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Research Article

The Effect of Systolic Blood Pressure on Cement Penetration Depth in Primary Total Knee Arthroplasty

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Abstract

Background: Cement Penetration Depth (CPD) into bone is an important factor for successful Total Knee Arthroplasties (TKA). Our study investigated the effect of Systolic Blood Pressure (SBP) on average tibial, femoral and total CPD in primary TKA.

Methods and Findings: In this retrospective cohort study, patients who had a primary TKA between November 2018 and February 2020 at four, academic medical centers were included. CPD was evaluated according to the Knee Society Radiographic Evaluation System on radiographs one month post-operatively. Two independent evaluators measured four zones of tibial penetration and three zones of femoral penetration and averaged their results. The measurements were combined to create an average tibial, average femoral and average total CPD. SBP was collected at the 3/4 time of surgery length- the estimated time of cementation.

1221 primary TKA cases were included in the study - 1128 in the tourniquet group and 93 in the tourniquet-less group. There were no significant differences between the age, sex, BMI, or LOS between the two cohorts. A multiple, multivariate analysis was performed. In the tourniquet-less group, SBP did not significantly affect average tibial CPD ($p=0.98$), average femoral CPD ($p=0.45$), or average total CPD ($p=0.23$). However, tourniquet use was found to significantly increase average femoral ($p<0.001$) and total penetration ($p=0.001$).

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Conclusion: SBP did not significantly affect tibial, femoral, or total CPD in patients undergoing tourniquet-less, primary TKA. However, the use of a tourniquet significantly aids in average femoral and total CPD. The clinical significance of this difference needs further investigation.

Keywords

Blood Pressure; Body Mass Index; Knee Arthroplasty; Anteroposterior

Introduction

With an aging population, the number of Total Knee Arthroplasty (TKA) surgeries throughout the United States are projected to increase over the coming years [1]. A proportional rise in complications can reasonably be expected, as well. Therefore, it is imperative to identify common complications and address potential avenues of mitigating them. Frequent causes of revision TKA include aseptic loosening, polyethylene wear, infection, instability, periprosthetic fracture, malalignment, extensor mechanism deficiency and arthrofibrosis [2,3].

Aseptic loosening is a particularly common complication representing 21.8% of revision TKAs [3]. Cement depth penetration in TKA is an important factor as adequate penetration is associated with reduced rates of aseptic loosening [4-6]. Cement depth penetration should be between three to five millimeters for optimal strength of the bone-implant interface [7-9]. A standardized technique to reach this zone of penetration is still unclear. Many surgeons use an intraoperative tourniquet during TKAs because of its benefits such as decreased blood loss, better visualizations of the surgical field and proposed ability to improve implant cementation [10,11]. However, some surgeons perform TKAs without tourniquets and in these surgeries, the effect of systolic blood pressure during the time of cementation is still unknown. Some studies suggest that bleeding and high flow rates impede cement penetration depth [12,13]. Therefore, some surgeons try to maintain hypotensive blood pressure during cementation to facilitate greater penetration. However, to our knowledge, no study has yet to investigate exactly whether systolic blood pressure during the time of cementation significantly affects the cement penetration depth.

In our study, we recorded systolic blood pressure at the estimated time of cementation in TKAs. We then used post-operative tibial lateral and Anteroposterior (AP) radiographs to determine CPD. Our aim is to determine whether systolic blood pressure impacts the amount of average, tibial and femoral cement penetration depth in tourniquetless TKA cases.

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Methods

A retrospective review of a cohort of patients from four, academic medical centers who underwent a TKA from November 2018 to February 2020 was performed. The current study received Institution Review Board (IRB) approval at each of the included institutions. Patients were eligible for the present study if they were older than or equal to 18-years-old, undergoing an elective primary TKA and had available tibial AP and lateral X-ray images within one month post-operatively. Variables collected in the study included cement penetration measurements (in mm) by radiographic zone, Length of Stay (LOS), whether a tourniquet was used and baseline patient demographics, such as age, Body Mass Index (BMI) and gender. SBP was collected from the patient's chart at the 3/4 time of surgery length- the time of cementation. We estimated this time point based on the average course of a TKA. Each site within this study utilized a different cementing protocol. The method of cement application differed between sites with some applying cement with a gun while the other used a finger packing and spreading technique, technique was constant throughout the study for each surgeon. All surgeons applied Simplex HV cement with antibiotics to both the implant, tibial bone surface and metaphysis. Average cement penetration between the sites were statistically similar. The primary outcome of the study was whether systolic blood pressure affected cement penetration.

Radiographic Cement Penetration Measurements

Radiographs were accessed using each institutions' digital radiograph repositories, Picture Archiving and Communication System (PACS). Measurements were made on radiographs found closest to one-month post-operatively. Radiographs were measured using a calibrated digital ruler. Using this calibrated ruler, each zone was divided into the appropriate number of sections.

Measurements were made in accordance to the zones described by the Knee Society Radiographic Evaluation System and used in previous studies of the topic [14]. Each of the zones in which more than one measurement were made, the average was taken to determine a complete penetration depth for that zone. These measurements were then used to determine the average tibia and femur penetration depths. Fig. 1 shows a radiographic example of the tibial measurements.

Measurements were made independently by two trained evaluators. If differences greater than 1.0 mm were found, each rater repeated the measurements until agreement within 1.0 mm was reached as has been done in previous studies [14]. Depth measurements from both raters were averaged to determine the average depth for each zone.

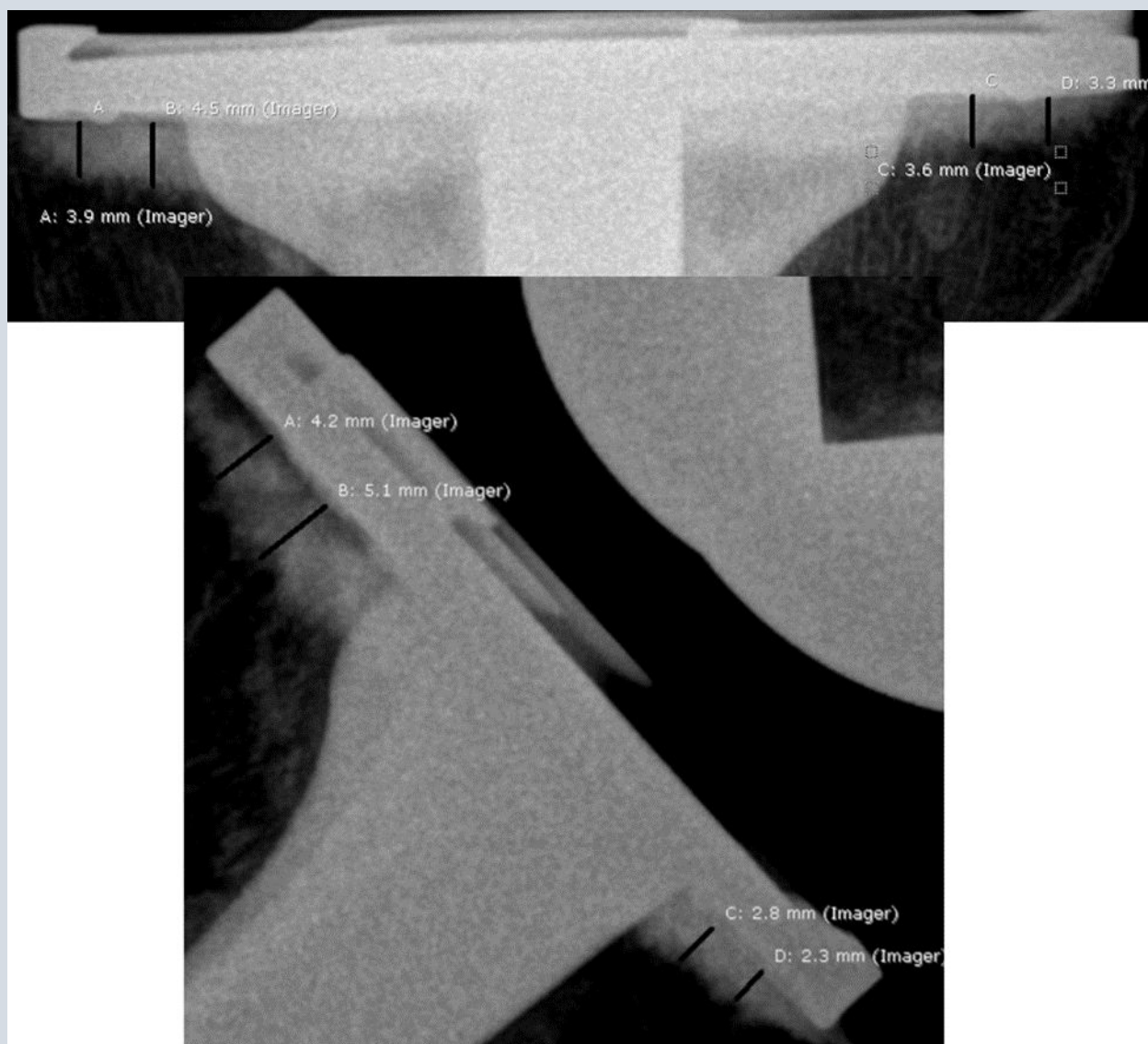


Figure 1: Example Tibial Cement Penetration Depth Measurement on AP and Lateral X-rays.

Statistical Analysis

For the recording of descriptive statistics means + standard deviation were used for continuous variables while counts (%) for categorical variables. Pearson correlation analysis was used to determine whether there was an association between blood pressure and cement penetration. All statistical analyses were performed using SPSS v25 (IBM Corporation, Armonk, New York). A p-value of less than 0.05 was considered to be statistically significant.

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Results

Participants

A total of 1,221 TKA patients were identified throughout the study period. Patients were separated into two cohorts based on tourniquet use: 1128 TKA cases were identified as having used a tourniquet and 93 TKA cases did not. This distinction was made due to the fact that the use of a tourniquet effectively eliminates systolic blood pressure in the operative limb. Within the tourniquet group, the average age was 62.05 ± 9.51 years and the average BMI was $33.81 \pm 7.15 \text{ kg/m}^2$. Moreover, the majority of patients in the tourniquet group were female (59% vs 41% male) and had a LOS of 2.15 ± 1.43 days. On average, the patients in the tourniquet-less group were 63.88 ± 9.98 -years-old, had a BMI of $31.62 \pm 5.79 \text{ kg/m}^2$ and a LOS of 2.49 ± 1.60 days (Table 1).

The primary outcome of the study was to determine whether there was an association between systolic blood pressure and cement penetration depth in TKA. In the tourniquet-less group there was no correlation between systolic blood pressure and average tibial cement penetration ($r(91) = -0.002$; $p = 0.98$), average femoral cement penetration ($r(91) = 0.08$, $p = 0.45$) or average total cement penetration ($r(91) = 0.13$; $p = 0.23$) (Table 2).

The tourniquet group had an average total cement penetration of $2.74 \pm 1.44 \text{ mm}$ with an average tibia penetration of $2.39 \pm 1.9 \text{ mm}$ and an average femoral penetration of $2.91 \pm 1.08 \text{ mm}$. The tourniquet-less group had a decreased cement penetration compared to the tourniquet cohort with an average total penetration of $2.58 \pm 0.78 \text{ mm}$, an average tibial penetration of $2.29 \pm 0.77 \text{ mm}$ and an average femoral penetration of $2.04 \pm 0.58 \text{ mm}$. The tourniquet-less group had a significantly decreased average femoral (-0.87 mm) and average total penetration (-0.16 mm) (Table 3).

	Tourniquet-Less (n=93)	Tourniquet (n=1128)	P-Value
Age (Years)	63.88 ± 9.98	62.05 ± 9.51	0.08
Sex			0.13
<i>Male</i>	32	458	
<i>Female</i>	61	672	
BMI (kg/m²)	31.62 ± 5.79	33.81 ± 7.15	0.003
Length of stay (days)	2.15 ± 1.43	2.49 ± 1.60	0.05

Table 1: Patient demographics.

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	Unstandardized Beta*	P-Value
Average Tibial Penetration	-0.002	0.98
Average Femoral Penetration	0.08	0.45
Average Total Penetration	0.13	0.23
*Increase of cement penetration depth (mm) per unit change of systolic blood pressure		

Table 2: Effect of SBP on CPD in Tourniquet-less TKA (n=93).

	Tourniquet-Less (n=93)	Tourniquet (n=1128)	P-Value
Average Tibial Penetration	2.29 ± 0.77	2.39 ± 1.9	0.704
Average Femoral Penetration	2.04 ± 0.58	2.91 ± 1.08	<0.001
Average Total Penetration	2.58 ± 0.78	2.74 ± 1.44	0.001

Table 3: Difference in CPD between Tourniquet-less vs. Tourniquet TKA.

Discussion

Cement penetration depth is an important factor that influences the strength of the bone-implant interface and, thus, the rate of aseptic loosening [4-6]. The ideal method of achieving optimal CPD is still debated and our study investigated the effects of one important variable - systolic blood pressure during TKA cementation.

We found that systolic blood pressure does not significantly affect tibial, femoral, or total average penetration in tourniquet-less TKAs. We made the distinction between tourniquet and tourniquet-less surgeries because the use of a tourniquet effectively eliminates blood pressure within the targeted limb, rendering the influence of systolic blood pressure during the cementation process null. Although Juliusson, et al., found that circulating bone diminished cement penetration into cancellous bone and Majkowski, et al., found that bleeding significantly reduced the shear strength of the bone-cement interface, we found the opposite to be true as systolic blood pressure did not significantly affect cement penetration depth in our patients [12, 13]. Some orthopedic surgeons maintain hypotensive anesthesia during cementation as a way of improving the cementation process. Our study contradicts this practice as we found no correlation between blood pressure and CPD.

Our study also found that the femoral and total cement penetration depths were significantly increased in patients who had a tourniquet used during cementation. On average, the average

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femoral cement penetration depth was 0.87 mm greater and the average total penetration was 0.16 mm greater. These increases could make the difference of whether a patient's cement penetration depth reaches the optimal 3-5 mm or not. The use of a tourniquet during TKAs has many pros and cons, our study adds supporting information to help surgeons make informed decisions during TKA.

Every effort should be made to improve the longevity and decrease the complication rates of TKAs. Our study adds to the growing body of literature focused on TKAs best practices and potential avenues of mitigating complications such as aseptic loosening. Our study is limited in that it was undertaken at four large, academic orthopedic hospitals. Larger studies that include multiple institutions, increased number of surgeons and a higher sample size are required to elucidate the impact this may have on the greater population. Other limitations include the lack of long term follow up to determine if the depth of cement penetration may affect the rates early aseptic loosening. Our study was a retrospective analysis, but a randomized control trial would be a more thorough way of comparing cohorts. We also did not examine different methods of clearing blood from the bone (hydrogen peroxide application, irrigation, Carbojet (Kinamed, Camarillo, CA, USA) that could affect the current results. Additionally, we did not determine why exactly certain patients had tourniquets used during TKA and others did not, which could lead to selection bias.

Conclusion

Systolic blood pressure did not significantly affect tibial, femoral, or total cement penetration depth in patients undergoing tourniquet-less, primary TKA. However, the use of a tourniquet significantly aids in average femoral and total cement penetration depth. The clinical significance of this difference needs further investigation. A future project to consider could be to use the tourniquet for the cementation portion of the surgery only. This method could potentially harness the cement penetration depth benefits of the tourniquet without the need for it to be applied throughout the whole procedure. Expanded research into tourniquets and cement penetration depth could benefit the arthroplasty field for total knee arthroplasties.

Conflict of Interest

All the author declare no conflict of interest regarding any aspect of the manuscript.

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