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Original Article

Estimation of Blood Loss in Total Knee Arthroplasty with or Without Tourniquet

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Abstract

Background: Total knee arthroplasty (TKA) is a procedure performed for end stage knee osteoarthritis to reinstate leg function, pain control and improve quality of life. The surgery, however, is associated with a substantial risk of concealed blood loss for which tourniquets have been used to control bleeding. There has been a lot of debate over the relevance and benefits of using tourniquets during TKA. It has no effect on postoperative blood loss and has been claimed to be associated with post-operative pain, nerve damage, superficial wounds infections and deep vein thrombosis.
Objective: The objective of the study was to compare the degree of blood loss and its clinical relevance in patients undergoing total knee arthroplasty with and without tourniquet.
Study type settings and duration: A Randomized Controlled Trial conducted at The Indus Hospital, Karachi, Pakistan from January 2015 to September 2015.
Methodology: In this randomized clinical trial, patients were recruited after local IRB approval. Sample size was calculated using OpenEpi and included all patients of age 40 to 80 years of either gender with chronic osteoarthritis, according to the Kellgren-Lawrence classification grade 4 of Osteoarthritis. The study included two groups, both consisting of 25 patients each. In group A (non-intervention, tourniquet), the tourniquet was inflated to 350 mmHg after the leg had been elevated and exsanguinated, and was deflated after closing the wound and application of compressive dressing. In group B (intervention, non-torniquet), the application of tourniquet took place but it was not inflated. Instead, electrical diathermy, and application of pressure with surgical swabs was performed intra-operatively to control bleeding. Blood loss was measured using the Mercuriali's formula.
Results: There was an average blood loss of 807 ml during TKA. Group A had a mean blood loss of 604.6 (203.9) ml while a relatively higher statistically significant mean blood loss of 1010.7 (272.7) ml was noticed in the intervention group on whom tourniquets were not used (p <0.005).
Conclusion: According to our study, calculated blood loss was relatively less in Group A, hereby showing that the use of tourniquet is superior to other forms of bleeding control during the surgery. We propose that the issue on the significance of the use of tourniquet during TKA verses no tourniquet use has to be decided on the basis of volume of blood loss.
Key words: Total knee arthroplasty, tourniquet, blood loss.

Introduction

Every year, Total Knee Arthroplasty (TKA) is being performed on thousands of patients with Rheumatoid arthritis or Osteoarthritis for improvement in their quality of life. It is one of the most common orthopedic surgeries performed in the world,[1] and reliably reduces pain and improves function in patients with Osteoarthritis.[2,3] In a resource-constrained country like Pakistan, there is a great demand for total knee arthroplasty and the situation is worsened when the waiting times are high.[4]

A study conducted in Lahore, Pakistan studied the quality of life before and six months after TKA and concluded that it significantly improves pain and quality of life.[5] However, there is a substantial risk of concealed hemorrhage associated with TKA. Intraoperative bleeding and postoperative drainage adds to the total blood loss during TKA. It disregards pooling of blood into the

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Authors Contribution

MAK, MAC & SKA conceptualized the project. RM also performed the literature search. MAK, RM & SKA did the statistical analysis. Data collection, drafting, revision & writing of manuscript was also done by MAK, MAC, RM & SKA.

tissues, remaining blood in the joint space and loss owing to hemolysis.[6] Different techniques have been applied to reduce the quantity of blood loss during TKA. Tourniquets have been used conventionally to prevent blood loss during surgery. Tourniquet is applied intra-operatively and released at the end of the surgery.[6] Tranexamic acid is also known to reduce blood loss associated with surgeries.[7] Epidural anesthesia, likewise, is recognized to prevent post-operative blood loss in major orthopedic surgeries[8] by decreasing the mean arterial blood pressure (MAP) and redirecting blood flow away from the operative site.[9]

There has always been a lot of disagreement on the practice of tourniquet use and its relevance during TKA. Surgeons, who use it, claim that it's excellent in managing intra-operative blood loss and helps in establishing a "bloodless surgical field".[10,11] However, it has no effect on postoperative blood loss. It has been claimed to be associated with post-operative pain, nerve damage, superficial wound infections and deep vein thrombosis.[10,11]

The controversy about use of tourniquets stems from the varied techniques used to measure blood loss in the literature. In most cases no scientific formula is applied and reliance is placed on measurement of soaked sponges. In those studies where formulae are used to calculate the final blood loss there can be a number of formulae used and thus comparison of one study with the other seems difficult.

The rationale of our study is to compare the degree of blood loss in patients undergoing total knee arthroplasty. Our aim is to assess the effect of tourniquet use on reducing blood loss and to determine its relevance and the possible risks of its use in TKA for patients with osteoarthritis.

Methodology

This was a Randomized Controlled Trial conducted at a The Indus Hospital, Karachi, Pakistan from January 2015 to September 2015, which provides free multi-care specialty surgical and medical care. Approximately 100 bilateral knee replacement surgeries were performed every year by the Orthopaedic surgeons. After local IRB approval, patients were recruited according to the inclusion criteria. The study included two groups: one group consisting of 25 patients on whom tourniquet was used (group A) and the group B in which no tourniquet was used during total knee arthroplasty. Several studies indicate that TKA can be successfully achieved without the use of tourniquet.[12] However, in our study, it was critical to effectively control intraoperative bleeding using electrical diathermy and application of pressure with surgical swabs in the absence of tourniquet inflation during the procedure. Our sample size was calculated using OpenEpi (Table-1).

Table 1: Sample size calculation using OpenEpi.

	Control Group	*Intervention Group*	*Sample size per group with 80% power and 90% CI*
	Mean (SD)		
Calculated/estimated blood loss (ml) (29)	1117 (221)	1298 (285)	25

Osteoarthritis is a devastating condition affecting usually the elderly but younger individuals are also susceptible.[13] In our clinics, many patients in their mid-thirties present with severe primary arthritis, which is refractory to treatment. For this reason, we decided to include all patients of age 40 to 80 years, of either gender, with chronic osteoarthritis, according to the Kellgren-Lawrence classification grade 4 of Osteoarthritis.[14] These patients did not have any blood or bleeding disorder, coagulopathy and malignancy, and were residents of Karachi, Pakistan. Only bilateral knee arthroplasties were performed in our study, which were accepted worldwide for the treatment of bilateral knee ostheoarthritis due its lower cost and rehabilitation process than staged total knee arthroplasty.[15] Tourniquets were applied on both limbs in patients of both groups, but not inflated in the intervention group (non-tourniquet).

All patients fulfilling the criteria in the orthopedic clinic were included in the study. Informed consent for the surgical procedure enrollment was taken from the patients, and they were randomized into one of the two study arms before the start of surgery. All patients had tourniquet applied and just before surgical preparation was started, the envelopes for SNOSE protocol (Sequentially Numbered, Opaque, Sealed Envelope) were opened to ascertain which group they were in.

The exclusion criteria were: total knee arthroplasty previously performed, patient who did not give consent to participate, patients<40 years of age, or unilateral knee replacements.

Blood loss was calculated by means of the Mercuriali's formula as follows:[16,17]

"Estimated blood loss = patient blood volume x (Hct_{preop} – $Hct_{postop\ day\ 5}$) + ml of red blood cells

transfused", where patient's blood volume (BV) will be calculated through the Nadler formula(16)
"Male blood volume: 604 + 0.0003668 x [height in cm]^3 +32.2 x weight in kg"
"Female blood volume: 183 + 0.000356 x [height in cm]^3 + 33 x weight in kg"

In the first group (non-intervention, tourniquet), the tourniquet was inflated to 350 mmHg after the leg had been elevated and exsanguinated, and was deflated after closing the wound and application of compressive dressing. In group B (intervention, non-tourniquet), the application of tourniquet took place but it was not inflated and the electric coagulation was used to seal active bleeding points along with application of pressure surgical swabs.

For both groups, A and B, patients had their knee placed in compressive dressing after applying wool and crepe bandage to the limb. The wound dressing was changed as per standard procedure. The affected limb was elevated to the heart level, along with placement of ice packs around the affected knee. Hemoglobin was measured 24 hours postoperatively and blood was transfused only if Hb value was less than 9 g/dl. On average, the immediate post-operative in-hospital stay was 15 days, until skin staples were removed. Most of our patients don't have access to physiotherapy and rehabilitation services, so we do delayed discharges for this reason. For purposes of calculating the estimated blood loss, pre-operative complete blood count as well as post-operative complete blood count on first and fifth post-op days was noted. Any blood transfusion done post-surgery due to a drop in hemoglobin below 9 g/dl was noted along with the amount of fluid (0.9% Normal Saline/ Ringer's Lactate) given per-operatively and post operatively.

SPSS version 21.0 was used for data entry and analyzing. Mean and Standard Deviation for age, weight and estimated total blood loss in both groups were calculated. Percentages and frequencies were calculated for each gender. T-test was used for blood loss comparison in both groups. Stratification with respect to age, weight and gender was done. Post stratification t-test was applied and a P value less than or equal to 0.05 was considered significant.

Results

A total of 50 patients were enrolled in the study for bilateral TKA.

Twenty five patients were randomly enrolled in tourniquet group and the other half in non-tourniquet group. 28% patients were male and 72% were female. There was not much of a difference in mean age, height and weight of the patients between both the groups, however significant difference was noted in the average blood loss between both the groups (*p*-value: 0.000). On average, significantly less blood loss were gauged in the control group A (tourniquet) than the intervention group (non-tourniquet) (*p*-value =0.005). Group A had a mean blood loss of 604.6 (203.9) ml while Group B had 1010.7 (272.7) ml. In females, on average, there was significantly less blood loss in comparison to males (*p*-value =0.021) (Table-2).

Discussion

Knee osteoarthritis is identified as the most common disability in Pakistan with a prevalence of 29.7–37.0 per 1000 people.[18] Impaired mobility and the pain associated with osteoarthritis often results in considerable reduction of quality of life.[5] Total

Table 2: Statistical Analysis.

	Table Univariate analysis *Study Arm*				*p-value*
	A		*B*		
	n	*Mean (SD)*	*n*	*Mean (SD)*	
Age in years	25	54.9 (8.7)	25	55.68 (9.77)	0.762
Weight (kg)	25	75.9 (16.06)	25	80.04 (16.0)	0.404
Height (cm)	25	157.5 (10.8)	25	162.1 (8.8)	0.104
Blood loss (ml)	25	604.6 (203.9)	25	1010.7 (272.6)	0.000**

*p-value <0.05, **p-value <0.0001, Independent sample t-test

	STUDY_ARM		*Total*	*p-value*
Gender	*Group A (Tourniquet)*	*Group B (Non-tourniquet)*		
	n (%)	n (%)	n (%)	
Male	5 (20)	9 (36)	14 (28)	
Female	20 (80)	16 (64)	36 (72)	0.208
Total	25 (100)	25 (100)	50 (100)	

Chi-square test

knee arthroplasty is the curative treatment for advanced, severe grade osteoarthritis of the knee and standard of care.[15] In order to reduce intra-operative blood loss associated with TKA and to create a clear surgical field, tourniquets have been used but is still a matter of debate,[19] due to the questionable reduction in total blood loss. Application of tourniquets have been in use since 199 BCE-500 CE.[20] The Romans were the first ones to use tourniquet, specifically during amputation to reduce bleeding.[21] Pneumatic tourniquets were introduced in 1904, and are also currently in use with greater modifications.[21] Tourniquets also help decrease the transfusion requirement.[22] Needless to say, the benefits and the advantages of tourniquet use should be weighed against the risks and deficiencies.

When comparing TKA with and without tourniquet, a few variables are considered. Studies have claimed to have a higher risk of thromboembolic events in the tourniquet group. Thromboembolism is a common complication after TKA and is a challenge of great proportions due to the morbidity and mortality associated with it.[19] According to a meta-analysis, the incidence of clinical thromboembolic events was lower in patients managed without a tourniquet.[19] Deflation of the tourniquet right after wound closure was extremely critical. One study showed no case of DVT in either group.[23]

Table 3: Characteristics of the surgical method.

Total no. of patients	*Timing of tourniquet release*	*No. of drains*	*Timing of removing the drain*	*Post-operative dressing*
Tourniquet: 25 Non-Tourniquet: 25	Late*	2	24-48 hours	Compressive dressing, application of wool and crepe bandages.

*Late: after closure of the wound.

In early post-operative stages of the intervention group, no substantial difference was noted in the surgical time, analgesia requirement, the blood volume collected in the drains, and postoperative inflammation. There was a difference noted in the level of pain, assessed on an analog score, between the two groups at one and six weeks. Patients with tourniquet reported more pain on post-operative day one, two, and three.[24] This can be attributed to the pressure applied by the tourniquet on the site during the surgery.[25] It, however, did not have any effect on the recovery of the patient and was only limited to the initial post-operative period only. It has also been noted that the knee flexion in the non-tourniquet group is significantly better at one week but was the same at six weeks and four months follow up, with no further improvement (Table-3).[23]

There is a high risk of concealed blood loss pertaining to TKA. “Concealed blood loss is defined as the residual blood in the joint, tissue extravasation,[26] and hemolysis”.[27] Blood loss may result from the raw surface of the distal femoral and proximal tibial bones, release of the soft tissue injury area, and reaming of the marrow cavity.[6,28]

There are different studies claiming contradictory outcomes of a tourniquet on blood loss following total knee arthroplasty.[29,30] According to our study, the intervention group had a relatively less blood loss in the intervention group (p <0.005). A probable explanation may be the decreased operating time in the intervention group. This, however, is in contrary to the findings of a few studies,[31] where the surgeons did not encounter any technical difficulties when operating without a tourniquet.

The possible reason that different studies have produced different outcomes for TKA with tourniquet is that a number of different formulae have been used to assess blood loss. A number of calculating methods have been used for evaluating blood loss in patients with TKA. Different methods may yield different results, which is why there is no uniformity in the outcomes for blood loss with/without TKA. A study compared four most commonly used methods for calculating blood loss and found large differences among calculations of blood loss after Primary TKA. These methods included: 1) Gross equation, 2) Hb- balance, 3) OSTHEO formula, and 4) Hb-dilution.[32] According to this study, results for Gross equation and Hb-balance were similar but significantly different from the other two methods.[32] A study by Bin Li calculated the blood loss using the formula reported by Nadler, and showed a difference of 181 ml of calculated blood loss between the intervention and control group.[29] Another study showed a mean calculated blood loss of only 5 ml between the two groups.[10]

Mercuriali’s formula was used in our study. Mercuriali et al. designed this formula on the basis of hematocrit on fifth post-operative day plus transfused RBC volume.[17] Because individual factors such as gender, height, weight, and volume of blood transfusion were taken into consideration, this equation reflects the actual postoperative blood-loss to some level. This results in its widespread application by medical teams, even though it does not involve Hb-related factors. User-friendliness,

well reproducibility in routine practice are some of its advantages.[17,33] Our study had a significant difference of 406.1 ml between the intervention and control group.

Because of the intricacy and variability of the mechanism of perioperative blood-loss from TKA surgery, different calculation methods may lead to different blood-loss determinations.[32] Our study included the Mercuriali's formula, which has been proven to be accurate in assessing blood loss.[33,34]

Our study did have a few limitations, like a small sample size. More variables, for e.g., post-operative complications should also be taken into account.

Total knee arthroplasty is the curative treatment for advanced osteoarthritis of the knee. In this manuscript we have explained that the use and the benefits of tourniquet is safe in TKA and should be continued due to the improvement in the quality of life and reduced pain following the surgery.[5] All things considered, Mercuriali's formula is suitable for similar studies concerning blood loss associated with TKA.[33]

Conflict of interest: None declared.

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