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ORIGINAL PAPER

Varus mechanism is associated with high incidence of popliteal artery lesions in multiligament knee injuries

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Abstract

Purpose This study aims to identify multiple ligament knee injury patterns that possess a high-risk of vascular lesion.

Methods We retrospectively compared torn ligament patterns and the presence of vascular lesions confirmed by magnetic resonance imaging and computed tomography angiography from 122 consecutive patients with diagnoses of multiple ligament knee injury made at the emergency department between January 2012 and December 2017. Patients were not eligible if they had an ipsilateral lower extremity lesion (dislocations or fractures at another level), initial evaluation at another hospital, or follow-up for less than 12 months. The primary outcomes were the comparison between the imaging findings of torn structures patterns and the presence of a vascular lesion.

Results We identified 48 eligible patients (50 knees) with multiligamentary knee lesions, of whom eight had popliteal artery damage, yielding an incidence of 16%. Our clinical examination detected six of these patients that were classified, according to the Schenck system, as KD-IIIL (6 knees) and KD-IIIM (2 knees). The odds of having a popliteal artery injury is 4.69 to 1 with a KD-IIIL injury that with any other type of injury on that classification (95% CI 0.960–22.98).

Conclusions This data suggests that varus forces causing enough energy to produce a KD-IIIL lesion possess a higher popliteal artery injury risk, making recommendable a thorough examination of the vascular integrity when diagnosing a KD-IIIL lesion.

Keywords Knee dislocation · Traumatic knee dislocations · Multiligament knee injury · Vascular injury

Introduction

Approximately 50% of multiple ligament knee injuries diagnoses are at risk of being missed, having up to 65% of vascular lesion incidence and an associated amputation rate of 10% [1–13]. According to Natsuhara et al., 13% of knee dislocations with vascular lesion will require arterial revascularization [1].

Despite the high risk of devastating consequences in the setting of multiple ligament knee injuries, there is still no

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Table 1 Anatomical classification of multiple ligament knee injuries

Type		Injured structures	Intact structures
I	IA	ACL	PCL LCL MCL
	IP	PCL	ACL LCL MCL
II		ACL + PCL	LCL MCL
III	IIIL	ACL + PCL + LCL	MCL
	IIIM	ACL + PCL + MCL	LCL
IV		ACL + PCL + LCL + MCL	
V		ACL + PCL + LCL + MCL + Fx	

ACL, anterior cruciate ligament; *PCL*, posterior cruciate ligament; *LCL*, lateral collateral ligament; *MCL*, medial collateral ligament; *Fx*, periarticular fracture

consensus for the screening of vascular lesions. Some scholars suggest that the absence of asymmetry in distal pulses is enough to rule it out, but other authors consider this approach as insufficient and prefer to complement their screening protocol with the use of the ankle-brachial index [14–17]. Current guidelines do not support the use of computed tomography angiography (CTA) as a screening test in high-risk trauma and only recommend it for patients with abnormal clinical findings [2–5, 8–10].

Because early diagnosis of a vascular lesion is critical for proper management, the identification of the injury mechanism risk is essential to optimize resources and reduce the underdiagnoses rate. The purpose of this study is to describe the multiple ligament knee injuries with vascular lesions to identify high-risk patterns.

Materials and methods

After approval from the ethical and institutional review board, we retrospectively analyzed the records of all patients between January 2012 and December 2017 with a diagnosis of multiple ligament knee injury made at the emergency department of a single university level I trauma center. Patients were identified using the institution code for these injuries (Lesión Multiligamentaria de rodilla) in the hospital-wide database. Eligible subjects were at least 18 years of age, had a complete rupture of two or more knee ligaments confirmed by a magnetic resonance imaging (MRI) scan, and had a CTA for the assessment of vascular lesions at the initial presentation. Patients were not eligible if they had ipsilateral lower extremity lesion (dislocations or fractures at another level), initial evaluation at another hospital, or follow-up for less than 12 months.

Due to a pilot protocol at our institution, all patients with suspicion of multiple ligament knee injury undergo an MRI scan (1.5-T, Magnetom AVANTO eco, Siemens Medical Solutions, USA) and a CTA. An independent musculoskeletal radiologist used the presence of direct signs of acute ligament tears to define a complete ligament rupture and to describe them according to the anatomical classification system of Robert Schenck (Table 1, Figs. 1 and 2) [13, 18].

In Table 2, we recorded age, gender, clinical findings of distal limb ischemia, vascular surgery if done, and amputation rate. The distal limb ischemia clinical findings were classified as hard signs, no signs, or soft signs [19, 20].

Odds ratio, absolute, attributable, and relative risk with 95% confidence intervals were used to establish

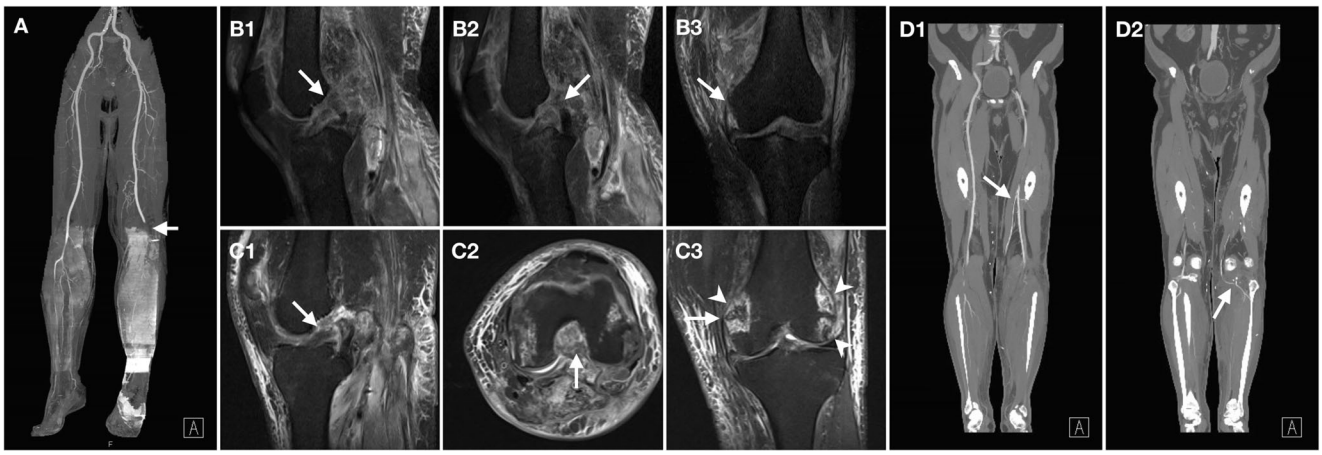

Fig. 1 Radiological findings of a KD-IIIM with a vascular lesion. Due to a pilot protocol at our institution, all patients with suspicion of multiple ligament knee injury underwent an MRI scan and CTA. (A) CTA coronal 3D reconstruction showing a complete stop of circulation (white arrow) of the popliteal artery. (B) and (C) are T1-wieighted MRI's; the images of (C) are a control study at three-months. (B) Sagittal view progressing from lateral to medial showing a complete ACL tear (B1 white arrow) and a complete PCL tear at its proximal insertion (B2 white arrow). (B3) Coronal view showing a complete MCL at its proximal insertion (white arrow). (C1) Sagittal view showing a complete ACL tear (white arrow). (C2) Axial view showing a complete PCL tear at its proximal insertion (white arrows). (C3) Coronal view showing healing of the MCL (white arrow) and multiple bone infarcts (white arrowheads). (D) CTA anterior coronal view progressing from anterior to posterior showing a collateral blood supply from the femoral artery to the popliteal artery (D1 and D2 white arrows). MRI, magnetic resonance image; CTA, computed tomography angiography; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament; MCL, medial collateral ligament

Fig. 2 Radiological findings of a KD-IIIL with a vascular lesion. Due to a pilot protocol at our institution, all patients with suspicion of multiple ligament knee injury underwent an MRI scan and a CTA. (A) and (B) are a CTA, showing a complete stop of the left popliteal artery (white arrows) from an axial view (A) and a coronal view (B) progressing from anterior to posterior. (C) to (E) are T1-wieighted MRI's. (C) Sagittal view progressing from lateral to medial showing a complete ACL tear (white arrow). (D) Axial view progressing from inferior to superior showing a partial PCL tear (white arrow). (E) Coronal view progressing from anterior to posterior showing a complete LCL tear (white arrow). (F) CTA in coronal view showing a successful popliteal bypass surgery (white arrow). MRI, magnetic resonance image; CTA, computed tomography angiography; ACL, anterior cruciate ligament; PCL, Posterior cruciate ligament; LCL, lateral collateral ligament

an association between the imaging findings of torn structures and vascular lesions. We performed all the statistical analyses with the Stata Statistical Software (StataCorp 2011, Release 12, College Station, TX: StataCorp LP).

Results

Of the 122 patients with multiple ligament knee injuries treated in the emergency during the 60 months of the inclusion period, 74 patients were excluded leaving a

Table 2 Clinical findings, demographics and outcomes of the multiple ligament knee injuries with vascular lesion

Age	Gender	Lesion pattern	Clinical findings	Vascular surgery	Amputation
67	M	KD-IIIM	Hard Signs	Yes	No
43	M	KD-IIIL	Hard Signs	Yes	Yes
51	M	KD-IIIL	No Signs	No	No
45	M	KD-IIIM	Hard Signs	Yes	No
57	M	KD-IIIL	Soft Signs	Yes	No
28	M	KD-IIIL	Soft Signs	Yes	Yes
35	M	KD-IIIL	No Signs	No	No
25	M	KD-IIIL	Hard Signs	Yes	No

KD-IIIM, injury to the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament; *KD-IIIL*, injury to the anterior cruciate ligament, posterior cruciate ligament, and lateral collateral ligament; *Hard signs*, active arterial bleeding, absent distal pulse, limb ischemia, expanding or pulsatile hematoma, bruit or thrill over injured area, hemorrhagic shock without other injuries; *Soft signs*, indeterminate clinical findings that do not fit either hard or no signs category; *No signs*, asymptomatic with Ankle-Brachial Index higher than 0.9

Table 3 Reasons for exclusion of patients from the analysis

Exclusion reasons	MLKI w/o VL	MLKI w/ VL
Floating knee	1 (2)	1 (6)
Tibial plateau fracture	30 (52)	7 (44)
Femur fracture	14 (24)	6 (38)
Peroneal nerve injury	2 (3)	
Sprain	3 (5)	
Referral		2 (12)
Missing CTA	8 (14)	

MLKI w/ VL, multiple ligament knee injury with vascular lesion; *MLKI w/o VL*, multiple ligament knee injury without vascular lesion; *CTA*, computed tomography angiography. Data is shown as *n* (%)

predominantly young male (mean age 44 years) population with 50 knees eligible for the analysis (Table 3).

We diagnosed eight popliteal artery lesions by CTA, of which the physical evaluation missed 2 (25%). All the vascular lesions were a result of a KD-III pattern, being 75% of them classified as KD-IIIL (Fig. 1). The average time elapsed since the trauma and the realization of the CTA was of 15 hours (range 1.2–70), and within 24 hours after trauma (mean time 11 h), all patients with a vascular lesion who needed surgery (6 patients) underwent a bypass revascularization procedure. In four patients, the procedure was considered successful, and in two patients, amputation of the limb was required (Fig. 3).

Figure 4 shows the distribution of the 50 multiple ligament knee injury patterns. While the 35 KD-III were divided into 16 KD-IIIL and 19 KD-IIIM, four of the 9 KD-I were because of a torn posterolateral corner (PLC) and two because of an anterior cruciate ligament (ACL). In the KD-II type of lesion, the ACL-PLC was the most frequent combination. When individualizing the injured ligaments, the most frequent was the ACL, occurring in 82% of the injuries, followed by the posterior cruciate

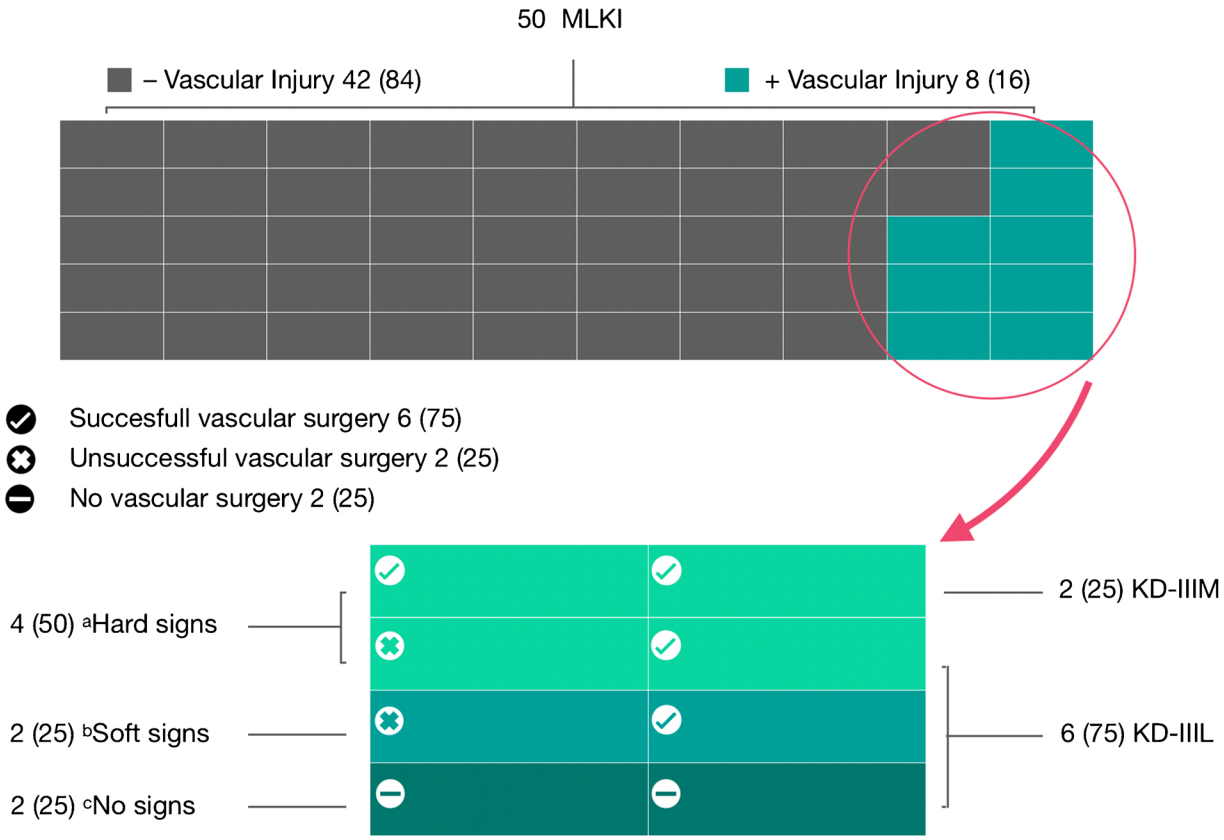

Fig. 3 Clinical findings, multiple ligament knee injury patterns, and outcomes of the vascular lesions. The graph at the top represents de 50 multiligament knee injuries divided into 42 (gray rectangles) without vascular lesion and eight (green rectangles) with a vascular lesion. We further subdivided the cases with vascular lesion into injury pattern (2 KD-IIIM and 6 KD-IIIL), clinical signs (4 hard signs, 2 soft signs, and 2 no signs), and outcome after the bypass revascularization surgery (6 successful, 2 unsuccessful). An unsuccessful vascular surgery denotes an amputation of the limb due to clinical deterioration. MLKI, multiple ligament knee injury; [a]Hard signs, active arterial bleeding, absent distal pulse, limb ischemia, expanding or pulsatile haematoma, bruit or thrill over injured area, haemorrhagic shock without other injuries; [b]Soft signs, indeterminate clinical findings that do not fit either hard or no signs category; [b]No signs, asymptomatic with capillary refill in less than 2 s; KD-IIIM, injury to the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament; KD-IIIL, injury to the anterior cruciate ligament, posterior cruciate ligament, and lateral collateral ligament. We present data as numbers and (percentages)

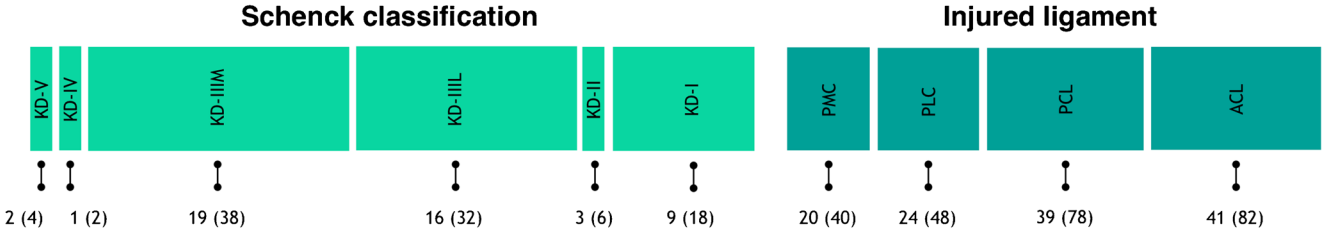

Fig. 4 Distribution of the multiple ligament knee injury patterns. KD-I, injury to a single cruciate ligament; KD-II, injury to both cruciate ligaments; KD-IIIM, injury to the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament; KD-IIIL, injury to the anterior cruciate ligament, posterior cruciate ligament, and lateral collateral ligament; KD-IV, injury to the anterior cruciate ligament, posterior cruciate ligament, lateral and medial collateral ligament; KD-V, multiple ligament knee injury with periarticular fracture. Data is shown as *n* (%)

ligament (PCL) in 78%, the PLC in 48%, and the posteromedial corner (PMC) in 40%.

We found that 31% of patients with KD-IIIL can expect to have vascular lesions, but only 22% are attributable to the pattern. Moreover, the KD-IIIL has a 254% increased risk of a vascular lesion when compared with any other types of multiple ligament knee injury (95% CI 0.963–13.024), and the odds of experiencing a vascular lesion with a KD-IIIL relative to any other multiligamentary lesion is 4.69 to 1 (95% CI 0.960–22.98).

Discussion

Our physical exam had a missing rate of 25 per 100 multiple ligament knee injuries over 5 years, with the patterns KD-IIIL being the most vulnerable for a vascular lesion with a 2.4-fold increased risk and the KD-IIIM being the most frequent with an incidence of 38%.

We found the lesions of the central pivot and the posterior corners of the knee as the most common types of multiligamentary lesions (38% KD-IIIM, 32% KD-IIIL), which is consistent with the studies of Moatshe and Becker, who reported an incidence of 52% of KD-IIIM and 28% of KD-IIIL and 43% of KD-IIIM and 17% of KD-IIIL, respectively [21, 22]. Moreover, our 16% incidence of vascular lesions and odds of almost 5 to 1 between KD-IIIL in comparison with any other multiligamentary pattern agree with the previous studies which reported nine times increased risk of vascular lesions with a KD-IIIL and incidence between 7 and 32% [23].

The most important finding of our study is the 2.4-fold increased risk of vascular lesions with a KD-IIIL. We believe a possible explanation is the relatively fixed popliteal artery at the adductor hiatus of the femur and the tendinous arch of the soleus muscle of the tibia, making shearing forces more prone to produce vascular lesions with this injury pattern. According to Medina, the prevalence of vascular injury in cases of KD-IIIL is 32%, with posterior knee dislocations producing intimal tearing or transection of the vessel and anterior knee dislocations stretching injuries [24].

Limitations of this investigation include the absence of the ankle-brachial index as part of the physical examination. Recent literature suggests that an ankle-brachial index above 0.9 with symmetrical distal pulses excludes a vascular lesion with a sensitivity and specificity close to 100%, so our results may overestimate the physical examination missing rate [25].

Because multiple ligament knee injuries are rare and usually due to high-energy mechanisms with life-threatening conditions, orthopedic surgeons can frequently underestimate associated vascular injuries. Therefore, an understanding of the lesions patterns allows early recognition and treatment of these injuries. Based on our findings, a lesion involving the central pivot and the PLC or PMC should raise high suspicion of a popliteal artery injury. For these cases, we suggest performing a CTA as a complementary test.

Compliance with ethical standards

Conflict of interest Gonzalo Espinoza is a paid consultant for Smith and Nephew. For the remaining authors, none was declared.

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