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# Simultaneous bilateral multiligamentous knee injuries are associated with more severe multisystem trauma compared to unilateral injuries

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**Abstract**
*Purpose* To compare the knee ligamentous injury patterns and associated multisystem trauma in patients who have sustained simultaneous bilateral knee multiligamentous injuries (MLI) to patients with unilateral MLIs.
*Methods* Patients with simultaneous bilateral and unilateral knee MLIs after motor vehicle accidents were identified from 2007 to 2014 at a single institution. Chart and radiographic reviews were performed to identify patient demographics, extremity fractures and associated head, thoracic, abdominal and spine injuries. The MLIs were characterized by ligamentous injury pattern and associated neurovascular deficits. Injury Severity Score (ISS) and New ISS (NISS) were calculated.
*Results* Seven bilateral MLIs and 32 unilateral MLIs were identified. Between the cohorts, there were no significant differences in ligamentous injury pattern or associated neurovascular injuries. For the bilateral MLI cohorts, 71.4 % of patients sustained chest trauma, 57.1 % abdominal trauma, 57.1 % at least a single-level spine injury and 28.6 % head trauma. The ISS was 33.4 ± 23.4 with patients spending an average of 12.4 days in the intensive care unit. Other than the number of days in the ICU, these values were all significantly higher than those of the unilateral knee MLI cohort. Additionally, there was a significantly higher post-operative complication rate in the bilateral MLI cohort (71.4 vs. 6.3 %, $P < 0.0001$).
*Conclusion* Compared to unilateral MLIs with similar mechanisms, patients with traumatic simultaneous bilateral knee multiligamentous knee injuries are at high risk of concomitant head, chest and abdominal injuries. Although the ligament injury profile is similar, the post-operative complication rate is higher for simultaneous bilateral injuries.
*Level of evidence* Case control study, Level III.

**Keywords** Multiligamentous · Knee · Dislocation · Reconstruction · Trauma

## Introduction

Multiligament injuries (MLI) of the knee are infrequent, but potentially devastating injuries [5, 10, 11, 14, 17, 22, 23]. Such injuries can occur through a variety of mechanisms, including high velocity such as motor vehicle collisions or falls from height, low velocity including sporting events or ultra-low velocity in morbidly obese patients during daily activities [1, 25, 27, 33–35]. There are high rates of associated periarticular injuries, including popliteal artery injury, peroneal nerve injury and tibial plateau fractures [4, 8, 12, 15, 16, 18–21, 23, 24, 26, 28]. The acute and definitive management of knee MLI varies, is the subject of debate and depends on the neurovascular status of the limb, the specific ligamentous injury pattern, patient factors including body mass index and surgeon familiarity with managing such injuries [22, 23, 30, 31, 35].

There is scarce literature reporting simultaneous bilateral knee dislocations resulting in MLI [6, 13, 29]. Simultaneous bilateral knee dislocations almost certainly require a high-energy mechanism of injury to occur. As previous

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studies are limited to single-patient case reports or very small series, no study has characterized the extent of associated injuries in patients with simultaneous bilateral knee dislocations, nor have any studies provided data regarding the frequency of associated limb neurovascular injury or prognosis for the limb after ligament reconstruction. A better understanding of the nature of non-orthopaedics injuries in patients with bilateral knee MLI will allow trauma and orthopaedic providers to better manage these patients in the acute setting.

The goal of the present study is to compare the multisystem trauma profile of patients who sustain simultaneous bilateral knee dislocations resulting in MLI to that of unilateral knee dislocations with a similar mechanism of injury. Additionally, the ligament injury patterns and associated neurovascular injures will be characterized. Our hypothesis is that simultaneous bilateral knee dislocations resulting in MLIs will experience more severe systemic injuries with a high frequency of associated non-orthopaedic injuries.

## Materials and methods

A retrospective chart review was performed on 238 patients who underwent a multiligamentous knee reconstruction from 2007 to 2014 by one sports medicine specialist at a single institution. Multiligamentous knee injuries were defined by having complete disruption of two or more of the following ligaments or ligament complexes as diagnosed by either MRI or stress radiography: anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), posterolateral corner (PLC) or medial collateral ligament (MCL). The inclusion criterion was patients who sustained either unilateral or simultaneous bilateral multiligamentous knee injuries after a motor vehicle accident (MVA). Exclusion criteria included any mechanism not involving a motor vehicle accident or patients who did not have all of their pre-operative care at the authors' institution. A total of 187 unilateral MLIs were not a result of a MVA, and 12 unilateral MLIs secondary to a MVA were not treated initially at this institution. No bilateral MLIs were excluded. The final study population included seven bilateral MLI patients and 32 unilateral MLIs.

All magnetic resonance imaging (MRI) studies were interpreted by one of the four fellowship-trained musculoskeletal radiologists as well as the attending surgeon. MRIs were assessed for damage to the knee ligamentous structures (ACL, PCL, PLC, MCL), meniscal tears and subchondral fractures. All additional radiographs and computed tomography (CT) imaging with and without arterial contrast were examined for additional fractures and head, thoracic and abdominal injuries. No imaging diagnoses were changed during the time of this chart review. Head injuries were defined as a subdural haematoma, epidural haematoma, subarachnoid haemorrhage or diffuse axonal injury. Thoracic injuries were defined as a rib fracture, pneumothorax or hemothorax. Abdominal injuries were defined as a splenic laceration, liver laceration, kidney laceration, adrenal haematoma or mesenteric haematoma.

At our institution, reconstructive surgery is recommended to every medically stable patient due to prior studies demonstrating improved outcomes compared to non-operative treatment. Surgery is performed acutely (within 2–3 weeks) when possible to allow for individual structure identification prior to excessive scar tissue formation.

A chart review was performed to garner additional information about patient demographics, general surgery and neurosurgical procedures, orthopaedic procedures (including details of knee reconstruction) and post-operative complications. Complications were defined as deep or superficial infections, deep vein thrombosis, pulmonary embolism and heterotopic ossification. Data from the chart review were utilized to calculate the Injury Severity Score (ISS) and the New Injury Severity Score (NISS) for each patient (Supplemental Table 1). The reason why the NISS was included is that, unlike the ISS, it allows for multiple extremity injuries to be included in the total final score. Based on this score, patients' injuries were stratified into mild (<9), moderate (9–15), severe (16–25) and profound (>25).

Institutional Review Board (IRB) approval was obtained from the University of Virginia IRB office under study number 16355.

### Statistical analysis

SPSS for Windows (version 22; SPSS Inc., Chicago, IL, USA) was used for statistical analysis. An independent *t* test was used for comparisons of continuous variables, and Chi-square test was used for the categorical variables. The significance level was set at $P < 0.05$. For non-significant *P* values, "n.s." will be denoted.

## Results

The bilateral MLI cohort included six males (85.7 %), with an average age of 37.6 ± 10.9 years and an average body mass index (BMI) of 36.5 kg/m$^2$. The unilateral MLI cohort consisted of 26 male patients (81.2 %), with an average age of 32.6 ± 10.4 years and an average body mass index (BMI) of 29.8 kg/m$^2$. The duration of follow-up between the bilateral and unilateral cohorts was not significantly different (16.1 ± 21.4 months v. 24.4 ± 29.1 months).

Between the unilateral and bilateral MLI cohorts, there were no significant differences in the number of

**Table 1** Comparison of the injured knee soft tissue structures between the bilateral and unilateral multiligamentous injury (MLI) cohorts

| | Bilateral MLI | | | Unilateral MLI | *P* value |
|---|---|---|---|---|---|
| | Right knee | Left knee | Incidence of injury (%) | Incidence of injury (%) | |
| ACL | 6 (85.7) | 6 (85.7) | 85.7 | 68.8 | n.s. |
| PCL | 6 (85.7) | 7 (100) | 92.8 | 78.1 | n.s. |
| PLC | 6 (85.7) | 5 (71.4) | 78.6 | 87.5 | n.s. |
| MCL | 3 (42.8) | 3 (42.8) | 42.8 | 28.1 | n.s. |
| MMT | 2 (28.6) | 4 (57.1) | 42.8 | 28.1 | n.s. |
| LMT | 3 (42.8) | 6 (85.7) | 64.3 | 37.5 | n.s. |

*ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament, *PLC* posterolateral corner, *MCL* medial collateral ligament, *MMT* medial meniscus tear, *LMT* lateral meniscus tear, *n.s.* non-significant

**Table 2** Comparison of the knee dislocation (KD) types between the bilateral and unilateral multiligamentous injury (MLI) cohorts

| | Bilateral MLI | Unilateral MLI | *P* value |
|---|---|---|---|
| KD-II | 4 (28.6) | 18 (56.2) | n.s. |
| KD-IIIL | 5 (35.7) | 8 (25.0) | n.s. |
| KD-IIIM | 2 (14.3) | 1 (3.1) | n.s. |
| KD-IV | 3 (21.4) | 6 (18.8) | n.s. |

*KD-II* anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) disruptions, *KD-IIIL* ACL, PCL and posterolateral corner (PLC) disruptions, *KD-IIIM* ACL, PCL and posteromedial corner (PMC) disruptions, *KD-IV* ACL, PCL, PLC and PMC disruptions, *n.s.* non-significant

individual ligament disruptions or combination of disruptions when classified using the Knee Dislocation (KD) system (Tables 1, 2). Three (21.4 %) of the bilateral MLI knees and zero of the unilateral MLI knees were provisionally placed in an external fixator. The remainder were stabilized with either a knee immobilizer or long-leg splint. Only one bilateral MLI patient sustained a popliteal artery transection, and the same patient also had the only peroneal nerve palsy. This limb subsequently underwent an above-knee amputation, and thus the risk of loss of limb in this cohort was 7 % (1/14). There were no amputations in the unilateral MLI cohort, although there were one popliteal artery intimal injury (3.1 %) and seven peroneal nerve palsies (21.9 %). These numbers were not significantly different from the bilateral MLI cohort. The average interval between the injury and reconstruction was 33.7 days; however, this includes two knees, which were reconstructed 174 days later due to extenuating circumstances. When these knees are excluded, the average interval was 10.3 ± 4.5 days. When five patients from the unilateral cohort were excluded from the calculation due to reconstruction for chronic instability, the average interval was 20.6 ± 23.5 days for the unilateral knees, and these two numbers were not significantly different ($P$ = n.s.). The characterization of the knee reconstructions is detailed in Table 3.

In the bilateral MLI cohort, every patient except for two (5/7, 71.4 %) was admitted to the trauma intensive care

**Table 3** Comparison of the reconstructed knee stabilizing soft tissue structures between the bilateral and unilateral multiligamentous injury (MLI) cohorts

| | Bilateral MLI | | | Unilateral MLI | *P* value |
|---|---|---|---|---|---|
| | Right knee | Left knee | Incidence of reconstruction (%) | Incidence of reconstruction (%) | |
| ACL | 5 (71.4) | 3 (42.8) | 57.1 | 68.8 | n.s. |
| PCL | 3 (42.8) | 5 (71.4) | 57.1 | 83.3 | n.s. |
| PLC | 5 (71.4) | 5 (71.4) | 71.4 | 87.5 | n.s. |
| MCL | 1 (14.2) | 2 (28.6) | 21.4 | 25.0 | n.s. |
| PMM | 2 (28.6) | 0 (0) | 14.2 | 15.6 | n.s. |
| MMR | 1 (14.2) | 1 (14.2) | 14.2 | 12.1 | n.s. |
| PLM | 1 (14.2) | 0 (0) | 7.1 | 15.6 | n.s. |
| LMR | 0 (0) | 0 (0) | 0.0 | 21.8 | n.s. |

*ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament, *PLC* posterolateral corner, *MCL* medial collateral ligament, *PMM* partial medial meniscectomy, *MMR* medial meniscus repair, *PMM* partial medial meniscectomy, *MMR* medial meniscus repair, *PLM* partial lateral meniscectomy, *LMR* lateral meniscus repair, *n.s.* non-significant

unit (ICU) compared to only 37.5 % (12/32) of the unilateral MLI cohort. Overall, NISS and ISS were significantly higher for the bilateral MLI cohort compared to the unilateral MLI cohort. Additionally, patients with bilateral MLIs were significantly more likely to have concomitant chest, abdominal and spine injuries (Table 4).

The complication rate for the bilateral MLI cohort was significantly higher than that seen in the unilateral cohort. Five of the seven bilateral MLI patients (74.4 %) experienced at least one complication (2 deep vein thromboses (DVTs), 2 deep infections and 1 heterotopic ossification), which was significantly higher ($P < 0.0001$) than the 6.3 % (3/32) rate seen in the unilateral MLI cohort (2 deep infections and 1 DVT). However, the reoperation rate was similar between the cohorts (42.8 % (6/14) and 40.6 % (13/32), respectively) (Table 5).

**Table 4** Comparison of the various multisystem injuries between the bilateral and unilateral multiligamentous injury (MLI) cohorts

| | Unilateral MLI | Bilateral MLI | *P* value |
|---|---|---|---|
| ICU stay (%) | 12 (37.5) | 5 (71.4) | n.s. |
| Number of ICU days | 4.0 ± 10.8 | 12.4 ± 12.8 | n.s. |
| ISS | 13.2 ± 6.8 | 33.4 ± 23.4 | <0.0001 |
| Severe or profound ISS (%) | 9 (28.1) | 5 (71.4) | <0.0001 |
| NISS | 14.9 ± 7.6 | 37.1 ± 19.6 | <0.0001 |
| Severe or profound NISS (%) | 13 (40.6) | 7 (100.0) | <0.0001 |
| Head trauma (%) | 5 (15.6) | 2 (28.6) | n.s. |
| Chest trauma (%) | 7 (21.9) | 5 (71.4) | 0.010 |
| Abdominal trauma (%) | 7 (21.9) | 5 (71.4) | 0.010 |
| Upper extremity fracture(s) (%) | 8 (25.0) | 4 (57.1) | n.s. |
| Lower extremity fracture(s) (%) | 10 (31.2) | 2 (28.6) | n.s. |
| Spine fracture(s) (%) | 6 (18.8) | 4 (57.1) | 0.035 |
| Pelvic ring injuries (%) | 6 (18.8) | 2 (29) | n.s. |
| Intubated during admission | 9 (28.1) | 4 (57.1) | n.s. |
| Feeding tube placed | 3 (9.4) | 4 (57.1) | 0.003 |

*ICU* intensive care unit, *ISS* Injury Severity Score, *NISS* New Injury Severity Score, *n.s.* non-significant

## Discussion

The most important finding of the present study was that patients with simultaneous bilateral MLI are more likely to sustain head trauma, chest trauma, abdominal trauma and at least a single-level spine fracture compared to patients with unilateral knee injuries. Additionally, patients with bilateral knee MLI have significantly higher ISS and NISS values. However, the pattern of knee ligament injuries and associated neurovascular injuries was not significantly different.

In one of the largest series of multiligamentous knee injuries, Becker et al. [2] noted a 10 % incidence of severe closed head injury, 14 % incidence of thoracic injuries, 13 % incidence of intra-abdominal injuries and 12 % incidence of spine fractures. Their study of 106 knees included 4 (4 %) bilateral injuries, but they did not analyse those separately. Cook et al. [7] reviewed 133 patients with unilateral knee injuries and uncovered only an 11.5 % incidence of non-orthopaedic injuries. However, the mechanism of these injuries was only graded as high energy in 39 % of patients. In the current study, patients with bilateral knee injuries all endured high-energy mechanisms and sustained a much higher incidence of multisystem injuries which, except for head trauma, were significantly higher compared to the unilateral MLI cohort.

The majority of high-energy knee injuries often present to level I trauma centres and thus undergo a standardized trauma evaluation due to the mechanism [2, 19]. Therefore, the idea of a multidisciplinary approach to high-energy knee injuries is not novel, as the early involvement of trauma and vascular surgeons is commonly discussed and recommended [2, 19, 32]. Early involvement is imperative, as many of the non-orthopaedic injuries may be life-threatening. In the current study, two patients with bilateral MLI underwent emergent exploratory laparotomies for positive focused assessment with sonography in trauma (FAST) examinations and were found to have active bleeding from the spleen and liver. Four bilateral MLI patients had emergent chest tubes placed for symptomatic pneumothoraces. The Injury Severity Score (ISS) was chosen to assess overall injury severity as it is considered by many to be the gold standard for trauma evaluation scores and accurately predicts mortality [3]. With the average score of 33.4

**Table 5** Characterization of subsequent procedures after the initial knee stabilization procedure

| | Bilateral MLI | Unilateral MLI | *P* value |
|---|---|---|---|
| Subsequent operations (%) | 6 (42.8) | 13 (40.6) | n.s. |
| Arthroscopic lysis of adhesions (%) | 3 (21.4) | 6 (18.8) | n.s. |
| Removal of hardware (%) | 6 (42.8) | 6 (18.8) | n.s. |
| Arthroscopic partial medial meniscectomy (%) | 1 (7.1) | 1 (3.1) | n.s. |
| Arthroscopic partial lateral meniscectomy (%) | 1 (7.1) | 0 (0) | n.s. |
| Tibial and/or femoral arthroscopic shaving chondroplasty (%) | 2 (14.3) | 6 (18.8) | n.s. |

for the patients with bilateral MLI, four injuries (57.1 %) were graded as profound, one (14.3 %) was severe, and two (28.6 %) were moderate. Using the new ISS (NISS) system, five injuries (71.4 %) were graded as profound and two (28.6 %) as severe. Thus, 100 % of these patients were graded as severe or profound compared to only 13 of 32 (40.6 %) of the unilateral MLI patients. Once again, this underscores the significant multisystem trauma that patients with bilateral MLIs experience.

Although there is significant variation in the literature, many larger studies show high rates of long-term functional sequelae after knee dislocations with or without reconstructions [1, 7, 9, 35]. While the average length of follow-up for the bilateral MLI patients (24.5 months) does not allow us to evaluate long-term outcomes, the short-term outcomes are particularly concerning. Five of the seven patients (74.4 %) experienced at least one complication, which was significantly higher ($P < 0.0001$) than the 6.3 % (3/32) rate seen in the unilateral MLI cohort. Three of seven (42.9 %) bilateral MLI patients underwent at least one additional procedure post-operatively, and one patient is now deceased. One knee from a bilateral MLI patient developed heterotopic ossification (HO), which is a complication previously described by Whelan et al. [35].

Of particular concern is the ability for patients with bilateral knee injuries to successfully undergo knee physical therapy, especially if there are concomitant multisystem injuries which preclude therapy participation. The most severely injured patient (based off of an ISS of 66) was an incomplete paraplegic after her injury and due to her head injury was in a medically induced coma for almost 2 weeks. Due to continued painful knee instability and failure of brace therapy, she eventually underwent reconstruction 174 days after her injury. For the bilateral MLI knees, there was an average 8.9 ± 7.1 degree flexion contracture compared to 2.5 ± 3.5 degrees in the unilateral MLI knees ($P = 0.001$).

The main limitation of the current study is the small number of patients with bilateral multiligamentously injured knees. As this is a relatively rare occurrence, it would be difficult to obtain a larger cohort of these patients. As there is no long-term follow-up for either of these cohorts, this study is unable to conclude that bilateral injuries have a worse functional outcome although our short-term data demonstrating increased complication rates and increased knee flexion contractures are concerning trends for this cohort.

In patients with simultaneous bilateral MLI, although the orthopaedic surgeon will focus on the management of the knee injuries, traumatic events with sufficient energy to cause bilateral knee ligamentous injury often lead to concomitant multisystem traumatic injuries. Therefore, the treating physicians must perform a complete trauma evaluation, particularly if the patient initially presents to a hospital system without a formal general surgery trauma service. Early intervention for these non-orthopaedic injuries may be life-saving for these patients.

## Conclusion

The current study demonstrates that patients with traumatic simultaneous bilateral knee multiligamentous knee injuries are at significantly higher risk of concomitant head, chest or abdominal injuries compared to unilateral knee MLI due to the same high-velocity mechanisms.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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