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Obese patients require higher, but not high pneumatic tourniquet inflation pressures using a novel technique during total knee arthroplasty

Obez hastalar yeni bir teknik kullanılarak total diz artroplastisi sırasında daha yüksek ama yüksek olmayan pnömatik turnike inflasyon basınçlarına gerek duymaktadır

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ABSTRACT

Objectives: This study aims to investigate the effect of obesity on pneumatic tourniquet inflation pressures determined with a novel formula during total knee arthroplasty (TKA).

Patients and methods: Data of 208 patients (19 males, 199 females; mean age 69.8 years; range, 53 to 84 years) who were performed TKA between January 2013 and December 2016 were evaluated prospectively. Patients were divided into two groups as non-obese (body mass index [BMI] ≤30.0 kg/m^2) and obese (BMI >30.0 kg/m^2) according to BMI. Tourniquet inflation pressures were set using arterial occlusion pressure (AOP) estimation method and adding 20 mmHg of safety margin to AOP value. All patients were assessed intra- and postoperatively with outcome measures such as systolic blood pressure, AOP, tourniquet pressure and its effectiveness. The quality of the surgical field and complications were assessed by the surgical team in a blinded fashion.

Results: The study included 118 and 90 lower extremity operations in obese and non-obese groups, respectively. Compared to non-obese group; extremity circumference, initial and maximal systolic blood pressures, AOP values, initial and maximal tourniquet pressures were higher in obese group. The performance of the tourniquet was assessed as "excellent" and "good" at almost all stages of the surgical procedure in all patients in both groups. No complication occurred intra- or postoperatively.

Conclusion: Compared to non-obese patients, higher tourniquet inflation pressure is required in obese patients during TKA due to their wider extremity circumference and higher systolic blood pressure profile.

Keywords: Arterial occlusion pressure; estimation method; knee arthroplasty; obesity; pneumatic tourniquet.

ÖZ

Amaç: Bu çalışmada obezitenin total diz artroplastisi (TDA) sırasında yeni bir formül ile belirlenen pnömatik turnike inflasyon basınçları üzerine etkisi araştırıldı.

Hastalar ve yöntemler: Ocak 2013 - Aralık 2016 tarihleri arasında TDA uygulanan 208 hastanın (19 erkek, 199 kadın; ort. yaş 69.8 yıl; dağılım 53-84 yıl) verileri prospektif olarak değerlendirildi. Hastalar vücut kitle indeksine (VKİ) göre obez olmayan (VKİ ≤30.0 kg/m^2) ve obez (VKİ >30.0 kg/m^2) olmak üzere iki gruba ayrıldı. Turnike inflasyon basınçları arteriyel oklüzyon basıncı (AOB) tahmini yöntemi kullanılarak ve AOB değerine 20 mmHg'lık güvenlik marjı eklenerek belirlendi. Tüm hastalar sistolik kan basıncı, AOB, turnike basıncı ve etkinliği gibi sonuç ölçümleri ile ameliyat sırasında ve sonrasında değerlendirildi. Cerrahi alan kalitesi ve komplikasyonlar ameliyat ekibi tarafından kör bir şekilde değerlendirildi.

Bulgular: Obez ve obez olmayan grupta sırasıyla 118 ve 90 alt ekstremite ameliyatı çalışmaya alındı. Obez olmayan grupla karşılaştırıldığında obez grupta ekstremite çevresi, başlangıç ve maksimum sistolik kan basınçları, AOB değerleri, başlangıç ve maksimal turnike basınçları daha yüksekti. Her iki gruptaki tüm hastalarda turnike performansı cerrahi girişimin hemen hemen tüm aşamalarında "mükemmel" ve "iyi" olarak değerlendirildi. Ameliyat sırasında veya sonrasında herhangi bir komplikasyon gelişmedi.

Sonuç: Obez olmayan hastalarla karşılaştırıldığında, obez hastalarda daha geniş ekstremite çevresi ve daha yüksek sistolik kan basıncı profili nedeniyle TDA sırasında daha yüksek turnike inflasyon basıncı gerekmektedir.

Anahtar sözcükler: Arteriyel oklüzyon basıncı; tahmin yöntemi; diz artroplastisi; obezite; pnömatik turnike.

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In recent years, there has been an increase in the number of obese patients undergoing total knee arthroplasty (TKA), parallel with the increase in obesity.[1] Although there are studies which investigated the impact of obesity on operative difficulty, operative time, length of hospital stay, complications and costs, to our knowledge, there is no report studying the optimal pneumatic tourniquet pressures and their effectiveness in obese patients undergoing knee arthroplasty surgery.[2-5]

The use of personalized rather than fixed inflation pressures according to arterial occlusion pressure (AOP) is recommended in tourniquet applications.[6-9] The most important factors affecting AOP are limb girth and systolic blood pressure, which are known to be higher in obese patients.[10,11] However, adequate knowledge about AOP and optimal tourniquet pressures in obese patients in the literature is lacking. Therefore, in this study, we aimed to investigate the effect of obesity on pneumatic tourniquet inflation pressures determined with a novel formula during TKA.[12]

PATIENTS AND METHODS

Data from 208 patients (19 males, 199 females; mean age 69.8 years; range, 53 to 84 years) assessed as class I-II according to American Society of Anesthesiologists (ASA) physical status who underwent primary-unilateral TKA at Başkent University Zübeyde Hanım Practice and Research Center between January 2013 and December 2016 were prospectively collected to analyze the influence of obesity on the results. Exclusion criteria were age outside the range of 18 to 85 years, ASA physical status ≥3, peripheral claudication, severe anemia, any contraindication to regional anesthesia, previous adverse reactions to medications used in the study, and inability to provide informed consent. Operations were performed by the same surgical team using the same pneumatic tourniquet (DTS-2000w; Daesung Maref Co. Ltd., Gyeonggi-do, South Korea). According their Body Mass Index (BMI), patients were divided into two groups as non-obese (BMI <30 kg/m^2) and obese (BMI ≥30). Age, gender, height, weight, BMI, and extremity circumference of the patients and surgical procedures were recorded. The study protocol was approved by the Institutional Review Board and Ethics Committee of Baskent University, Ankara, Turkey (Project no: KA16/337). A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

In the operating room, following standard monitoring including systolic blood pressure (SBP), diastolic blood pressure, electrocardiogram, oxygen saturation and end-tidal carbon dioxide, patients received general, spinal, epidural or combined epidural-spinal anesthesia according to anesthesiologist's decision. Since SBP is the most important manageable factor in tourniquet pressure optimization, SBP of the patients should be kept as low as possible and maintained throughout surgery. Therefore, we used the controlled hypotension and minimal inflation pressure (CHAMIP) technique, which provided a bloodless field in all patients, with a mean tourniquet pressure of 169.7±7.9 mmHg for lower extremity surgeries and 118.2±7.2 mmHg for upper extremity surgeries in our previous studies, values significantly lower than those previously reported and recommended in the literature.[13,14]

In all patients, the thigh circumference was measured 20 cm proximal to the superior pole of the patella with the knee extended by a tape measure and recorded. The tourniquet cuff was placed around the thigh with the distal edge 15 cm proximal to proximal

TABLE I

Tissue padding coefficients based on limb circumferences[6]

Extremity circumferences (cm)	Estimated K_{TP}
20	0.91
21	0.90
22	0.89
23	0.88
24	0.87
25	0.86
26 to 27	0.85
28	0.84
29	0.83
30 to 31	0.82
32 to 33	0.81
34	0.80
35 to 36	0.79
37 to 38	0.78
39 to 40	0.77
41 to 43	0.76
44 to 45	0.75
46 to 48	0.74
49 to 51	0.73
52 to 54	0.72
55 to 57	0.71
58 to 60	0.70
61 to 64	0.69
65 to 68	0.68
69 to 73	0.67
74 to 75	0.66

K_{TP}: Tissue padding coefficient.

TABLE II

Patient demographics

	Non-obese group (n=90)		Obese group (n=118)			
	n	Mean±SD	n	Mean±SD	*p*	
Age (year)		71.1±8.7		68.9±8.0	0.050	
Gender					0.089	
Female	78		111			
Male	12		7			
Height (cm)		161.5±6.6		159.6±6.2	0.030	
Weight (kg)		69.4±7.9		90.1±11.2	0.001	<0.05
Body Mass Index (kg/m^2)		26.5±2.3		35.5±5.0	0.001	<0.05
Limb circumference (cm)		47.3±4.9		56.8±6.5	0.002	<0.05

SD: Standard deviation.

pole of the patella. Standard pneumatic tourniquet with an 11 cm cuff was applied by an orthopedic surgeon. Arterial occlusion pressure estimation formula was used to determine the appropriate tourniquet inflation pressure. The calculation was made using initial SBP and tissue padding coefficient (K_{TP}) values from a list (Table I) according to limb circumferences of the patient with a calculator [AOP=(SBP+10)/K_{TP}].[6] Calculated AOP with an addition of 20 mm as a safety measure (Tourniquet pressure=AOP+20 mmHg) was applied. After exsanguination with an Esmarch bandage or elevation of the limb for three minutes, the tourniquet cuff was inflated to the proper setting. The tourniquet pressure (TP) was manually raised 10 mmHg in response to each 10 mmHg increment in SBP measured at five-minute intervals throughout the tourniquet period. Initial SBP, initial TP, maximal SBP, maximal TP and tourniquet time were recorded. The surgeon, who was not aware of the tourniquet pressure, rated the performance of the tourniquet as excellent, good, fair or poor (Excellent= There is no blood in the surgical field, Good= There is some blood in the surgical field but not interfering with surgery, Fair= There is blood in the surgical field but not significantly interfering with surgery, Poor= The blood in the surgical field obscure the view) at the beginning (start= after skin incision), in the middle (at the end of the osteotomies) and at the end of the procedure (skin closure). All patients were examined daily during their hospital stay for signs of any complications, such as skin damage, nerve palsies, vascular occlusion or infection.

Statistical analysis

All data and resulting outcomes were analyzed using SPSS for Windows version 15.0 (SPSS Inc., Chicago, IL, USA). The t-test was used for continuous data. The Chi-square test was used for comparison of categorical data. A *p* value of less than 0.05 was considered to be statistically significant.

RESULTS

Data were obtained from 208 TKA cases from 118 obese and 90 non-obese limbs, respectively. Body mass index and extremity circumference of the patients were significantly higher in obese group compared with non-obese group (Table II).

TABLE III

Systolic blood pressures, tourniquet pressures and tourniquet times

	Non-obese group (n=90)	Obese group (n=118)		
	Mean±SD	Mean±SD	*p*	
Initial systolic blood pressure (mmHg)	96.0±7.8	103.4±9.7	0.001	<0.05
Estimated AOP (mmHg)	143.4±11.5	159.7±14.3	0.001	<0.05
Initial tourniquet pressure (mmHg)	164.1±11.5	180.0±13.9	0.001	<0.05
Maximal systolic blood pressure (mmHg)	100.2±8.3	108.1±10.2	0.001	<0.05
Maximal tourniquet pressure (mmHg)	167.9±11.3	184.5±14.6	0.001	<0.05
Tourniquet time (minute)	77.3±18.3	77.7±18.4	0.894	

SD: Standard deviation; AOP: Arterial occlusion pressure.

TABLE IV

Surgeon's opinion about performance of tourniquets at various stages of surgery

Surgeon's opinion	Non-obese group (n=90)						Obese group (n=118)					
	Start		Middle		End		Start		Middle		End	
	n	%	n	%	n	%	n	%	n	%	n	%
1= Excellent	86	95.55	90	100	90	100	111	94.06	118	100	118	100
2= Good	3	3.33	0	0	0	0	4	3.38	118	100	118	100
3= Fair	1	1.11	0	0	0	0	3	2.54	0	0	0	0
4= Poor			0	0	0	0			0	0	0	0
Complications			0						0			

The mean initial SBP under anesthesia (102.3±9.6 mmHg versus 95.3±7.8 mmHg) and estimated AOP values (155.7±17.7 mmHg versus 141.6±10.6 mmHg) were significantly higher in obese group compared with non-obese group ($p<0.01$). In obese group, the mean initial TP (177.2±13.0 mmHg versus 162.0±10.7 mmHg) and the mean intraoperative maximal SBP (107.2±10.8 versus 99.3±8.6) was found to be more elevated ($p<0.05$). Additionally, the mean intraoperative maximal TP utilized was also significantly higher (182.6±15.0 versus 165.9±10.5) in obese group ($p<0.01$). There were no differences in mean total tourniquet times between the groups (Table III).

Performance of the tourniquets was assessed as "excellent" and "good" in almost all stages of the procedure in all cases in both groups (Table IV). No complications such as damage to skin, vessels, nerves or compartment syndrome were observed during or after surgery until discharge. There were no postoperative wound infections in obese or non-obese groups.

DISCUSSION

The present study showed that more than half of the patients undergoing TKA were obese and these patients have wider extremity circumference, higher SBP profile and AOP values leading to the utilization of higher tourniquet inflation pressures compared with non-obese patients during TKA.

Previous studies investigated different aspects of obesity in patients who underwent TKA such as operative difficulty, operative time, complications and costs and length of hospital stay.[1-5] Although obese patients often present a problem in tourniquet application due to their excessive subcutaneous tissue, to our knowledge, this is the first study which investigates the relationship between obesity and tourniquet pressures applied in patients undergoing TKA using a novel formula to determine and maintain safer tourniquet pressures.[6] AOP is the lowest pneumatic tourniquet inflation pressure required to stop the arterial blood flow into the limb and its usage has been shown to be useful in optimizing tourniquet cuff pressures.[7-9] The main factors affecting AOP are limb circumference, systolic blood pressure and the width and shape of tourniquet cuff.[10,11]

Several experimental studies investigated tissue pressures under the tourniquet cuff and found that the applied pressure transmitted to the underlying soft tissue is less than larger limbs of obese specimens. Therefore, the attenuation of pressure in small size limbs was smaller. This may be of clinical significance in determining the appropriate tourniquet pressures in obese patients.[15-18] The quantitative meaning of this pressure concentration K_{TP} was measured in lower and upper limbs of anesthetized patients and confirmed the experimental studies.[6] In our study, extremity circumference of the patients were significantly higher (46.6±4.0 cm vs. 55.9±5.8 cm) in obese group compared with non-obese group.

Intraoperative SBP of the patients is another important factor affecting AOP. Therefore, SBP of the patients should be kept as low as possible and maintained this way throughout the surgery. In our previous studies, we used a CHAMIP technique which provided a bloodless field in all patients with a mean tourniquet pressure of 169.7±7.9 mmHg and 118.2±7.2 mmHg which were significantly lower inflation pressures than reported and recommended in the literature in lower and upper extremity surgeries respectively.[13,14,19] Nwachukwu et al.[20] also found that obesity is an independent risk factor for poor hemodynamic control during TKA. In our study, the mean initial systolic blood pressures and the mean intraoperative maximal systolic blood pressures were found to be more elevated in obese group. These results are also consistent with the studies which

pointed out that maintaining hemodynamic stability is difficult in obese patients.[21-23]

Various studies suggested the use of wider tourniquet cuffs since they transmit a greater percentage of the applied tourniquet pressure to deeper tissues and allow arterial closure at lower pressures.[24,25] Although wider cuffs stop the arterial flow with lower inflation pressures, Mittal et al.[25] found that wider cuffs impair the nerve conduction more severely than narrower cuffs. Moreover, larger and wider cuffs decrease the distance from the distal edge of the tourniquet to the incision site narrowing the operating field. Additionally, the K_{TP} values we used in our study were determined using 11 cm wide tourniquet cuffs in AOP estimation method.[6] Therefore, we applied the same size cuff in all patients that we use in our daily practice. In our study, the surgical team was satisfied with the performance of the tourniquet in all cases with the mean maximal tourniquet pressures of 165.9±10.5 mmHg and 182.6±15.0 mmHg in non-obese and obese patients, respectively. Main features of our study were the use of CHAMIP technique allowing lower inflation pressures to be used, AOP estimation formula to obtain quick and accurate results, and safety margin of 20 mmHg, lower than recommended in the literature.

The most important limitation of our study was the subjective assessment method (four-point scale) used for rating the quality of bloodless surgical field. It is difficult to quantify the effectiveness and performance of a tourniquet inflation pressure. Ideally, the assessment could be performed by weighing surgical swabs. However, all of the operations were performed and the adequacy of the bloodless field was rated by the same, experienced surgical teams and their subjective assessment was recorded. Moreover, the four-point scale we used has also been used in previous studies.[9,14,26] Additionally, the circumference and length of the limb in obese patients were variable although the size of the cuff we used in our study was standard. This might lead to variability in limb circumference and limb length to cuff size ratio. However, this variability also existed in non-obese patients and K_{TP} values we used were determined for 11 cm wide tourniquet cuffs in AOP estimation method.[6]

In conclusion, more than half of the patients undergoing TKA surgery are obese and require higher pneumatic tourniquet inflation pressures due to wider extremity girth and higher intraoperative SBP profile than non-obese patients. Intraoperative hemodynamic stability is crucial in the maintenance of bloodless field allowing lower inflation pressures without subjecting them to complications of unnecessary high tourniquet inflation pressures.

Declaration of conflicting interests

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