, and because the sample size is relatively large, we deemed it reasonable to conduct parametric analysis for all outcomes. Hence, we analyzed outcome data using either linear regression or logistic regression where the outcome
was dichotomous. To characterize the cohort, we used chi² test and Student t test to compare patients operated with and without tourniquet. All demographic, anamnestic, and perioperative data were analyzed for correlation with either tourniquet time or postoperative opioid using Student’s t test (dichotomous), 1-way analysis of variance, and linear regression (continuous) to identify possible confounders. We corrected the results of the primary outcome for the confounders, using the appropriate regression analysis. All the tests were 2 sided, and statistical significance was set to $P \leq .05$. We used SPSS version 20 (IBM Corporation, Armonk, NY) for statistical analyses.

### 3. Results

We included 603 patients in this study. Of these patients, 358 underwent surgery with tourniquet, and mean tourniquet time was 70.20 minutes (SD, 26.81). Thus, 245 patients were not exposed to tourniquet. Table 1 shows how the demographic, anamnestic, and perioperative characteristics were distributed among patients operated with and without a tourniquet. Only mean time under anesthesia and mean postoperative opioid consumption were different between the two groups. Patients operated without tourniquet had a mean postoperative opioid consumption of 15 mg, whereas it was 18 mg in the patients operated with a tourniquet. This means tourniquet use was associated with a 20% increase in opioid consumption with a $P$ value of .008 (univariate regression).

All demographic, anamnestic, and perioperative data were analyzed for correlation with either tourniquet time or postoperative opioid consumption. Only the types of fracture had significant differences in mean tourniquet time. BMI, smoking, type of fracture, and type of anesthesia were significantly correlated to postoperative opioid consumption. Therefore, these were included in the multiple analysis shown in Table 2.

Table 2 shows a correlation between tourniquet time and postoperative opioid consumption. The slope is 0.04, which means that the opioid consumption increases by 0.4 mg for every 10 minutes of tourniquet time.

We only performed simple regression analysis on the secondary outcomes, which are shown in Table 3. Linear regression shows that PPS and time in PACU had small positive slopes. This means that PPS increased by 0.002, and time in PACU increases by 0.16 (0.04-0.29) minutes for every minute of tourniquet time. The correlations are statistically significant. Logistic regression revealed no increased risk of need for antiemetic medication related to tourniquet use.

### 4. Discussion

The main finding in this study was a correlation between tourniquet time and postoperative opioid consumption. It is a relatively small effect of 0.4 mg per 10 minutes of tourniquet time. In addition, PPS and time in PACU increased with increasing tourniquet time. Although PPS is only analyzed with univariate linear regression and although the magnitude is probably of minor clinical significance, it supports the hypothesis that tourniquet use increases postoperative pain.

Using pain medication as a surrogate measure for perceived pain has been investigated in a large cohort undergoing oral surgery [10]. The study found that the patient’s choice to take pain medication was a better indicator of pain than numerical pain scales. Although the increase in opioid consumption was...
that pain and swelling were increased at day 5 and week 6 undergoing open reduction and internal fixation of ankle fractures, higher pain scores were found in the tourniquet group both 24 and 48 hours postoperatively [13].

Limited, any intervention to reduce opioid use should be investigated and incorporated in a multimodal approach to treatment of postoperative pain [11].

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>B (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>0.3 (0.09 to 0.51)</td>
<td>.005</td>
</tr>
<tr>
<td>Smoking</td>
<td>No</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>2.33 (0.12 to 4.53)</td>
</tr>
<tr>
<td>Type of fracture</td>
<td>Medial malleolus</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Lateral malleolus</td>
<td>5.13 (0.91 to 9.34)</td>
</tr>
<tr>
<td></td>
<td>Bimalleolar</td>
<td>5.76 (1.57 to 9.94)</td>
</tr>
<tr>
<td></td>
<td>Trimalleolar</td>
<td>8.93 (4.38 to 13.47)</td>
</tr>
<tr>
<td>Type of anesthesia</td>
<td>SA †</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>SA + PNB §</td>
<td>−2.39 (−5.04 to 0.26)</td>
</tr>
<tr>
<td></td>
<td>GA ‡</td>
<td>6.16 (2.75 to 9.56)</td>
</tr>
<tr>
<td></td>
<td>GA + PNB</td>
<td>0.78 (−2.08 to 3.57)</td>
</tr>
<tr>
<td></td>
<td>Misc †</td>
<td>1.15 (−4.05 to 6.36)</td>
</tr>
<tr>
<td>Tourniquet time, min</td>
<td>0.04 (0.02 to 0.07)</td>
<td>.001</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.
* The B value is the predicted increase in postoperative opioid consumption for each listed variable or per unit of listed continuous variable with correction for other factors.
† Spinal anesthesia.
‡ Peripheral nerve blockade.
§ General anesthesia.
∥ Miscellaneous; including peripheral nerve blockade alone, spinal + general anesthesia, and spinal + general anesthesia + peripheral nerve blockade.

Time in PACU increases by 1.6 minutes per 10 minutes of tourniquet time. Our study was not designed to investigate why the PACU time increases, but pain and opioid treatment might have a negative effect [12].

Previous studies have shown similar results. In a randomized controlled study including 32 patients undergoing surgery for ankle fractures, higher pain scores were found in the tourniquet group both 24 and 48 hours postoperatively [13]. In another randomized clinical trial including 54 patients undergoing open reduction and internal fixation of ankle fractures with or without the use of tourniquet, it was found that pain and swelling were increased at day 5 and week 6 after tourniquet use [14]. None of the studies reported uses of opioids for analgesia.

Our primary outcome was opioid consumption during the first 24 hours after surgery, which is a period not specifically investigated in the previous studies we found. The first 24 hours after surgery are a very critical period for pain management in the sense that it can prolong length of stay in both PACU and in hospital in general [14,15]. The biggest strength of this study is the large cohort investigated, giving the opportunity to evaluate confounders. A cohort of 603 patients gives us a unique opportunity to investigate and find significant correlations. The registration of the primary outcome parameter was done as a matter of routine, reducing the risk of observer bias.

Several limitations were present. Our study was not a randomized controlled study, and data were registered as a matter of standard treatment not in a manner defined in a protocol, thereby increasing risk of inconsistent data registration, etc. It is standard treatment to prescribe 30 mg of morphine (three 10-mg tablets) to all patients, which should then be given to them by the nurses one at a time on request. The medicine registration system, however, shows that the 3 tablets were often administered at the same time. This means the first 30 mg might be administered to patients who did not actually require pain medication in that amount. Several limitations exist when using the digital medicine registration system as a primary data source. The clinical staff does not always handle the registration correct as in the example above, and, in other cases, registration is simply forgotten.

Information on details concerning the tourniquet use is not available in this study. The placing of the tourniquet on the extremity, the pressure applied as well as whether the tourniquet was applied using preconditioning, if release intervals were used for long procedures, and if postconditioning or staggered release, etc, took place were not information available to us. This information would have been valuable because these factors might affect complication rate and opioid consumption [6,9].

Several mechanisms demand attention when using tourniquet. A systematic review [16] found that tourniquet led to several systemic and localized complications. Local effects included nerve, muscle, skin, and vascular injuries. Ischemia and reperfusion can result in muscle damage, “no reflow phenomenon” [9], and “posttourniquet syndrome [9,16].”

Mechanisms of muscle damage are numerous and lead to apoptosis and necrosis [9]. “No reflow phenomenon” is

Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>PPS * (min)</th>
<th>Time in PACU (min)</th>
<th>Need for additional antiemetic medicine †</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B (95% CI)</td>
<td>B (95% CI)</td>
<td>Odds ratio (95% CI)</td>
</tr>
<tr>
<td>Tourniquet time, min</td>
<td>0.002 (0.001-0.004)</td>
<td>0.16 (0.04-0.29)</td>
<td>0.99 (0.99;1.01)</td>
</tr>
</tbody>
</table>

* Univariate linear regression.
† Logistic regression.
‡ The B value is the predicted increase in listed factor per minute of tourniquet time.
when blood flow does not return to all areas after prolonged ischemia. The phenomenon is caused by leucocytes adhering to postcapillary venules and disruption of microvascular barriers causing edema [8,9]. “Posttourniquet syndrome” is characterized by stiffness, pain, weakness without paralysis, and subjective numbness. The syndrome is a result of combined muscle ischemia, edema, and microvascular congestion [9,16]. These phenomena are all associated with pain. Systemic consequences of I/R including acute lung injury and systemic inflammation after I/R in relation to tourniquet use have been seen [9]. Animal studies even show that sepsis syndrome, septic shock, and multiple organ dysfunction can occur after I/R in skeletal muscle [17].

Minimizing oxidative stress would theoretically decrease the severity of I/R injury. A study on the effect of vitamin C as prevention of complex regional pain syndrome type I in ankle and foot surgery found that complex regional pain syndrome type I occurred significantly less in the vitamin C–treated group. Complex regional pain syndrome type I is a syndrome combining pain, trophic disturbance, and bone demineralization and it is also thought to be a result of oxidative stress [18].

It is unclear whether tourniquet should be used routinely, as sufficient guidelines are lacking [4,6,7,19], and therefore its application is up to the surgeon’s preference only. Our data show that tourniquet was not applied in 40.6% of ankle fracture surgeries in our institution. The type of fracture does not seem to determine if tourniquet is used, and the type of fracture is the only indicator of the severity of the fracture available to us in this study. The type of fracture was included in the multiple regression analysis to correct for possible confounding. The length of operation expressed as time under anesthesia is not shorter in the tourniquet group (see Table 1). This indicates that tourniquet does not improve the surgeon’s working conditions. Whether the risks associated with tourniquet use overshadow the benefits for the surgeon is widely discussed [6,19].

In conclusion, we found that tourniquet use was associated with increased postoperative opioid use, higher peak pain severity, and longer PACU stay. Preventive measures with antioxidant treatment should be investigated in the future.

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