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Soft-tissue damage during total knee arthroplasty
Focus on tourniquet-induced metabolic and ionic muscle impairment

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ABSTRACT

Purpose: Advantages of tourniquet use in TKA include benefits for surgeons and patients, varying from a bloodless operation site to a reduced intervention time. The time under ischemia and the reperfusion period are crucial phases for affected soft-tissue, most commonly the extensor mechanism.
Case reports: documented its impact on soft-tissue, ranging from necrotic muscle damage to systemic inflammation. Recently, research regarding tourniquet application patterns discuss clinical outcome parameters in the context of soft-tissue damage, excluding the underlying pathophysiological mechanisms.
Methods: This review summarizes the molecular aspects of soft-tissue damage occurring during tourniquet application in TKA with special focus on ischemia/reperfusion injury. Recent meta-analyses and original trials were reviewed for data on muscle damage and are presented.
Conclusion: Although underlying pathomechanisms are well known and presented, clinical orthopedic research has so far not addressed this issue. In context of physical training, positive effects regarding postoperative recovery might be possible if more attention is paid to prepare involved muscle preoperatively to TKA (prehabilitation).

1. Introduction

Knee arthroplasty is a well-established surgical care for patients with knee arthritis and has been extensively advanced since the first total knee arthroplasties (TKA) in the 1960ies. Yearly implantation rates increased over the last years in Germany (>134 implantations per 100.000 inhabitants),[1] mostly due to good restoration and enhancements in patient's quality of life. In the United States 650.000 primary TKAs were performed in 2008, summarizing to costs of $9 billion in total. The expected increase in the number of annual TKA surgeries is estimated to be around 3.48 million by 2030.[2] Still, despite substantial advances in surgical technique and implant technology, only 72–86% of patients are satisfied with their primary TKA.[3] Reasons for ongoing dissatisfactory results seem to be not exclusively dependent on the surgical treatment or implant associated (bone-overhang,[4] malrotation of a component,[5] malalignment),[6] but also on patient age, patient expectation[3] and functional improvement.[7]

In an elderly, multi-morbid but active patient population, the rapid restoration of unimpaired function, range of motion and muscle strength, are major concerns regarding possible complications, patient satisfaction and duration of recovery. Consequently, "rapid recovery" programs have been established to limit the duration of bed rest and thus leading to a quicker mobilization and discharge. Described programs focus on perioperative pain management through catheters and intraoperative injections, early physiotherapy and mobilization to ensure discharge only seven days after surgery.[8] Independent from the surgical approach and the type of implant, most TKA includes the use of a tourniquet to provide a relatively bloodless operative field.[9] However, the use of a pneumatic tourniquet during TKA surgery is associated with an increased risk for soft-tissue damage, postoperative complications as well as intraoperative challenges, e.g. by impaired patella mobility/tracking.[10] Based on the additional possibility of thrombosis or missed arterial bleeding,[11] surgeons are reevaluating the necessity and benefits of tourniquet application.

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Hence it is necessary to assess, identify and optimize the crucial surgical procedure of TKA under tourniquet use. Exogenous (surgical approach, impairment of knee extensor mechanism, implant and implantation accuracy) as well as endogenous (hypoxic tissue damage, ischemia/reperfusion injury, IR-Injury) factors are responsible for early postoperative results and

Table 1
Selected studies reporting outcome parameters of tourniquet related muscle damage after knee arthroplasty. TQ = Tourniquet.VAS = visual analog scale for pain assessment w/o = without.

Outcome parameter	Study		year	Group size	tourniquet application	Findings	pro TQ	+/−	contra TQ
duration of surgery	Zhang et al. [25]	Meta-analysis	2014	9 trials, 442 patients (224 vs. 218)	tourniquet/no tourniquet	4.57 min less operating time with tourniquet use	x		
	Tai et al. [24]	Meta-analysis	2011	6 trials, 2 studies 432 patients (282 vs.131)	late release (after wound closure)/early release (after cementation)	faster operating time with late release: deflation after wound closure	x		
	Yi et al. [26]	Meta-analysis	2014	8 studies, 572 patients, (239 vs. 233)	tourniquet/no tourniquet	5.01 min less operating time with tourniquet use	x		
postoperative pain	Abdel-Salam et al. [30]	original data	1995	80 patients (40 vs. 40)	tourniquet/no tourniquet	VAS less 4 h postop and less analgesic injections (5/6 vs. 3/4)			x
	Vandenbusche et al. [35]	original data	2002	80 patients (40 vs. 40)	tourniquet/no tourniquet	VAS sign. lower 6 h postop			x
	Huang et al. [31]	original data	2014	90 patients (30 vs. 30 vs. 30)	tourniquet for whole surgery/ after hardening of cement/only during cementation	no difference between three groups		x	
	Ledin et al. [33]	original data	2012	50 patients (25 vs. 25)	tourniquet/no tourniquet	VAS less in four days post surgery (VAS 4.9 vs.4.1)			x
	Kumar et al. [39]	original data	2015	30 patients bilateral (30 vs. 30)	tourniquet/no tourniquet	VAS sign. less on day one, two, three postop			x
	Ejaz et al. [40]	original data	2014	64 patients (33 vs. 31)	tourniquet/no tourniquet	no difference on day of operation and 8 weeks postop		x	
						lower VAS at day of discharge w/o tourniquet use			x
	Chen et al. [41]	original data	2014	64 patients (32 vs. 32)	tourniquet for whole surgery/ toutrniquet from osteotomy to wound closure	no sign. difference at postop day seven		x	
						better w/o tourniquet at day one and three postop			x
	Unver et al. [33]	original data	2013	38 patients (17 vs. 21)	tourniquet with minimal pressure/tourniquet with 300 mmHg	patients with low pressure TQ with less pain postop day eight			x
						no difference between two groups postop day one and two		x	
	Pfitzner et al. [27]	original data	2016	90 patients (45 vs. 45)	tourniquet/no tourniquet	sign. less pain postop day four at rest and mobilisation			x
	Tai et al. [43]	original data	2012	72 patients (36 vs. 36)	tourniquet/no tourniquet	sign. less pain on postop day four			x
CK (Creatinkinase)	Huang et al. [31]	original data	2014	90 patients (30 vs. 30 vs. 30)	tourniquet for whole surgery/ after hardening of cement/only during cementation	less CK in group w/o tourniquet			x
	Tai et al. [43]	original data	2012	72 patients (36 vs. 36)	tourniquet/no tourniquet	sign. Less CK on postop day one and two			x
CRP (C-reactive proteine)	Huang et al. [31]	original data	2014	90 patients (30 vs. 30 vs. 30)	tourniquet for whole surgery/ after hardening of cement/only during cementation	sign.less CRP in group with tourniquet during cementation only on postop day two and three			x
	Tai et al. [43]	original data	2012	72 patients (36 vs. 36)	tourniquet/no tourniquet	sign. Less CRP on postop day two and four			x
IL-6 (Interleukin 6)	Huang et al. [31]	original data	2014	90 patients (30 vs. 30 vs. 30)	tourniquet for whole surgery/ after hardening of cement/only during cementation	least IL-6 activity (23.0 +/− 23.4 pg/ml) in group with tourniquet during cementation only on postop day three			x
duration of hospitalization	Vandenbusche et al. [35]	original data	2002	80 patients (40 vs. 40)	tourniquet/no tourniquet	no difference (11.2 days vs. 11.8 days)		x	
	Abdel-Salam et al. [30]	original data	1995	80 patients (40 vs. 40)	tourniquet/no tourniquet	shorter w/o toruniquet (12 days (9 to 20) vs. 12 days (8 to 19)			x
	Huang 2015 [36]	Meta-analysis	2015	2 studies, 160 patients (80 vs. 80)	late release (after wound closure)/early release (before wound closure)	no difference found regarding hospitalization		x	
strength	Dennis et al. [44]	original data	2016	28 patients bilateral (28 vs. 10/18)	tourniquet after cementation/ no tourniquet or during cementation only	patients better after 3 weeks and 3 months			x
	Abdel-Salam et al. [30]	original data	1995	80 patients (40 vs. 40)	tourniquet/no tourniquet	faster in straight leg raise w/o tourniquet (4.6 days vs 2.4 days)			x
	Unver et al. [33]	original data	2013	38 patients (17 vs. 21)	tourniquet with minimal pressure/tourniquet with 300 mmHg	no difference in day of straigt leg raise		x	