

Escalated Tourniquet Deflation Strategy Reduces the Incidence of Hypotension After Total Knee Replacement Surgery: A Randomized Double-Blinded Controlled Trial

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Abstract: Pneumatic tourniquets have been widely used to reduce total blood loss in total knee arthroplasty, but its use increases the incidence of post-operative hypotension. So, strategies to manage tourniquet use during knee replacement are important to minimize systemic complications.

In this randomized, controlled, double-blinded protocol, patients were assigned to two groups (sudden tourniquet deflation or gradual tourniquet deflation). During surgery, limb tourniquet was kept inflated with 350 mmHg pressure in both groups.

Blood pressure and heart rate were analyzed in all patients 24h before surgery, immediately before tourniquet deflation, 1 minute after full tourniquet deflation, five minutes after full tourniquet deflation and 24 hours after surgery.

Gradual tourniquet deflation reduced the incidence of tachycardia and hypotension after total knee arthroplasty. This hemodynamic effect elicited lower double product just after tourniquet deflation.

Keywords: Blood pressure, total knee arthroplasty, tourniquet.

1. INTRODUCTION

Annually, approximately 400,000 knee replacements are performed in the United States, and these numbers are expected to rise due to the aging population [1]. This surgery is characterized by significant blood loss [2,3], which can lead to hypotension and cardiac events after surgery. The frequency of events such as acute myocardial infarction is even higher if surgery is performed in patients with cardiovascular diseases and high cardiovascular risk factors [4].

Pneumatic tourniquets have been widely used to reduce total blood loss in total knee arthroplasty [5-7], but its use increases the incidence of post-operative hypotension [5]. In fact, tourniquet deflation causes a rapid shift of blood volume back to the previous ischemic limb and decreases

cardiac preload which can result in hypotension and tachycardia [8].

We have hypothesized that the velocity of tourniquet deflation would influence the hemodynamic effects of tourniquet deflation after total knee arthroplasty. Thus, the aim of the present study was to compare the hemodynamic effects of two different strategies of tourniquet deflation after total knee arthroplasty.

2. METHODS

2.1. Subjects

During a four-month period, all consecutive patients scheduled to a total knee replacement surgery in our Institution were invited to participate in the study. We enrolled in the study patients presenting red blood cells, hematocrit, platelets, prothrombin time and activated partial thromboplastin time within normal limits.

Patients should not be taking any nonsteroidal anti-inflammatory drug for at least 14 days. Patients with rheumatological diseases were not included in this study.

2.2. Ethics

The study procedures were approved by the Institutional Ethics Committee and written informed consent was obtained from all participants prior to the experimental procedures.

2.3. Study Protocol

This study followed a randomized, controlled, double-blinded protocol, where patients and the physician responsible for data analysis were blinded to randomization. Patients were randomly assigned to two groups (sudden tourniquet deflation or gradual tourniquet deflation). During surgery, limb tourniquet was kept inflated with 350 mmHg pressure in both groups. After surgery, the pressure in the tourniquet was suddenly reduced to zero in patients in the sudden tourniquet deflation group, while in the gradual tourniquet deflation group tourniquet pressure was reduced by 87.5 mmHg per minute. Thus, gradual tourniquet deflation took four minutes to be completed.

Blood pressure and heart rate were analyzed in all patients 24h before surgery, immediately before tourniquet deflation, 1 minute after full tourniquet deflation, five minutes after full tourniquet deflation and 24 hours after surgery.

Anesthesia strategy was the same in both groups (sedation plus rachianesthesia and peripheral nerve block). During surgery the infusion of cristaloid solutions and hemoderivatives was guided by the anesthesiologist and registered for further comparison.

2.4. Statistical Analysis

Continuous variables are reported as means and standard deviations and compared using Student’s t-test. Categorical variables are reported as proportions and compared using a Chi-square test. A two-sided P-value < 0.05 was considered significant.

For comparison of groups’ hemodynamic variables in various moments, regression analysis was done, stratifying for demographic variables that shown significant differences among the

studied groups at baseline (table1) and total tourniquet time.

All statistical analyses and graphs were derived from STATA 14.2 (StataCorp, Texas, USA).

3. RESULTS

This study included 46 patients submitted to total knee arthroplasty (23 patients were randomized to the gradual tourniquet deflation group and 23 patients to the sudden tourniquet deflation group). Despite randomization patients in the gradual tourniquet deflation group were older [Table 1]. Although the total tourniquet time was higher in the sudden tourniquet deflation group, total infused volume was not different between groups.

Table1. *Clinical, demographic and surgery characteristics in patients submitted to total knee arthroplasty with different tourniquet deflation strategies.*

	Tourniquet deflation		p value
	Sudden (n=23)	Gradual (n=23)	
Age, years	71 ± 6	77 ± 4	<0.001*
Gender (male)	8 (35)	8 (35)	0.621
Body mass index, kg/m ²	30 ± 2	30 ± 2	0.307
Diabetes, n (%)	6 (26)	6 (26)	0.631
Hypertension, n (%)	6 (26)	6 (26)	0.631
Total infused volume during surgery (mL)	1978 ± 281	1833 ± 318	0.105
Total tourniquet time, min	111±8	105±9	0.019

*Patients were randomized in two groups according to sudden (n=23) or gradual (n=23) tourniquet deflation. Data analysis evidenced that patients submitted to sudden deflation were younger than the ones in the gradual deflation. N: number of patients; mL: milliliters; min: minutes. * p<0.05.*

Although both groups had similar blood pressure and heart rate before surgery and just before tourniquet deflation, patients in the sudden tourniquet deflation group exhibited lower blood pressure and higher heart rate after surgery [Figures 1 and 2], which lead to higher double product [Figure 3] just after finishing the surgical procedure.

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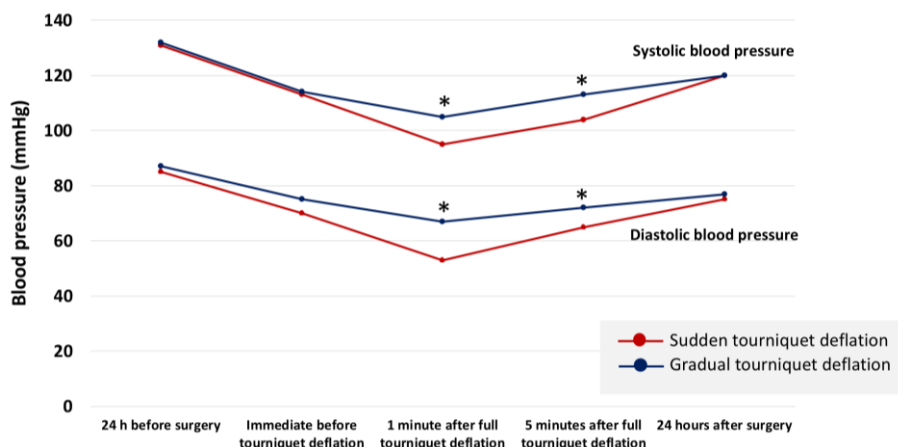


Figure1. Systolic and diastolic blood pressure before, during and after total knee replacement in patients submitted to different tourniquet deflation strategies.

In both groups, systolic and diastolic blood pressure decrease from 24 h before surgery up to 1 minute after all tourniquet deflation and then increase up to 24 h after surgery, without reaching preoperative values. h: hour; * $p < 0.05$ vs. sudden tourniquet deflation group, at same moment

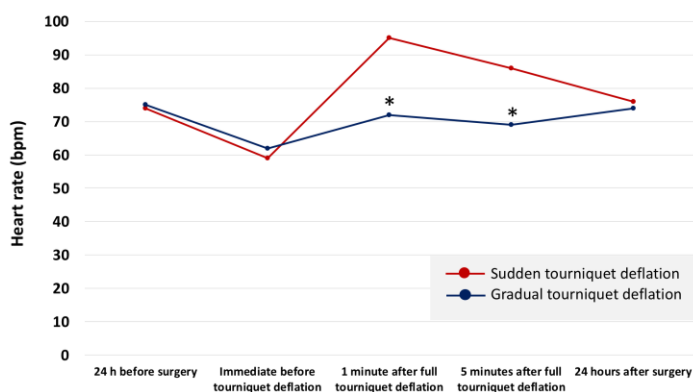


Figure2. Heart rate before, during and after total knee replacement in patients submitted to different tourniquet deflation strategies.

Heart rate decreases in both groups from 24 h before surgery to immediate before tourniquet deflation, and then increases up to 1 minute after all tourniquet deflation. In the sudden tourniquet deflation group, heart rate decreases after full tourniquet deflation up to 24 h after surgery. h: hour; * $p < 0.05$ vs. sudden tourniquet deflation group, at same moment.

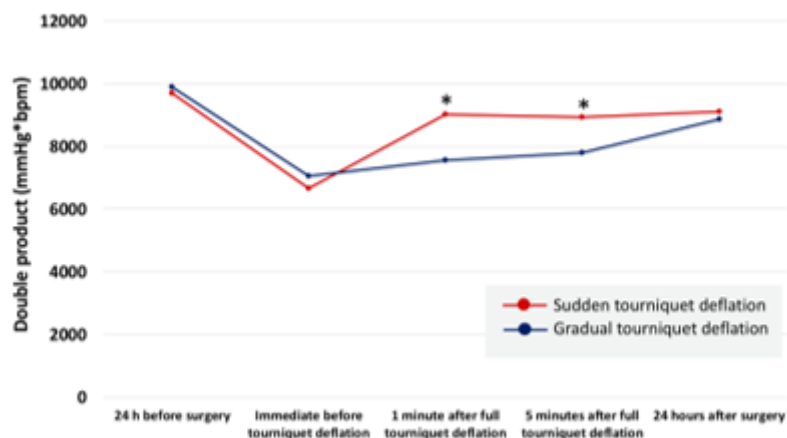


Figure3. Double product before, during and after total knee replacement in patients submitted to different tourniquet deflation strategies.

In both groups, double-product decreased from 24 h before surgery up to immediate tourniquet deflation and, then, raised up to 24 h after surgery. h: hour; * $p < 0.05$ vs. sudden tourniquet deflation group, at same moment.

4. DISCUSSION

The present study shows that gradual tourniquet deflation reduced the incidence of tachycardia and hypotension after total knee arthroplasty. This hemodynamic effect elicited lower double product just after tourniquet deflation.

Total knee arthroplasty is usually performed in patients with advanced age and comorbidities that increase the risk of cardiac events [1,4]. Pneumatic tourniquets are used during total knee replacement to reduce blood loss [5-7], but its use is known to increase the incidence of post-operative hypotension [5,9], thromboembolic events and other related complications [10].

Zhang et al. [5]. reported postoperative acute hypotension in 12.3% of patients submitted to total knee replacement with pneumatic tourniquet use. The same study found that older age was a risk factor for postoperative acute hypotension [5]. Hypotension may lead to worsened skin and subcutaneous blood flow, which can cause wound hypoxia and complications as infection [11]. In our study, even after stratifying for age, patients submitted to sudden tourniquet deflation presented lower blood pressure values than the ones submitted to gradual tourniquet deflation.

Double product is an indirect measurement of myocardial oxygen consumption. Thus, increases in double product could lead to an oxygen consumption-perfusion mismatch in patients with coronary artery disease, the physiological basis to myocardial ischemia. To our knowledge this is the first study to propose a strategy potentially able to reduce the odds of myocardial ischemia after total knee replacement surgery. Although this was not the main objective of the study, this potential benefit of gradual tourniquet deflation should be evaluated in further studies including patients with coronary artery disease undergoing total knee arthroplasty.

The limitation of the study is that we did not evaluate blood losses that could be related tourniquet release and influence on blood pressure, although this was not the focus of this study.

5. CONCLUSION

Gradual tourniquet deflation elicits less hemodynamic disturbance than sudden tourniquet deflation immediately after total knee arthroplasty. Further studies including patients with higher surgical risk should evaluate the clinical benefits of this effect.

COMPLIANCE WITH ETHICAL STANDARDS

Each author certifies that his or her institution approved the human protocol for this research and that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

REFERENCES

- [1] Lee K, Goodman SB (2008). Current state and future of joint replacements in the hip and knee. *Expert Rev Med Devices*. 5(3):383-393.
- [2] Prasad N, Padmanabhan V, Mullaji A (2007). Blood loss in total knee arthroplasty: an analysis of risk factors. *Int Orthop* 31(1):39-44.
- [3] Banerjee S, Issa K, Kapadia BH, et al. (2013). Intraoperative nonpharmacotherapeutic blood management strategies in total knee arthroplasty. *J Knee Surg* 26(6):387-393.
- [4] Dy CJ, Wilkinson JD, Tamariz L, Scully SP (2011). Influence of preoperative cardiovascular risk factor clusters on complications of total joint arthroplasty. *American journal of orthopedics (Belle Mead, NJ)*. 40(11):560-565.
- [5] Zhang YM, He J, Zhou C, Li Y, Yi DK, Zhang X (2015). Acute hypotension after total knee arthroplasty and its nursing strategy. *Int J Clin Exp Med* 8(8):13946-13953.
- [6] Tetro AM, Rudan JF (2001). The effects of a pneumatic tourniquet on blood loss in total knee arthroplasty. *Can J Surg* 44(1):33-38.
- [7] Abdel-Salam A, Eyres K (1995). Effects of tourniquet during total knee arthroplasty. A prospective randomised study. *J Bone Joint Surg Br* 77(2):250-253.
- [8] Huang GS, Wang CC, Hu MH, et al. (2014). Bilateral passive leg raising attenuates and delays tourniquet deflation-induced hypotension and tachycardia under spinal anaesthesia: a randomised controlled trial. *Eur J Anaesthesiol* 31(1):15-22.
- [9] Kahn RL, Marino V, Urquhart B, Sharrock NE (1992). Hemodynamic changes associated with tourniquet use under epidural anesthesia for total knee arthroplasty. *Reg Anesth*. 17(4):228-232.

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- [10] Zhang W, Li N, Cheng S, Tan Y, Al-Aidaros M, Chen L (2014). The effects of a tourniquet used in total knee arthroplasty: a meta-analysis. *J Orthop Surg Res* 9:13.
- [11] Clarke MT, Longstaff L, Edwards D, Rushton N (2001). Tourniquet-induced wound hypoxia after total knee replacement. *J Bone Joint Surg Br* 83(1): 40-4.

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