

Research Article

Inflating a thigh tourniquet anteriorly displaces the popliteal artery relative to the posterior tibial cortex: an in vivo magnetic resonance imaging study

Justen Elbayer, MD^{1,2a}, David Swanson, MD^{1,3b}, Nicholas Tsouris^{1c}, Dorian Cohen^{1d}, Gloria Coden^{3,4e}, Elaine Gould, MD^{5f}, Mingqian Huang^{5,6g}, David Komatsu^{1h}, Kenneth Wengler^{7,8i}, Corey Ho^{9,10j}

a Dr. Elbayer is an orthopedic sports medicine surgeon in Long Island, NY.

[Visit Dr. Elbayer's Website](#)

[Conflicts of Interest Statement for Dr. Elbayer](#)

b David R. Swanson III, MD is a board-eligible and fellowship-trained Orthopedic Surgeon specializing in Sports Medicine, Joint Replacement Surgery, and General Orthopedic Trauma.

After graduating with the distinction of Honors from Gordon College, Dr. Swanson earned his medical degree from the Wright State University Boonshoft School of Medicine. Upon completion of his MD, Dr. Swanson was inducted into the prestigious Alpha Omega Alpha Honor Medical Society, which recognizes only the top 10% of medical students across the United States.

Dr. Swanson underwent rigorous training in Orthopedic Surgery during residency at Stony Brook University Hospital, where he was elected and served as Executive Chief Resident in his final year. He was subsequently selected to pursue advanced fellowship training in Sports Medicine and Arthroscopic Surgery of the shoulder, hip and knee at New England Baptist Hospital in Boston, MA. During his time in Boston, Dr. Swanson served as one of the team physicians for the 17-time World Champion Boston Celtics, where he provided care to some of the highest level athletes in the world. In addition to his experience as a professional team physician, Dr. Swanson has provided care to a broad spectrum of athletes, from Division I athletes at Bentley University and Stony Brook University, to collegiate club hockey, to junior varsity and junior high football teams.

[Visit Dr. Swanson's Website](#)

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c Nick Tsouris is currently a fifth year orthopedic resident at Stony Brook University Hospital on Long Island in New York. He will be venturing on to a sports medicine fellowship at the University of Colorado next year.

[Visit Dr. Tsouris's Website](#)

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d [Conflicts of Interest Statement for Dorian Cohen](#)

e [Connect with Gloria Coden on LinkedIn](#)

[Conflicts of Interest Statement for Gloria Coden](#)

f Dr. Gould is currently Chair of Radiology and Chief of Musculoskeletal Radiology at Stony Brook medicine and Professor of Radiology at Renaissance School of Medicine, NY.

[Conflicts of Interest Statement for Dr. Gould](#)

g Dr. Huang is a fellowship trained musculoskeletal radiologist. Her research interest has focused on using advanced imaging techniques to study musculoskeletal conditions that can benefit the patients and lead to new understanding of better clinical management. Starting from her radiology residency training at NYU Langone Medical center, she has been at the forefront of different projects that aims to develop better paradigm of comprehensive imaging evaluation of musculoskeletal conditions.

She continued her research work in her fellowship at Hospital of Joint Disease and collaborating with surgeons. Based on these experiences, she has authored a comprehensive review of radiology's role of our better understanding of articular disease over the years in our society leading journal after her fellowship.

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[Visit the Open Payments Data Page for Dr. Huang](#)




[Conflicts of Interest Statement for Dr. Huang](#)

h [Conflicts of Interest Statement for David Komatsu](#)

i [Conflicts of Interest Statement for Kenneth Wengler](#)

j Following training in New York, Corey Ho practices in Colorado focusing of musculoskeletal imaging and intervention. The practice ranges from sports imaging to pain management and tumor ablation.

[Conflicts of Interest Statement for Corey Ho](#)

Dharmesh Tank^{9,11}^k, James Paci, MD^{1,12}^l, James Penna, MD¹^m

¹ Orthopaedic Surgery, Stony Brook University, ² Orthopaedic Surgery, New York University Langone Medical Center, ³ Orthopaedic Surgery, New England Baptist Hospital, ⁴ Stony Brook University, ⁵ Musculoskeletal Radiology, Stony Brook University, ⁶ Radiology, Mount Sinai Health System, ⁷ Biomedical Engineering, Stony Brook University, ⁸ Psychiatry, Columbia University, ⁹ Radiology, Stony Brook University, ¹⁰ Radiology, University of Colorado Health, ¹¹ Radiology, Atlantic Health System, ¹² Orlin and Cohen Orthopedic Group

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Background

Previous work has demonstrated that with increasing knee flexion angles, the popliteal artery is located further away from the posterior tibial cortex (PTC), thus offering a safer position for procedures about the knee. Prior studies did not, however, incorporate the use of a surgical thigh tourniquet, a device commonly used by orthopaedic surgeons. Thigh tourniquet effect on popliteal spatial anatomy will be assessed in this study.

Methods

Using 3 Tesla magnetic resonance imaging, 6 volunteer knees were evaluated in both full extension and 90 degrees (°) of flexion, with and without a thigh tourniquet inflated to 200 millimeters of mercury. Axial images at the level of the posterior cruciate ligament (PCL) tibial insertion were obtained. The distance of the popliteal artery from the PCL tibial insertion and the PTC at this level were calculated.

Results

Without a tourniquet, at 0° and 90° of flexion, the mean distance between the popliteal artery and the PTC was 6.9 and 9.4 millimeters, respectively. With a tourniquet, at 0° and

^k [Conflicts of Interest Statement for Dharmesh Tank](#)

^l James M. Paci, MD joined the Orlin and Cohen Orthopedic Group as the Director of Orthopedic Surgery and Sports Medicine for Suffolk County in 2018 and is an Associate Professor of Orthopedic Surgery at the Donald and Barbara Zucker School of Medicine at Hofstra/Northwell. He is a board-certified sports medicine orthopedic surgeon specializing in the care of athletes and disorders of the shoulder, elbow and knee.

Dr. Paci is the head team physician and medical director for the New York Riptide, NLL professional lacrosse team, and Farmingdale State College, and an orthopedic consultant for many high schools on Long Island, including Huntington High School.

Dr. Paci is a member of the Suffolk County, Section XI Sports Safety Committee, and Vice President of the Andrews Sports Medicine Fellowship Alumni Blind Squirrel Society. Prior to joining Orlin and Cohen, Dr. Paci was a member of Stony Brook Orthopedic Associates and an Associate Professor in the Department of Orthopedics within the Stony Brook University School of Medicine. During that time, Dr. Paci was a team orthopedic physician for the Stony Brook University Seawolves. He has also served as a team physician for the New York Lizards (MLL), Long Island University, Dowling College and Suffolk County Community College and as an orthopedic consultant for the Premier Lacrosse League.

Dr. Paci completed an orthopedic sports medicine fellowship at the American Sports Medicine Institute (ASMI) in Birmingham, Alabama, under the direction of Dr. James Andrews, where he received the 2009-2010 award for excellence in clinical research. In Birmingham, Dr. Paci was the team physician for Huntingdon College and Bessemer Academy, and assisted with the care of athletes from the University of Alabama, Auburn University, the Washington Redskins football team, and the Montgomery Biscuits (AA) and Birmingham Barons (AA) baseball teams.

[Visit Dr. Paci's Website](#)

[Connect with Dr. Paci on LinkedIn](#)

[Visit the Open Payments Data Page for Dr. Paci](#)

[Conflicts of Interest Statement for Dr. Paci](#)

^m Dr. James Penna is the Chair of Orthopaedics at Stony Brook University Medical Center. He was previously the residency program director (20 years) where he developed my interest in more advanced clinical training options. His clinical practice is focused on sports medicine and related disease.

[Visit Dr. Penna's Website](#)

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90° the mean distance between the popliteal artery and the PTC decreased to 6.2 (-0.7) and 8 (-1.4) millimeters, respectively. These reductions in distances with inflating the tourniquet were statistically significant ($p < 0.05$). The distance between the artery and the PCL attachment did not change with and without inflating the tourniquet.

Conclusions

Inflating a thigh tourniquet moves the popliteal artery approximately 1 millimeter (8.5 percent) anterior towards the PTC and has no effect on the relationship between the popliteal artery and PCL insertion.

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INTRODUCTION

The use of surgical tourniquets in orthopaedic surgery has been well described (Alcelik et al. 2012; Fan et al. 2014; Wang et al. 2016). Benefits of tourniquet use include decreased intraoperative blood loss as well as improved visualization of the operative field. For these reasons, it has become common practice to place a tourniquet about the thigh for orthopaedic procedures involving the knee (Alcelik et al. 2012).

Although rare, accounting for only 0.05-1.0% of all complications in total knee arthroplasty and knee arthroscopy, arterial injury is a known and potentially devastating complication, with the possibility of significant morbidity and mortality (DeLee 1985; Small 1986; Sundaram et al. 2020). Several authors have attempted to define positions of the knee that displace the popliteal artery furthest from the posterior tibial cortex (PTC), offering a lower risk of arterial injury during surgery. Matava et al. defined the distance of the popliteal artery from the posterior cruciate ligament (PCL) tibial insertion, showing that with increasing knee flexion angles, the risk of arterial injury during PCL reconstruction was reduced by displacing the popliteal artery further from the PCL tibial insertion (Matava, Sethi, and Totty 2000). However, no study to date has evaluated the effects of a thigh surgical tourniquet on the spatial anatomy of the popliteal neurovascular structures, most notably the popliteal artery, as it relates to the bony and ligamentous anatomy of the knee.

The purpose of this study is to evaluate whether an inflated thigh surgical tourniquet alters the distance that the popliteal artery rests from both the PCL tibial insertion and the PTC directly anterior to the artery. The authors hypothesize that inflating a thigh tourniquet would tether the arterial system proximally, thus translating the popliteal artery closer to the posterior tibia.

METHODS

Institutional Review Board approval was obtained for human subjects research. 6 knees were evaluated in 4 different subjects between July of 2017 and April of 2018. All subjects were male volunteers over 18 years old, with an average age of 29 years. None of the subjects had previous surgical procedures on the knee being evaluated, skeletal deformities, previous or known ligamentous injury, joint contractures, history of deep venous thrombosis or peripheral vascular disease, magnetic resonance imaging (MRI)-incompatible implants, and pregnancy. Using 3 Tesla MRI, 2-dimensional proton density weighted axial images at the level of the PCL tibial insertion were obtained in both full extension and 90 degrees (°) of flexion, with and without a thigh tourniquet inflated to 200 millimeters of mercury. Tourniquet inflation was limited to 200 millimeters of mercury for subject comfort. The level of the tibial PCL insertion was then confirmed using localizer images.

Extension was evaluated first (Figure 1A). A tourniquet was placed on the thigh of each subject, and the knee was first imaged with the tourniquet deflated. Localizing imaging as well as 2-dimensional proton density weighted images were obtained. This series took an average of 5 minutes. Each subject then inflated the tourniquet to 200 millimeters of mercury, and the knee was re-imaged (Figure 1B). Subjects were instructed to hold the extremity still as the same prior localizers were used for subsequent imaging with the tourniquet inflated. This series took an average of 3 minutes.

The exam was then repeated at 90° of flexion (Figures 1C and 1D). In order to allow for proper fitting of subjects into the MRI tube with the knee flexed to 90°, each subject assumed a lateral decubitus position corresponding to which ever knee was being studied; for example, if the left knee was being studied, the patient assumed a left lateral decubitus position.

The distance to the popliteal artery was then measured from both the PCL tibial insertion and the PTC directly an-

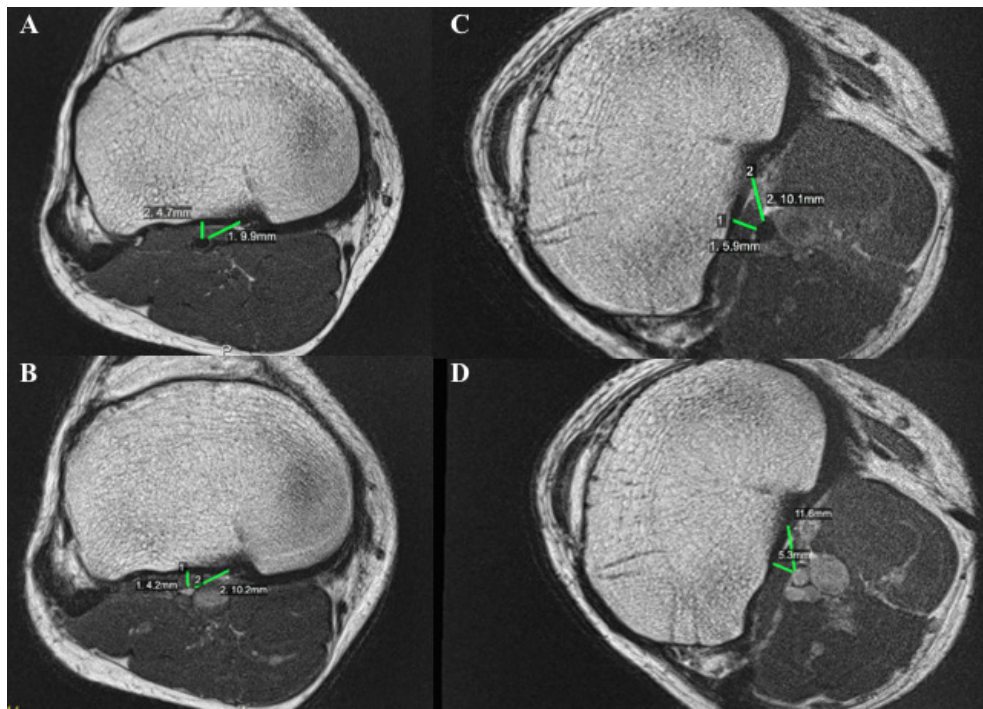


Figure 1. Axial MRI Images at Level of PCL Tibial Insertion

MRI images from knees positioned at 0° without tourniquet (A), 0° with tourniquet (B), 90° without tourniquet (C), 90° with tourniquet (D). On all images, line 1 is the PTC to the popliteal artery and line 2 is the PCL to popliteal artery.

MRI=magnetic resonance imaging, PTC=posterior tibial cortex, PCL=posterior cruciate ligament, °=degrees

terior to the anterior margin of the popliteal artery at the level of the PCL tibial insertion. Measurements were performed on axial rather than sagittal views to obviate the necessity of accounting for obliquity. Any images affected by subject movement were discarded and re-performed. Of note, no pre-inflation exsanguination was conducted.

Changes in popliteal artery position following application of the tourniquet were assessed using Related-Samples Wilcoxon Signed Rank tests at each angle of flexion. Analyses were carried out using SPSS Version 22 (International Business Machines Corporation, Yorktown, New York) and significance was determined for values of $p < 0.05$. The effect size was subsequently calculated with Cohen's d .

RESULTS

The popliteal artery could be traced proximally from the posterior distal femur to the level of the PCL tibial insertion in all MRIs. The popliteal artery was found posterior and slightly lateral to the PCL tibial insertion in all knees.

Descriptive statistics are shown in [Table 1](#) with statistical comparisons between the relative position of the popliteal artery in flexion and extension both with and without the tourniquet. Initial measurements were obtained without the tourniquet inflated. In full extension, the mean distance between the PCL tibial insertion and the popliteal artery was $9.82 (\pm 1.36)$ millimeters (mm), and the mean distance between the PTC and the popliteal artery was $6.88 (\pm 1.49)$ mm. In 90° of flexion, the mean distance between the PCL tibial insertion and the popliteal artery was $10.45 (\pm 3.14)$ mm, and the mean distance between the

PTC and the popliteal artery was $9.43 (\pm 3.43)$ mm. There was a statistically significant increase in the distance from the PTC to the popliteal artery when going from full extension to 90° flexion, both with and without tourniquet use ($p = 0.046$ for both groups).

Subsequent measurements were obtained with the thigh tourniquet inflated to 200 millimeters of mercury. In full extension, the mean distance between the PCL tibial insertion and the popliteal artery was 10.23 mm, and the mean distance between the PTC and the popliteal artery was $6.17 (\pm 1.13)$ mm. In 90° of flexion, the mean distance between the PCL tibial insertion and the popliteal artery was 10.38 (± 2.44) mm, and the mean distance between the PTC and the popliteal artery was $7.95 (\pm 1.96)$ mm.

Statistical analysis of the effect of the tourniquet on relative popliteal artery position is shown in [Table 2](#), accompanied by the calculated effect sizes for each condition. When comparing the distance between the PTC and the popliteal artery in both flexion and extension, there was a statistically significant decrease in the distance when a tourniquet was used, compared to when it was not ($p = 0.028$ and $p = 0.046$, respectively). As noted in [Table 2](#), the effect size for this decrease was moderate in both flexion and extension ($d = 0.53$ and $d = 0.54$, respectively).

DISCUSSION

This study is the first of its kind to evaluate the *in vivo* effects of an inflated thigh surgical tourniquet on the spatial anatomy of the popliteal artery using MRI. Our results suggests that while using an inflated thigh tourniquet, the

Table 1.

	Knee at Full Extension	Knee at 90° of Flexion	p-value
Tourniquet Deflated			
Distance from Popliteal Artery to PCL (mm), mean (sd)	9.82 (1.36)	10.45 (3.14)	0.462
Distance from Popliteal Artery to PTC (mm), mean (sd)	6.88 (1.49)	9.43 (3.43)	0.046
Tourniquet Inflated			
Distance from Popliteal Artery to PCL (mm), mean (sd)	10.23 (2.49)	10.38 (2.44)	0.917
Distance from Popliteal Artery to PTC (mm), mean (sd)	6.17 (1.13)	7.95 (1.96)	0.046

Distances from popliteal artery to PCL and PTC in at 0° and 90° with and without inflated tourniquet.

PCL=posterior cruciate ligament, PTC=posterior tibial cortex, mm=millimeters, sd=standard deviation, °=degrees

Table 2.

	p-value with Knee at Full Extension	Cohen's d with Knee at Full Extension	p-value with Knee at 90° of Flexion	Cohen's d with Knee at 90° of Flexion
PCL	0.345	0.02	0.753	0.02
PTC	0.046	0.54	0.028	0.53

Effect of inflation of the tourniquet on the distance from the popliteal artery from PCL and PTC at 0° and 90° of knee flexion.

PCL=posterior cruciate ligament, PTC=posterior tibial cortex, mm=millimeters, sd=standard deviation, °=degrees

popliteal artery rests slightly closer to the PTC in both flexion and extension versus if no tourniquet were utilized. Our study also suggests that flexion of the knee displaces the popliteal artery further from the PTC, confirming previous findings, and demonstrates that this effect is limited by an inflated tourniquet (Matava, Sethi, and Totty 2000; Ahn et al. 2007; Shetty et al. 2003). Furthermore, these findings have a moderate effect size, indicating that the approximation of the popliteal artery and the PTC may be large enough to have a clinical impact above and beyond the implications of a statistically significant difference.

There has been extensive prior investigation to define the safest intraoperative position of the knee during open and arthroscopic surgery to minimize the risk of vascular injury. Both cadaveric and human studies utilizing ultrasonography, MRI, and angiography have been conducted. Shetty et al. demonstrated a statistically significant increase in popliteal artery distance from the PTC with increasing knee flexion from 0° to 90° via duplex ultrasonography in the majority of human knees tested (Shetty et al. 2003). In a cadaveric study by Matava et al., increasing knee flexion caused the popliteal artery to rest further away from the PTC (Matava, Sethi, and Totty 2000). Ahn et al. performed a cadaveric angiographic study in which they measured the relationship and distances between the popliteal artery and the posterior cruciate ligament (Ahn et al. 2007). The authors found that the distance between the popliteal artery and the PCL at the joint level increased after flexion of the knee joint (Ahn et al. 2007). We found similar results to prior studies regarding the distance between the popliteal artery and the posterior aspect of the proximal tibia. Cosgarea et al. found a mean sagittal distance of 9.7 mm between the PCL tibial fovea and the popliteal artery with knees in 90° flexion in 9 specimens (Cosgarea et al. 2010). Without tourniquet use, our results show a mean of 10.23 mm between the popliteal artery and PCL tibial fovea

in 90° flexion, consistent with prior results. Keser et al. showed that in the majority of knees evaluated with MRI, the popliteal artery sat lateral to the central axis at the joint line (Keser et al. 2006). Similar findings were seen in our study.

There are several limitations to this study. The study carries a small sample size, all of whom are young adult males. This study was not powered to evaluate other factors that may contribute to popliteal artery displacement, such as height, body habitus, and exact placement of thigh tourniquet. Furthermore, in order to evaluate knee flexion, subjects had to lay in the lateral decubitus position to allow proper fitting in the MRI tube, theoretically eliminating a gravity-driven posterior displacement of the popliteal artery. The tourniquet inflation was limited to 200 millimeters of mercury. While this was necessary for subject comfort, tourniquets are often inflated higher when used intraoperatively, we believe that this may further decrease the distance between the popliteal artery and the PTC. Finally, we were unable to exsanguinate the limbs prior to evaluation, as this would have required subjects to undergo localizing imaging with the tourniquet inflated, adding more time than the three minutes required for each series.

CONCLUSIONS

The primary objective of this study was to redefine the previously described spatial anatomy of the popliteal artery to account for the effects of an inflated thigh surgical tourniquet. Based on our findings, inflating a thigh tourniquet results in the popliteal artery resting approximately 1 mm closer to the posterior aspect of the tibia ($p=0.028$), and it does not change the distance between the popliteal artery and the PCL with any statistical significance. Further investigation is required to assess the clinical significance of this

effect on the risk of vascular injury in the context of knee surgery. Submitted: April 10, 2023 EDT, Accepted: June 23, 2023 EDT



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REFERENCES

- Ahn, Jin Hwan, Joon Ho Wang, Sang Hak Lee, Jae Chul Yoo, and Woo Joo Jeon. 2007. "Increasing the Distance between the Posterior Cruciate Ligament and the Popliteal Neurovascular Bundle by a Limited Posterior Capsular Release during Arthroscopic Transtibial Posterior Cruciate Ligament Reconstruction: A Cadaveric Angiographic Study." *The American Journal of Sports Medicine* 35 (5): 787–92. <https://doi.org/10.1177/0363546506297908>.
- Alcelik, Ilhan, Raymond D. Pollock, Mohammed Sukeik, Josette Bettany-Saltikov, Patrick M. Armstrong, and Peter Fismar. 2012. "A Comparison of Outcomes with and without a Tourniquet in Total Knee Arthroplasty: A Systematic Review and Meta-Analysis of Randomized Controlled Trials." *The Journal of Arthroplasty* 27 (3): 331–40. <https://doi.org/10.1016/j.arth.2011.04.046>.
- Cosgarea, Andrew, Dennis Kramer, Michael Bahk, William Totty, and Matthew Matava. 2010. "Proximity of the Popliteal Artery to the PCL During Simulated Knee Arthroscopy – Implications for Establishing the Posterior Trans-Septal Portal." *The Journal of Knee Surgery* 19 (03): 181–85. <https://doi.org/10.1055/s-0030-1248103>.
- DeLee, Jesse C. 1985. "Complications of Arthroscopy and Arthroscopic Surgery: Results of a National Survey." *Arthroscopy: The Journal of Arthroscopic & Related Surgery* 1 (4): 214–20. [https://doi.org/10.1016/s0749-8063\(85\)80086-4](https://doi.org/10.1016/s0749-8063(85)80086-4).
- Fan, Yu, Jin Jin, Zhijian Sun, Wenjing Li, Jin Lin, Xisheng Weng, and Guixing Qiu. 2014. "The Limited Use of a Tourniquet during Total Knee Arthroplasty: A Randomized Controlled Trial." *The Knee* 21 (6): 1263–68. <https://doi.org/10.1016/j.knee.2014.08.002>.
- Keser, Selçuk, Ahmet Savranlar, Ahmet Bayar, Suat Can Ulukent, Tülay Özer, and İbrahim Tuncay. 2006. "Anatomic Localization of the Popliteal Artery at the Level of the Knee Joint: A Magnetic Resonance Imaging Study." *Arthroscopy* 22 (6): 656–59. <https://doi.org/10.1016/j.arthro.2006.04.076>.
- Matava, Matthew J., Navin S. Sethi, and William G. Totty. 2000. "Proximity of the Posterior Cruciate Ligament Insertion to the Popliteal Artery as a Function of the Knee Flexion Angle: Implications for Posterior Cruciate Ligament Reconstruction." *Arthroscopy* 16 (8): 796–804. <https://doi.org/10.1053/jars.2000.18243>.
- Shetty, A. A., A. J. Tindall, F. Qureshi, M. Divekar, and K. W. K. Fernando. 2003. "The Effect of Knee Flexion on the Popliteal Artery and Its Surgical Significance." *The Journal of Bone and Joint Surgery. British Volume* 85-B (2): 218–22. <https://doi.org/10.1302/0301-620x.85b2.13559>.
- Small, Neal C. 1986. "Complications in Arthroscopy: The Knee and Other Joints." *Arthroscopy* 2 (4): 253–58. [https://doi.org/10.1016/s0749-8063\(86\)80080-9](https://doi.org/10.1016/s0749-8063(86)80080-9).
- Sundaram, Kavin, Inyang Udo-Inyang, Michael A. Mont, Robert Molloy, Carlos Higuera-Rueda, and Nicolas S. Piuze. 2020. "Vascular Injuries in Total Knee Arthroplasty: A Systematic Review and Meta-Analysis." *JBJS Reviews* 8 (1): e0051–e0051. <https://doi.org/10.2106/jbjs.rvw.19.00051>.
- Wang, Kai, Songjia Ni, Zhichang Li, Qunjie Zhong, Rujun Li, Hu Li, Yan Ke, and Jianhao Lin. 2016. "The Effects of Tourniquet Use in Total Knee Arthroplasty: A Randomized, Controlled Trial." *Knee Surgery, Sports Traumatology, Arthroscopy* 25 (9): 2849–57. <https://doi.org/10.1007/s00167-015-3964-2>.