Systematic Review

Tourniquet Use During Anterior Cruciate Ligament Reconstruction Is Associated With Postoperative Quadriceps Atrophy and Pain but No Negative Effects in the Long Term: A Systematic Review

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Purpose: To evaluate the effect of tourniquet use during ACL reconstruction on quadriceps strength, intraoperative and postoperative blood loss, operative time, thigh girth or calf girth, and postoperative pain. **Methods:** A systematic review using PubMed, EMBASE, and Cochrane Database of Systematic Reviews was conducted following the PRISMA guidelines. Randomized controlled trials and nonrandomized studies that evaluated intraoperative and postoperative effects of tourniquet usage during arthroscopic ACL reconstruction published between November 1996 and January 2023 were included. Outcomes evaluated included intraoperative visualization, pain, quadricep strength thigh or calf girth, blood loss, and operative time. **Results:** Eight studies with 502 total patients were included in this review. There were 253 total patients in the tourniquet (T) group and 249 in the non-tourniquet (NT) group. Postoperative blood loss was higher in the T group ($P < .05$). Two studies reported significantly increased postoperative analgesic usage within the T group ($P < .05$), while 2 studies listed no significant differences between groups. Postoperative pain was not significantly increased in either group 2 days postoperation; however, 2 studies reported an increase in pain in the T group within the 10-hour, postoperative window ($P < .05$). Although 3 studies indicated an initial decrease in quadriceps strength within the T group following surgery ($P < .05$), overall findings consistently demonstrated a recovery of quadriceps strength within a few weeks. Similarly, there were no long-term significant differences in thigh or calf girth reported. Decreased operative time was reported with tourniquet use across included studies with 1 study demonstrating a significant difference ($P < .05$). **Conclusions:** Tourniquet use during ACL reconstruction does not have negative long-term effects on quadriceps strength. Although tourniquet use was associated with increased quadriceps atrophy and pain in the immediate postoperative period, these effects did not persist. **Level of Evidence:** Level II, systematic review of Level I and II studies.

The tourniquet is a tool surgeons may select to use for lower extremity surgeries.[1] The surgical tourniquet has several benefits, including reducing intraoperative blood loss, decreasing operative time, and improving intraoperative visualization, but its use may impart risks, including increased pain, increased postoperative blood loss, decreased leg strength, skin damage, and neurologic injury.[2-7] Specifically, its use during anterior cruciate ligament (ACL) reconstruction has been debated.

It is estimated that approximately 400,000 ACL reconstructions are performed annually in the United

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States.[8] The majority of ACL reconstructions are performed arthroscopically assisted, and the surgeon may elect to use a pneumatic tourniquet. Studies are conflicting regarding the use of a tourniquet during ACL reconstruction surgery. Some have reported significant differences in leg strength, blood loss, and postoperative pain associated with tourniquet use, while others have shown that tourniquet use has no significant impact on outcomes following ACL reconstruction.[3-6,8-11] However, most of these studies are limited to a small number of patients.

The purpose of this study is to evaluate the effect of tourniquet use during ACL reconstruction on quadriceps strength, intraoperative and postoperative blood loss, operative time, thigh girth or calf girth, and postoperative pain. The authors hypothesize that the use of a tourniquet will decrease quadriceps strength in the immediate postoperative period and will return to baseline long-term, and that changes in secondary outcomes will vary with the use of a tourniquet.

Methods

This systematic review was prepared by utilizing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) checklist.

Three reviewers (C.H., S.I., A.C.) searched MEDLINE through PubMed, CENTRAL (Cochrane), and Embase databases for related publications between November 1996 and January 2023. The PROSPERO data were utilized to see whether there were any previous systematic reviews on this specific topic. The search algorithm used for MEDLINE, CENTRAL, and Embase was "tourniqueted" OR "tourniquets" [MeSH Terms] OR "tourniquets" OR "tourniquet") AND ("anterior cruciate ligament" [MeSH Terms] OR ("anterior" AND "cruciate" AND "ligament") OR ("anterior cruciate ligament" OR "ACL"). The search term used on PROSPERO was "ACL reconstruction with tourniquet."

Publication titles and abstracts were evaluated to determine which studies could be eligible for inclusion. Studies were included if they evaluated outcomes of tourniquet use on outcomes following ACL reconstruction surgeries. Both randomized and nonrandomized studies were included. Studies were not disqualified if they included concurrent meniscal repair or partial meniscectomy; however, other concurrent ligament procedures were disqualified. Scientific conference abstracts, literature reviews, case reports, and articles that were published in a non-English language were excluded.

Once papers were chosen for potential eligibility, the full texts were reviewed. Additionally, the 3 reviewers manually explored the references utilized by the articles selected to identify any applicable studies. All 3 reviewers extracted and evaluated the data from the eligible studies. Discrepancies between selected studies were settled by consensus.

Cohen's κ was used to measure inter-reviewer reliability of included studies. Assessment of the methodological quality and risk of bias was determined using the Critical Appraisal Skills Programme (CASP) cohort study checklist. Checklist questions were answered with "Yes", "No," or "N/A," "Yes" answers were given a value of "1," and "No" or " N/A" values were given a value of "0," Values from 11 answered questions were added in total for each study and then averaged across all included studies.

Results

The literature search resulted in 224 nonduplicate studies. After reviewing the titles and abstracts for the selected studies, 208 studies were excluded due to discordance with the inclusion criteria. Of the remaining 16 manuscripts, 8 additional studies were excluded in the final screening. Of the 8 manuscripts excluded, 1 was an abstract, 5 were systematic reviews/meta-analyses, and 1 was a retrospective study. Subsequently, 8 total studies from November 1996 to January 2023 were included in the final article (Figure 1 and Table 1). The κ values after title and abstract screening and full-text screening were 0.883 and 0.75, respectively, indicating substantial agreement between the reviewers. Assessment of the methodological quality and risk of bias revealed an average score of all included studies of 8.75, indicating a "good" methodological quality assessment and risk of bias (Table 2).

Quadriceps Strength

Five included studies measured postoperative quadriceps strength (Table 3).[2,3,6,9,10] Three of these studies were randomized, controlled trials, and one was a prospective, randomized study. Overall, these studies via isokinetic quadriceps strength testing found no significant differences with tourniquet use at 3 months, 6 months, or 1 year postoperatively.

Two studies reported values at 6 months. One randomized, controlled trial measured quadriceps strength as a percentage of body weight with concentric and eccentric loading.[6] During concentric loading, the tourniquet group and nontourniquet group had torque values of 40.1% and 35.28%, respectively ($P = .38$). During eccentric loading, the tourniquet group and nontourniquet group both had torque values of 47% ($P = .98$). Another randomized, controlled trial measured torque values as a percentage of the nonoperative extremity.[9] The tourniquet group and nontourniquet group had torque values of 32% and 35%, respectively ($P = .59$).

Another randomized, controlled trial compared preoperative and postoperative quadriceps strength via

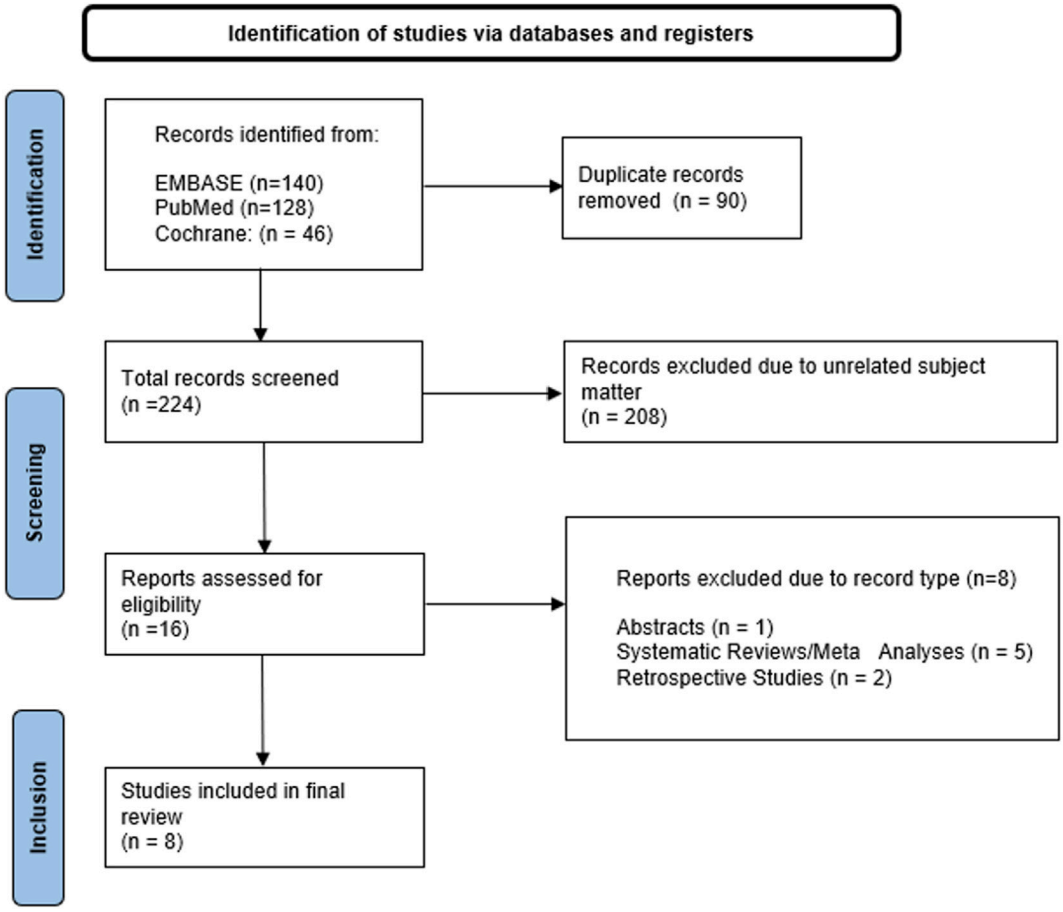

Fig 1. Flow diagram of included and excluded studies. Records were identified using several online databases, then reviewed for eligibility based on our inclusion criteria.

electroneuromyography readings with a tourniquet inflated to low pressure (250 mm Hg) or high pressure (350 mm Hg).[10] While no significant differences were found between high- and low-pressure tourniquet inflation at 3 weeks, postoperative slowing of motor and sensory conduction were demonstrated when the high- and low-pressure groups were combined, including a reduced interference pattern in the vastus medialis postoperatively ($P = .002$).[10]

Thigh or Calf Girth

Six included studies reported results on thigh girth for tourniquet use in ACL reconstruction (Table 4).[2-4,6,9,11] A randomized, controlled trial found no significant differences between tourniquet groups for thigh girth when progressing postoperatively from time points of 1 month to 6 months. A prospective, randomized study found no significant differences throughout the study from time points spanning 3 days to 3 weeks.[4,6] Additionally, a double-blinded, randomized controlled trial demonstrated no differences in thigh, knee, or calf girth at 48 hours postoperatively.[2] In contrast to these findings, 3 randomized, controlled trials have demonstrated continuous significant decreases in thigh girth for tourniquet patients from day of surgery to terminal time points of 2 weeks, 21 days, and 3 months ($P < .05$).[3,9,11] Differences in thigh girth from these studies were 3.5, 1.19, and 1.4 cm, respectively.

Total Operative Time

Total operative time was reported in 5 studies (Table 4).[2-6] Only the included double-blinded, randomized controlled trial demonstrated a significant decrease in operative time with tourniquet use from a mean time of 72.5 (SD = 5.6) to 58.4 minutes (SD = 5.7; $P < .05$).[2] Of note, one included randomized, controlled trials included concurrent procedures to ACL reconstruction, which could have affected reported results on total operative time.[6] Tranexamic acid (TXA) use was not reported in any included study. Epinephrine used in included studies was administered in varying dosages via intra-articular injections,[3,5] irrigation fluid,[4,9] or subcutaneous injections at skin incisions.[6,11] Utilization of epinephrine only differed between tourniquet groups when administered in irrigation fluid for the nontourniquet groups.

Table 1. Patient Demographics and Tourniquet Data

Authors, Year Published	Study Design; Level of Evidence	Autograft Type	No. of Subjects		Mean Age (years)		Sex (M/F)		Mean Tourniquet Duration (minutes)		Inflated Pressure (mm Hg)
			T	NT	T	NT	T	NT	T	NT	
Arciero et al.,[6] 1996	RCT; I	Patellar	20	20	24.8	26.7	13/7	17/3	87	0	269
Hooper et al.,[5] 1999	RCT; I	Not stated	14	15	35.3	35.7	5/9	10/9	U	U	300
Kokki et al.,[10] 2000	RCT; I	Patellar	13	13	31	33	9/4	11/2	108	101*	350 (High pressure group) 250 (Low pressure group)
Nicholas et al.,[9] 2001	RCT; I	Patellar	25	23	33	32	13/12	16/7	85	0	300
Nakayama and Yoshiya,[4] 2013	Prospective, randomized study; II	Not stated	28	23	24.8	26.7	11/17	16/7	11.8	11.8†	300
Reda et al.,[3] 2016	RCT; I	Hamstring	30	33	25.5	25	25/4	24/5	64	0	350
Choudhary et al.,[11] 2020	RCT; I	Hamstring	23	22	29.3	29.6	21/2	17/5	76.5	0	293.2
Zaid et al.,[2] 2023	Double-blinded RCT; I	Hamstring	100	100	26.8	25.2	69/31	71/29	U	U	260.7

NT, nontourniquet; RCT, randomized controlled trial; T, tourniquet; U, unavailable.
*Total time for low-pressure group.
†Tourniquet inflated only during hamstring harvest.

Table 2. Critical Appraisal Skills Programme Cohort Study Checklist

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Total Score
Arciero et al.[6]	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	9
Hooper et al.[5]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	9
Kokki et al.[10]	Y	Y	Y	Y	N/A	Y	N/A	N	Y	N	Y	7
Nicholas et al.[9]	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y	10
Nakayama and Yoshiya[4]	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	8
Reda et al.[3]	Y	Y	Y	Y	N/A	Y	Y	N	Y	Y	Y	9
Choudhary et al.[11]	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	9
Zaid et al.[2]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	9
										Average Score =		8.75

Q, Question; *Y*, Yes; *N*, No; *N/A*, not assessed; Y = 1, N = 0, N/A = 0.

Table 3. Isokinetic Quadriceps Strength Testing With and Without Tourniquet Use

Study	Time Point(s)/Isokinetic Testing Type		Tourniquet Group	Nontourniquet Group	*P* Value	Dynometer Isokinetic Acceleration
*Arciero et al.[6]	6 months postoperatively	Concentric loading	40.1% (range: 22.7%−85.9%)	35.28% (range: 13.6%−61.23%)	.38	60°/s
		Eccentric loading	47% (range: 25%−96%)	47% (range: 19.5%−86%)	.98	
	1 year postoperatively	Concentric loading	53% (range: 28.7%−107%)	63.8% (range: 36.7%−85.4%)	.91	
		Eccentric loading	80.2% (range: 30%−132.6%)	87% (range: 50.9%−113.9)	.45	
†Nicholas et al.[9]	6 months postoperatively		32% (range: 26%−45%)	35% (range: 21%−43%)	.59	60°/s
Nakayama and Yoshiya[4]	3 months postoperatively		NR	NR	.74	60°/s
Reda et al.[3]	6 months postoperatively		NR	NR	NS	180°/s

NR, exact values not reported; NS, nonsignificant *P* value.
*Mean torque values reported as percentage of body weight.
†Mean torque values reported as percent deficit of nonoperative extremity.

Blood Loss

Intraoperative blood loss was reported in 1 included study (Table 4).[2] The double-blinded, randomized controlled trial reported a significantly greater intraoperative blood loss with tourniquet use of 230.2 (SD = 22.3) to 95.3 mL (SD = 25.1; $P < .05$).

Postoperative blood loss was reported in 3 included studies (Table 4).[2-4] In all 3 studies, tourniquet use resulted in a significant increase in postoperative blood loss. The randomized, controlled trial reported increases with tourniquet use from 85.3 (SD = 47.3) to 133.6 mL (SD = 62.4; P =.02), and the prospective, randomized study reported increases from 186.7 (SD = 47.1) to 327.6 mL (SD = 57.4; P =.001).[3,4] The double-blinded, randomized controlled trial reported an increase with tourniquet use from 75.6 (SD = 15.3) to 240.3 milliliters (SD = 44.5; $P < .05$).[2] Of note, total blood loss was measured in one prospective, randomized controlled trial, in which no differences were found with tourniquet use.[4]

Postoperative Opioid Consumption

Postoperative opioid consumption was measured in 3 included studies (Table 4).[2,3,5] An included randomized, controlled trial, and a double-blinded, randomized controlled trial observed no additional analgesic consumption in the first several hours after surgery in the tourniquet group; opioid consumption up to 6 months after surgery was also similar between both groups.[2,5] In contrast, a randomized, controlled trial demonstrated a significant increase with tourniquet use in opioid consumption on postoperative day 1 from 4.3 (SD = 2.9) to 8.8 mg (SD = 3.7; P = .001) of morphine.[3]

Pain

Postoperative pain levels were reported in 5 included studies (Table 4).[2-5,11] Two randomized, controlled trials and 1 double-blinded, randomized controlled trial demonstrated no difference in pain between the 2 groups at terminal time points of 5 hours, 48 hours, and postoperative day 1.[2,4,5] In contrast, 2 randomized controlled trials demonstrated increased pain levels via the VAS postoperatively at 10 hours from 4.8 (SD = 1.2) to 5.7 (SD = 1.3; P =.006), and at 22 hours from 4.6 (SD = 1.1) to 5.7 (SD = 1.0; P = .001).[3,11]

Discussion

The primary finding of this study is that tourniquet use during ACL reconstruction does not appear to have negative long-term effects on quadriceps strength. Tourniquet use does seem to increase short-term quadriceps atrophy and pain in the immediate postoperative period, but such effects do not persist in the long term.

Table 4. Differences in Perioperative and Postoperative Outcomes With and Without Tourniquet Use

	Blood Loss (mL)		Analgesia Consumption (mg of morphine)		Pain[§]			Thigh or Calf Girth (cm)		Operative Time (min)	
Study	T	NT	T	NT	T		NT	T	NT	T	NT
Arciero et al.[6]								NS		128	137[†]
Hooper et al.[5]			9.8 ± 7.1	11.4 ± 10.2[†]	NS					60.8 ± 9.6	65.3 ± 15.5[†]
Nicholas et al.[9]								3 months postoperatively			
								Thigh: 2.5 (1.3,3.7)[‡]	Thigh: 1.1 (0.4,1.8)*		
Nakayama and Yoshiya[4]	Day 1 postoperatively				NS			NS		115 ± 18	122 ± 17[†]
	133.6 ± 62.4	85.3 ± 47.3*									
Reda et al.[3]	24 hours postoperatively		4.3±2.9	8.8± 3.7*	4 hour	8.5 ± 1.1	4.6 ± 0.9*	2 weeks postoperatively		64 ± 8.7	62 ± 9.1[†]
	327.6±57.4	186.7±47.1*			10 hour	5.7 ± 1.3	4.8 ± 1.2*				
					16 hour	4.8 ± 0.9	4.8 ± 1.1				
					22 hours	4.3 ± 0.8	4.2 ± 0.9	Thigh: 33.4 ± 1.9	Thigh: 36.9 ± 2.9*		
								Calf: 30.9 ± 1.8	Calf: 33.1 ± 3*		
Choudhary et al.[11]					4 hour	7.4 ± 1.5	6.1 ± 1.5*	21 days postoperatively		–	–
					10 hour	9.0 ± 1.0	6.0 ± 1.5*				
					16 hour	7.4 ± 1.3	5.1 ± 1.1*	Thigh:	Thigh:		
					22 hour	5.7 ± 1.0	4.6 ± 1.1*	2.5 ± 0.8[‡]	1.41 ± 0.58*		
Zaid et al.[2]	Intraoperative		24 hour:	24 hour:	12 hour	5.1 ± 1.2	4.9 ± 1.3[†]	48 hours postoperatively		58.4 ± 5.7	72.5 ± 5.6*
	95.3 ± 25.1	230.2 ± 22.3*	19.8 (15.7, 25.1)	20.7 (16.8, 25.4)[†]	24 hour	4.5 ± 1.3	4.0 ± 1.0[†]				
	Postoperative		48 hour:	48 hour:	48 hour	3.2 ± 1.0	2.8 ± 1.3[†]	Thigh: 51.8 ± 6.2	Thigh: 53.6 ± 4.6[†]		
	240.3 ± 44.5	75.6 ± 15.3*	21.8 (17.4, 27.6)	21.3 (16,8, 27.0)[†]				Knee: 43.8 ± 4.8	Knee: 44.5 ± 3.0[†]		
								Calf: 38.9 ± 4.8	Calf: 39.3 ± 5.0[†]		

NS, No significance; NT, Nontourniquet; T, Tourniquet.

*$P < .05$.

[†]No statistical difference reported. NS, No significance; T, Tourniquet; NT, Non-tourniquet.

[‡]Presented as difference of means.

[§]Values reported on visual analog scale.

The included studies did not demonstrate any long-term, negative effects on quadriceps strength dependent on tourniquet use. The effects of tourniquet use on quadriceps strength have been demonstrated for other orthopaedic procedures involving the lower extremities. Two studies evaluating total knee arthroplasty (TKA) found that tourniquet use did not cause long-term deficits in quadriceps function.[12,13] Similarly, another study demonstrated that tourniquet use did not alter recovery of quadriceps strength after arthroscopic meniscectomy.[14] Even when evaluating postoperative cellular mitochondrial content and contractile ability via biopsy of the vastus lateralis, tourniquet use has not been correlated with changes in these variables.[15] These findings suggest that tourniquet use is not associated with long-term functional changes at either the microscopic or macroscopic level.

Quadriceps strength has been associated with thigh girth.[16,17] Six included studies that tracked changes in thigh girth showed varying outcomes, which may have resulted from a variety of measurement methods.[2-4,6,9,11] Four of the 6 studies were able to demonstrate that tourniquet use resulted in significantly smaller measurements in thigh girth from 24 hours to 1 month postoperatively.[3,6,9,11] It has been demonstrated that tourniquet use in total knee arthroplasty results in atrophy, EMG changes and reduced quadriceps function up to 6 months after surgery,[18] which is consistent with findings from our study.[3,6]

A relationship in this study between graft type with quadriceps strength was unable to be demonstrated as the 2 included studies that provided values both used patellar autografts.[6,9] Previous studies have demonstrated that the type of autograft used during ACL reconstruction surgery may impact leg strength.[19-21] A meta-analysis demonstrated that quadricep tendon autografts exhibited significantly greater isokinetic extensor and flexor strength 6 months postoperatively compared to other autograft harvest sites.[21] No differences in isokinetic strength was found between quadriceps, patellar, and hamstring autografts after 12 and 24 months; however, this study reported severe bias. In contrast, a randomized, controlled trial demonstrated via limb symmetry greater quadriceps strength for hamstrings autografts and greater hamstring strength for quadriceps autografts.[22] As different graft types have different advantages and disadvantages, graft selection should be based on patient characteristics.

Tourniquet use during lower limb procedures such as TKA and below-knee amputations has been demonstrated to lower intraoperative blood loss.[23,24] Similarly, tourniquet use during isolated ACL reconstruction has also been shown to decrease intraoperative blood loss.[2] Postoperatively, 3 included studies showed that tourniquet use during ACL reconstruction surgery significantly increases postoperative blood loss volume.[2-4] Use of epinephrine and increased use of intraoperative cauterization to maintain visibility during procedures where a tourniquet was not used could potentially contribute to the decrease in postoperative blood loss observed.[3,4] Because overall blood loss during ACL reconstruction is significantly lower than other more invasive procedures, transfusions are uncommon. Thus, the clinical significance of tourniquet use on overall blood loss is questionable.

Five studies measured pain outcomes, and postoperative pain results were mixed. Time points at which pain measurements were collected created increased variation between the studies, making direct comparison of results more difficult. One study sought to understand the factors influencing tourniquet-induced pain. The authors found that the incidence of pain following a procedure using a tourniquet was directly proportional to the length of the surgery and strongly associated with the usage of a local anesthetic.[25] Previous studies have theorized the mechanism of tourniquet-induced postoperative pain, but the exact mechanism is still not completely understood.[25-28] Prior studies have suggested that tourniquet use heightens the normal pain response and creates an indistinct, dull postoperative pain through unopposed action of unmyelinated, slow C nerve fibers after the myelinated A-delta fibers are inhibited by tourniquet compression. These impacts on neurons combined with nerve compression and ischemia cause blockage of low-threshold mechanoreceptors in the spinal cord and an increase in spontaneous activity of high-threshold nociceptive neurons.[25,29] Clinically, pain levels are similar following ACL reconstruction regardless of tourniquet use at 24 hours postoperatively.[2,3] This finding is similar to pain levels reported following tourniquet use for other orthopedic procedures such as TKA.[30]

There may also be a slight reduction in operative time associated with tourniquet use, with multiple studies demonstrating a mild decrease in total operative time.[2,4-6] Only 1 study noted a statistically significant reduction.[2] The reduction in operative time is most likely due to improved visualization and reduction in time required to obtain hemostasis. In prior studies aiming to optimize visibility during arthroscopy, the addition of epinephrine was demonstrated to create acceptable visibility during knee arthroscopy without use of a tourniquet.[31] Additionally, TXA has been proven to offer a number of benefits during orthopedic procedures, including increased visibility and decreased risk of hemarthrosis.[32,33] While tourniquet use may have some benefit in reducing operative time, potentially through increased visibility and faster achievement of hemostasis, it appears pharmacological interventions are also clinically effective in achieving

hemostasis and maintaining visibility when a tourniquet is not used. Further studies are needed to directly compare these 2 interventions.

A previous systematic review and meta-analysis article was performed by Kuo et al.[34] This study demonstrated similar findings regarding long-term quadriceps strength, postoperative pain, leg girth, and blood loss. The current study included a total of 502 patients compared to the previous study that included 226, providing a larger sample size to report on with more updated information. The current study also included more specific results on short-term postoperative quadricep strength, the study's primary outcome, and postoperative pain.

On the basis of the results of this systematic review, clinicians can feel comfortable using a tourniquet as long-term quadriceps strength does not appear compromised. However, if hemostasis can be achieved with pharmacologic intervention, surgeons should consider no tourniquet use to avoid immediate postoperative pain, decreased short-term quadriceps strength, and increased postoperative blood loss.

Limitations

This study is not without limitations. Each study used a different set of quantitative and qualitative measurements to gauge outcomes at varying time points introducing heterogeneity. The variation in inflated tourniquet pressure, measurement tools, and time points by each study makes direct comparisons difficult. Patients receiving concurrent meniscus surgery were also included in the study, which may confound pain and operative time. Furthermore, it is difficult to discern if there were any trainees involved that may have confounded operative time. Different graft types used in the included studies also may have affected reported quadriceps strength.

Conclusions

Tourniquet use during ACL reconstruction does not have negative long-term effects on quadriceps strength. Although tourniquet use was associated with increased quadriceps atrophy and pain in the immediate postoperative period, these effects did not persist.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: E.W.B. reports board membership in EBSCO and consulting fees from Link Orthopaedics and Orthopaedic Design. A.J.C. reports consulting fees from Arthrex. A.M.M. reports consulting fees from Arthrex, Fidia Pharma USA, Miach Orthopaedics, and CONMED Linvatec; board membership in *Arthroscopy*; and stocks in Reparel. K.E.W. reports nonfinancial support from AlterG and Performance Health; consulting fees from Bauerfeind Brace, ERMI Devices Blazepod, Churchill LivingstoneCV MosbySlack Publishing, and Lite Cure Laser. All other authors (C.V.H., S.M.I., A.E.C., J.R.J., M.D.H., C.A.R., T.B.E.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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