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The effect of elbow position at the time of tourniquet inflation on clinical outcomes

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Abstract. – OBJECTIVE: The aim of this study was to prospectively investigate the effects of elbow position on perioperative and postoperative clinical outcomes during tourniquet inflation.

PATIENTS AND METHODS: The patients were divided into two groups based on their elbow position during tourniquet inflation: patients with elbows extended group E (30 patients), patients with flexed elbows group F (30 patients). Both groups were compared in terms of perioperative bloodless surgical field, tourniquet pain, time to onset of pain, and pain in the tourniquet area on the first postoperative day, plus elbow-forearm range of motion deficit on both the perioperative and postoperative first day.

RESULTS: The bloodless surgical field provided by the tourniquet was 0.46 (0-5) in Group E and 0.4 (0-4) in Group F. Perioperative tourniquet pain started in an average of 51 (33-71) minutes in 4 patients in Group E and 49 (31-74) minutes in 5 patients in Group F. Pain was present in 2 patients in both groups in the postoperative tourniquet area. When the preoperatively measured elbow flexion-extension and forearm supination-pronation deficits were compared with the perioperative values, the deficits were 1%, 2%, 1%, 1% in Group E, and 1%, 1%, 2%, 1% in Group F, respectively. When compared with the postoperative values, 1%, 3%, 1%, 1% in Group E and 1%, 2%, 1%, and 1% in Group F were observed, respectively.

CONCLUSIONS: There was no statistically significant difference between the two groups, but since repositioning the elbow after the tourniquet is inflated will cause an additional shearing effect on the tissues under the cuff, we recommend inflating the tourniquet in that position in which the operation will be performed in upper extremity surgeries.

Key Words:
Upper extremity, Tourniquet inflation, Elbow position.

Introduction

The tourniquet, known since the ancient roman surgeons, entered a new era with the invention of pneumatic tourniquets at the beginning of the 20th century, providing more convenient use[1]. Safe use and complications of tourniquet – which includes many potential dangers as well as advantages such as minimal intraoperative blood loss, optimization of visualization, thereby shortening surgical duration – has always aroused curiosity and a large number of clinical studies[1,2] have been conducted on this subject. The majority of these focused on tourniquet duration and pressure, showing that the prolongation of the application period and the high pressure increase the risk of complications in direct proportion[1,2]. In some studies[3-5], different variables such as application localization, shape of cuff, type of padding were examined. Apart from the factors related to the surgeon and the tourniquet device, patient-related factors such as height, weight, age, race, gender, and comorbidities have also been reported to affect the existing complication risks[1].

There are only a few studies on the appropriate position of the extremity during tourniquet inflation, and all of these studies are on the lower extremity[6-8]. Our aim in this study, which is the first in the literature for upper extremity surgeries to the best of our knowledge, is to prospectively examine the effects of elbow position during tourniquet inflation on perioperative and postoperative clinical outcomes and to be a prelude to further studies on this subject.

Patients and Methods

Between May 2022 and July 2022, patients, on whom tourniquets were used for upper extremity surgery participated in the study. Inclusion criteria were: (1) 18-65 years old; (2) operations related to hand area only; (3) no effect of the surgery on forearm rotations; (4) the duration of the surgery being between 30-90 minutes. Exclusion criteria were: (1) Having a history of previous shoulder, humerus and elbow operations or having lim-

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itations in these regions; (2) patients requiring general anesthesia due to a problem occurring in perioperative regional block; (3) diseases that are proven to increase tourniquet complications such as peripheral neuropathy, vascular diseases, Reynaud's disease, history of DVT, sickle cell disease.

After patient eligibility was confirmed 60 patients were randomly assigned to one of two groups: those with the elbow in extension during tourniquet inflation (Group E), and those with flexion (Group F). Patients were randomly allocated to a treatment group using an electronic random number generator, with those having an even number receiving elbow extension and those having an odd number receiving elbow flexion. This prospective study was approved by the Institutional Review Board at Institutional Ethical Committee (EAUEC: 2022-4/7) and all patients gave informed consent.

Clinical and Functional Outcome Measures

Before surgery, forearm movements such as elbow flexion-extension when the shoulder was in full adduction and supination-pronation when the elbow was in 90 degrees flexion were measured with the aid of a goniometer. The visual analogue scale (VAS) was used while evaluating the bloodless surgical field that the tourniquet should provide. The surgeon scored 0 points for no blood leakage at the surgical site, and 10 for excessive blood leakage. The time of first onset of pain was noted in patients who reported perioperative tourniquet pain. Elbow ROMs were measured just before the post-surgical tourniquet deflation and compared with pre-surgical values as a percentage. On the postoperative first day, elbow ROM was measured similarly and compared with preoperative values. Pain at tourniquet localization with postoperative palpation was assessed by VAS. With 0 standing for the absence of pain, and 10 for worst pain ever felt, scoring was made by the patient in the range of 10 points. Patients who continued to have tourniquet pain after the first postoperative day were followed up until these complaints subsided. Perioperative and postoperative complications related to tourniquet were noted.

Tourniquet Application Technique

In addition to axillary block, intercostobrachial nerve block (ICBN) was applied to all patients for tourniquet pain. Similar to both groups, a straight shape, single, fabric cuff was positioned over the two layers of cotton padding, 6-7 cm above the elbow joint. Patient was prepped and draped in the usual sterile approach. After the limb was exsanguinated by an Esmarch bandage, the compressed air tourniquet (VBN, Bremen, Germany) was inflated to 100 mmHg above the systolic blood pressure in Group E with elbow in full extension (Figure 1), and Group F with elbow in full flexion (Figure 2). After surgery and wound closure, the tourniquet was deflated. Tourniquet usage time was noted. Except for the recommendations for simple elbow ROM exercises, no patient-specific rehabilitation program was initiated for the elbow.

Statistical Analysis

The statistical analysis was performed using the Statistical Package for Social Sciences (SPSS®) version 28.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistical methods were used to evaluate study data. The normality of the data was tested using the Shapiro-Wilk test. For comparison the dependent variable, paired *t*-test was performed to assess the variation in range of motion. An independent *t*-test

Figure 1. Inflating the tourniquet with the elbow extended.

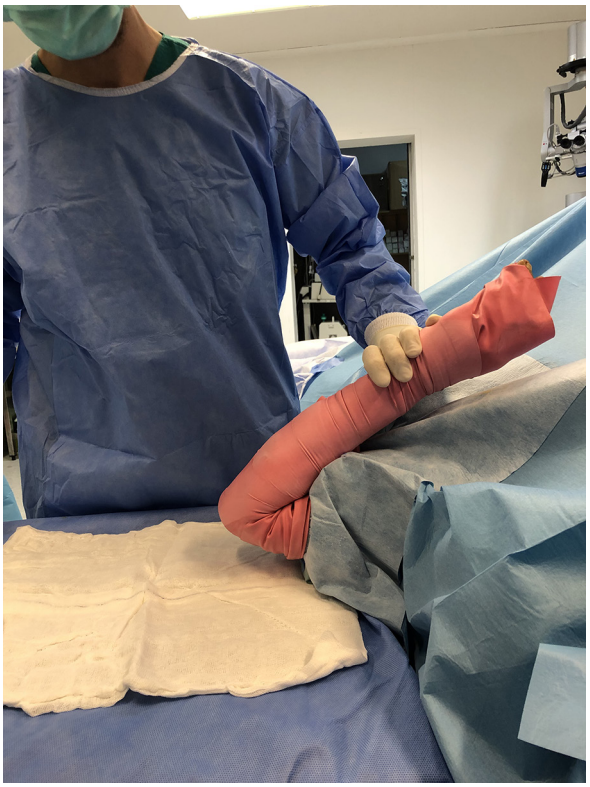

Figure 2. Inflating the tourniquet with the elbow flexed.

was performed to compare age, BMI, tourniquet time, tourniquet pressure, perioperative and postoperative tourniquet pain, perioperative and postoperative elbow ROM deficit, complications. Pearson Chi-square test, Fisher-Freeman-Halton test, and Fisher's exact test were used to compare qualitative variables. *p*-value of <0.05 was regarded as significant.

Results

Baseline demographic data are presented in Table I. No significant differences were observed between both groups in terms of age and gender ($p>0.05$). There were 30 patients (15 females; 15 males) in the Group E with a mean age of 42.7 (range: 18-64) years, 30 patients (13 females; 17 males) in the Group F with a mean age of 44.1 (range: 18-65) years. Group E 14 right and 16 left hands, with the dominant hand involved in 14 cases. Group F 13 right and 17 left hands, with the dominant hand involved in 14 cases. The body mass index (BMI) was 24.7 (21.9- 35.4) in Group E and 25.8 (22.4-36.3) in Group F. Average tourniquet time was 52.2 (32-88) minutes for Group E and 50.8 (30-86) minutes for Group F. Average tourniquet pressure was 217 (195-240) mm Hg in Group E and 221 (190-245) mm Hg in Group F (Table I). The same regional block was applied to all patients by the same anesthesiologist. All patients were operated by the same surgeon (OA) specializing in hand surgery. There were no significant differences between the demographic and clinical data of the patients. All perioperative evaluations were performed by the operating physician (OA), while the postoperative first day examination was conducted by an independent surgeon who did not attend any of the operations. In the perioperative evaluation of Group E, the VAS provided by the tourniquet without bleeding was 0.46 (0-5), while it was 0.4 (0-4) in Group F ($p>0.05$). In comparison of the perioperative ROM measurements just before tourniquet descent with the preoperative ROM measurements, Group E had 1% extension and 2% flexion deficit in the elbow, and 1% supination and 1% pronation deficit in the lower extremity. In Group F, there was 1% extension, 1% flexion, 2% supination and 1% pronation difference in the forearm ($p>0.05$). In Group E, the surgical tourniquet was completed painlessly in 26 patients. 4 patients (13.3%) started to describe tourniquet pain in the 51st (33-71) minute of the operation. In Group F, 25 patients completed the surgery without pain, while 5 patients (16.6%) started to describe pain at the 49th (31-74) minute of the operation. In comparison of the values measured on the first postoperative day with the preoperative values: in Group E, mean elbow extension 1%, flexion 3%,

Table I. Demographic and clinical data of the two groups.

	Group extension	Group flexion	*p*-value
Participants (female/male)	30 (15/15)	30 (13/17)	0.605
Age in years (range)	42.7 (18-64)	44.1 (18-65)	0.603
Hand R/L (dominant involved)	14/16 (14)	13/17 (14)	0.795
BMI (kg/m^2) (min-max)	24.9 (21.9-35.4)	25.8 (22.4-36.3)	0.374
Tourniquet Time (min) (range)	52.2 (32-88)	50.8 (30 -86)	0.652
Tourniquet Pressure (mmHg) (range)	217 (195-240)	221 (190-245)	0.216

forearm mean supination 1%, pronation difference 1%; in Group F, there was an average of 1% extension, 2% flexion at the elbow, 1% supination and 1% pronation difference in the forearm (p>0.05). When the pain in the tourniquet application area was questioned, 28 patients in Group E had no pain, while 2 patients had VAS 1 pain. And the pain in both was gone within the second day after the operation. In Group F, 28 patients had no pain, but one patient had VAS 1 pain, and this pain disappeared on the second postoperative day. The other patient described VAS 1 pain. This pain went away on the third postoperative day. No tourniquet-related complications were encountered in either group (Table II).

Discussion

The tourniquet, which is widely used in lower and upper extremity surgeries, may cause feared complications and increase the healthcare burden with its local (cuff compression) and systemic (ischemia-reperfusion) effects, in addition to its advantages. In fact, when studies with large series are examined, it is seen that the complications of upper extremity tourniquets are very low, such as 1/6,000[9]. The reason behind such low rates is the prevention of many complications by the widespread use and definition of the safe tourniquets[1-3]. The important point is that it is necessary not only to evaluate the negative effects of tourniquet use in terms of serious complications, but also to consider temporary problems. For example, it is necessary to define perioperative complaints such as inability to provide a bloodless surgical field and tourniquet pain, and uncomfortable conditions such as restriction of post-operative joint movements and pain in the postoperative cuff area.

"10 rules for the safe use of tourniquet", which was first defined by Bruner[5] in 1951, was later modified by Braithwaite and Klenerman in 1962[6]. Although there have been many studies[1,2,6-8] on the safe use of tourniquet, which has always attracted attention by physicians dealing with extremity surgery, there are only three studies in the literature on extremity position at the time of tourniquet inflation. And all of these are studies on knee replacement surgeries in the lower extremities[7-9]. Zura et al[7] reported that tourniquet inflation in flexion provides a statistically significant, clinically insignificant 1 degree knee ROM advantage in the postoperative period compared to inflation in extension. Matsui et al[8] on the other hand, stated that on the basis of inflation, the knee position has no role on the knee GAP in arthroplasty. Tanavalee et al[9] investigated the contribution of different inflation positions to the lateral patellar displacement measured during arthrotomy. They reported that in deep flexion, where the quadriceps is more elongated, the patella will move more easily with inflation, and thus arthrotomy and exposure will be made easier. This is not known, as there have been no studies on the mobilization of a muscle under

Table II. Comparison of clinical outcomes of both groups.

		Group extension	Group flexion	*p*-value
Bloodless surgical field (0/1/2/3/4/5)		23/4/1/1/0/1	23/5/0/1/1/0	0.683
Patient with perioperative tourniquet pain (%)		4 (%13.3)	5 (%16.6)	0.718
Onset time in patients with tourniquet pain (range)		51 ± 15 (33-71)	47.8 ± 17 (31-74)	0.784
Patient with postoperative tourniquet area pain		2 (6.6%)	2 (6.6%)	1
Perioperative ROM Deficit (%)	Extension	1 ± 2 (0-5)	1 ± 2 (0-5)	1
	Flexion	2 ± 2.8 (0-10)	1 ± 2 (0-5)	0.120
	Supination	1 ± 2 (0-5)	2 ± 3.3 (0-10)	0.170
	Pronation	1 ± 2 (0-5)	1 ± 2 (0-5)	1
Postoperative ROM Deficit (%)	Extension	1 ± 2 (0-5)	1 ± 2.4 (0-10)	1
	Flexion	3 ± 4.4 (0-15)	2 ± 3.1 (0-10)	0.319
	Supination	1 ± 2 (0-5)	1 ± 2.4 (0-10)	0.500
	Pronation	1 ± 2 (0-5)	1 ± 2.4 (0-10)	0.500

pressure (elongen - shorten). However, according to Tanavalee et al[9], patella movements are affected because this elongation is reduced. In fact, if we make an evaluation for the upper extremity in parallel with this view: in anterior elbow surgery requiring perioperative extension position, inflammation may provide ease of movement in the extension where the humerus anterior region muscles lengthen. In posterior elbow region surgeries requiring flexion, flexion inflation, in which the posterior humerus muscles remain long, can be recommended. However, we did not observe any significant differences in our study in which we compared the perioperative (just before the tourniquet descending) elbow movements in both groups.

Perioperative tourniquet pain is a complication that negatively affects surgery. Kamath et al[11] observed 51.8% of tourniquet pain in upper extremity surgeries lasting less than 60 minutes. We attribute our observation of this pain (Group E: 13.3%, Group F: 16.6%) at lower rates in a similar period (50-52 minutes) in our study to the intercostobrachial nerve block in addition to the axillary block. Another discomfort described for tourniquet pain is pain at the site of postoperative tourniquet application, which is usually temporary and perhaps underestimated. We observed similar short-term (2-3 days) tourniquet pain in two patients in both groups.

Estebe et al[4] blames the shearing effect as well as the compression in the negative effects of the tourniquet cuff on the skin, muscle, and nerve tissue. In particular, he stated that the use of conical cuff had less shearing effect than the use of straight cuff. In his study, he stated that a new position should not be given to the arm after the tourniquet was inflated in order not to cause shearing effect. The majority of hand surgeries are performed with the patient in the supine position, with the shoulder abducted at 90 degrees, and the elbow extended on the arm table. The process of inflating the tourniquet while the elbow is flexed, then extending the arm and placing it on the arm table can lead to a new shearing effect as it causes the inflated atourniquet to be placed in a new position. Although we did not observe any difference in terms of complications between the two groups, inflation in extension may be recommended in hand-table surgeries in order not to cause a new shearing effect.

According to Rajpura et al[12], padding under the cuff causes some loss in the transmission of tourniquet pressure required to cut off arterial pressure. With elbow flexion, the biceps length is shortened, and its volume increases more. This suggests that higher pressure may be required to interrupt the flow by padding on the brachial artery. In our study, we applied a tourniquet pressure of 100 mmHg above the standard systolic pressure in all patients and we did not observe any difference between the groups in terms of providing a perioperative bloodless surgical field. However, this hypothesis needs to be investigated with devices such as doppler USG, which shows the pressure at which the flow is cut off more clearly. In addition, it is known that the radial nerve is the most prone to injury during upper extremity tourniquet applications regardless of position[13]. Changes in muscle volumes and nerve movements in the upper arm with elbow flexion-extension may cause some changes in nerve injury risks by causing differences in the effects of the cuff on the nerves. We have not encountered a study in the literature showing the relationship between elbow movements and nerves at the humerus level with muscles. However, further studies such as dynamic MRI may be beneficial in demonstrating this relationship.

Some positions cause an increase or decrease in the muscle mass under the cuff (7 cm) by lengthening and shortening the muscle, thus causing more or less muscle to be under mechanical pressure. The effects of mechanical press such as loss of muscle functional strength, contractile speed and fatigability are known. In fact, in some studies[2,4], muscle necrosis was investigated with data such as technetium-99m, CK-MB, and myoglobinuria. Another hypothesis is that with inflation in flexion, more muscle volume in the anterior region of the humerus can be achieved, and with inflation in extension, more muscle volume in the posterior region can be under the cuff. Our study is insufficient to clearly reveal how much these muscles are affected by mechanical compression. Although tourniquet-related muscular injury is known more influenced by ischemic time rather than direct compression pressure, exposure of muscle volume to cuff compression at varying rates with arm positions and its results can be examined by further studies[1,2].

The present study has some strengths. These are its prospective nature, providing both perioperative and postoperative evaluation, and being a comparative study. In similar studies[7-9] on the lower limb, knee prosthesis surgery also affects the knee joint and the muscles of the knee region, and the isolated effect of the tourniquet on the

muscles is not revealed. In our study, however, the isolated effect of the tourniquet on the muscles around the elbow was evaluated more clearly, since surgical applications affecting the movements of the elbow region were excluded from the study.

Limitations

Our study has some weaknesses; although the demographic data, single surgeon and surgeon durations of both groups were similar, it could have resulted in more homogeneous groups consisting of patients undergoing the same surgical procedure (e.g., dorsal ganglion excision, carpal tunnel release) in both groups. In our study, we evaluated the perioperative and postoperative effects of the upper extremity tourniquet inflating position with objective data such as ROM, as well as subjective data such as satisfaction and pain scores. In any case, the effects of inflation should be investigated with more objective measurement tools such as blood tests, radio diagnostics (USG, MRI), electromyography (EMG) and muscle strength measurement, according to the elbow positions that we aim to be a starting point in the upper extremities.

In our study, which requires further investigation, we observed that the upper extremity tourniquet inflating position had no perioperative and postoperative effects. However, we recommend that the upper extremity tourniquet inflating position be performed with the elbow extended, given that the majority of hand surgeries are performed with the elbow extended and the negative consequences of increased biceps volume in flexion are taken into account.

Conclusions

Many of the tourniquet complications are preventable complications. Prevention of these complications increases postoperative patient satisfaction as well as providing perioperative comfort for the surgeon. Unlike previous studies on safe tourniquet use, we did not observe any difference between the groups in our study in which we examined the clinical results of the tourniquet inflating position in the upper extremity. However, we suggest investigating this effect with more objective studies.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Ethics Approval

This study was approved by the Ethics Committee of Erzurum Atatürk University Medical Faculty (EAÜEC: 2022-4/7).

Informed Consent

Patients were informed about the study and consent was obtained.

Authors' Contribution

Muhammet Çağatay Engin – Resources, Software, Supervision, Validation. Ömer Ayık – Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Writing.

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