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Review article

A systematic review on management and outcome of irreducible knee dislocations

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ABSTRACT

Background: Irreducible knee dislocations (IKD) are rare and can often be missed or misdiagnosed. The incidence of knee dislocation is quoted between 0.01% and 0.2% of all orthopaedic injuries, with up to 4% of these dislocations sub-classified as irreducible. The primary aim of this systematic review was to analyse cases of IKD described in the literature, with a secondary aim of producing a streamlined approach for managing these patients.
Patients and methods: A systematic review of the literature was conducted on 1st September 2021 in accordance with the PRISMA guidelines using the online databases Medline and EMBASE. The review was registered prospectively in the PROSPERO database. Case reports or clinical studies or reporting on IKD were included. The studies were appraised using the Methodological Index for Non-Randomized Studies (MINORS) tool and Newcastle-Ottawa quality assessment scale.
Results: The search strategy identified 60 studies eligible for inclusion, giving a total of 114 cases of IKD. Posterolateral dislocation was most common, seen in 85% of cases. The dimple sign was present in 70%. All cases required surgical intervention to achieve joint reduction. The most commonly involved structure blocking reduction was the medial collateral ligament (MCL) ± medial structures, seen in 52.4%. MCL reconstruction or repair was carried out in 32.3% cases. The overall incidence of neurovascular injury was 9% and the overall complication rate was 14.4%.
Conclusion: Based on the findings of this SR we conclude that: the most common type of IKDs are PL dislocations, and the MCL, medial retinaculum and capsule and vastus medialis oblique form the most common structures involved in block to reduction and often will require open reduction and repair in acute setting if arthroscopic reduction fails. The most common pattern of injury to ligament is likely to be ACL, PCL, MCL ± other structures but the MCL will be the most commonly repaired ligament. The dimple sign is often present and is highly pathognomonic of IKD. The incidence of neurovascular injury is uncommon. The most common post-operative complications likely to be encountered is medial skin necrosis and postoperative knee stiffness. Therefore, patients should be mobilised as early as possible with ROM in hinge brace.
Level of evidence: IV.

1. Introduction

Irreducible knee dislocations (IKD) are a rare injury that can result from high or low energy trauma [1–60]. The diagnosis can often be difficult to make and some IKD can therefore be missed or misdiagnosed. The incidence of dislocation of the knee is quoted between 0.01% and 0.2% of all orthopaedic injuries, with 4% of these dislocations being irreducible [2,9,16,21,24,25,28,29,35,44,47,48,51,56–61]. There are a number of ways of classifying knee dislocations with French Society of Orthopaedic Surgery and Traumatology classifying it according to mechanism of injury [62] whilst others classify it based on direction or ligaments injured [63,64].

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Table 1a
MINORS scores for case series.

	Griswold 1951	Quinlan 1958	Wand 1989	Nystrom 1992	Dubberley 2001	Uruden 2004	Chirpaz-Cerbat 2004	Gu 2004	Lee 2009	Xu 2018	Hongwu 2018	Zhang 2020
A clearly stated aim	2	0	2	0	1	1	2	2	1	1	2	2
Inclusion of consecutive patients	2	1	2	2	1	2	2	2	2	2	2	2
Prospective collection of data	0	0	0	0	0	0	0	0	0	0	0	0
Endpoints appropriate to the aim of the study	1	0	2	0	0	0	2	1	1	2	2	2
Unbiased assessment of the study endpoint	1	0	2	0	1	0	2	1	0	2	2	2
Follow-up period appropriate to the aim of the study	2	0	2	0	1	1	2	2	1	2	2	2
Loss to follow up less than 5%	2	2	2	2	1	0	2	1	1	2	2	0
Prospective calculation of the study size	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
An adequate control group	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
Contemporary groups	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
Baseline equivalence of groups	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
Adequate statistical analyses	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
Total	10	3	12	4	5	4	12	9	6	11	12	18

The earliest case of IKD was reported in 1900 [31]. Since then, there are multiple published case reports and few small case series reporting on outcomes of IKD with no uniform algorithm for management. There are few reviews on IKD but these include small patient numbers [9,55]. An approach to associated ligamentous injury with IKD has been previously suggested by Malik SS & MacDonald PB [61]. The aim of this systematic review therefore was to look at:

- injury characterisation;
- structures involved;
- management and;
- postoperative rehabilitation and outcomes.

Through examining injury mechanism, associated neurovascular injuries, interposed structures and surgical approaches described in all published cases to date, we suggest a streamlined approach to effectively manage this uncommon knee injury. We hypothesised that the most common dislocation would be posterolateral with medial collateral ligament along with medial retinaculum and capsule with the most injured structures. These will also offer a block to knee reduction therefore requiring further surgery.

2. Methods

A systematic review of the literature was conducted in accordance with the PRISMA guidelines using the online databases Medline and EMBASE. The review was registered on the PROSPERO database (Reg. No. CRD42020205151). The searches were performed independently by two authors for studies published between 1900 and 2020. To increase accuracy of the searches they were performed on two separate occasions (1st September 2021 and the 5th October 2021) using the EMBASE and Medline search strategy. Keywords used during the search included: “irreducible” AND “knee” AND “dislocation”.

The eligibility criteria were clinical studies, including case series or case reports, reporting on irreducible knee dislocation. All titles and abstracts were screened to identify case reports and case series reporting on irreducible knee dislocation. Only primary clinical research studies published in the English language were considered for review, with any comments, review articles, editorials and technique articles excluded. To ensure that the search was complete, the bibliographies and references of eligible articles were reviewed to identify additional relevant studies. Any disagreement between investigators were resolved through discussion with the senior author.

Table 1b
Newcastle – Ottawa quality assessment scale case control studies.

Study	Selection	Comparability	Exposure
Zhang et al., 2020	***	*	**

The clinical studies were appraised independently by two authors and quality assessment of non-randomised studies (Table 1a) was completed using the Methodological index for non-randomised studies (MINORS) tool [65] and Newcastle-Ottawa quality assessment scale (Table 1b) [66].

2.1. Data extraction

The abstracts of the studies were screened initially, and full text articles were reviewed where insufficient information was available from the abstracts. Data extracted from included articles comprised mechanism of injury, MRI findings, block to reduction, time to theatre, operative findings and any subsequent follow-up including any further surgeries. Other information obtained from each article included study design, total number of study participants and their demographics.

2.2. Statistical analysis

Data aggregation was performed where outcome was uniformly reported in two or more studies. For any further data, descriptive statistics were calculated. Continuous variable data were reported as means and/or standard deviations of the means if applicable. They were reported as frequencies with percentages.

3. Results

The literature search identified 165 studies whose titles and abstracts were screened for inclusion. After applying eligibility criteria, 60 studies were included for final analysis. A flow chart of review process is shown in Fig. 1. All but one study were retrospective case reports with no comparison group or case series, examining a total of 114 cases of IKD between 1900 and 2020. There was only one study that compared irreducible with reducible knee dislocations [60]. There were 66.7% (76) males and 27.2% (31)

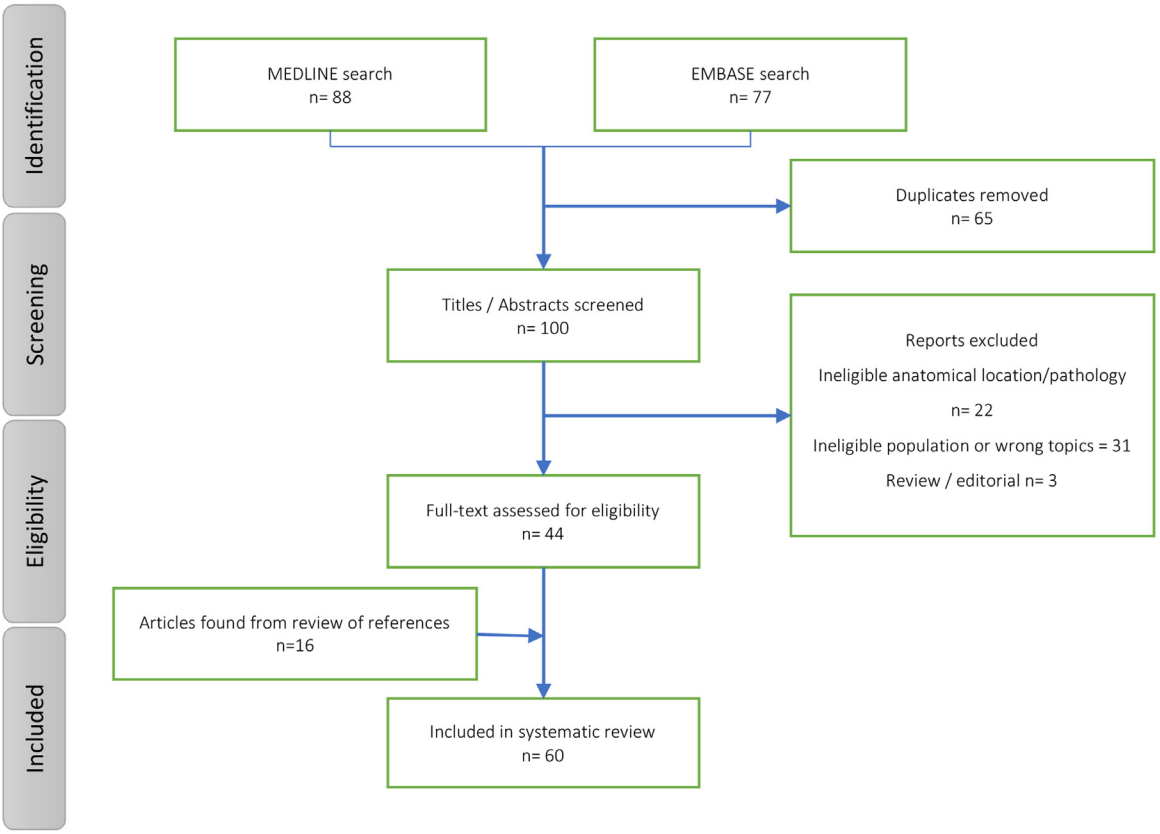

Fig. 1. Flow diagram of review process.

females with 6.1% (7) unknown gender. The mean age was 44 years (44–85). The mean follow-up was 25 months (6 weeks to 7 years). All studies were retrospective case series or case reports.

3.1. Injury characterisation

The mechanism of injury was reported in 96.5% (110) cases and the most common cause of IKD was from a fall in 44.5% (51) of cases. The second most common cause of IKD was road traffic accident (RTA) in 32.7% (37) cases. Motorcycle accident was the third most common cause in 11.8% of cases.

Dislocation type was reported in 93 of 114 cases (81.6%). Posterolateral dislocation was the most common type in 85% (97) of cases followed by lateral dislocation in 9.7% (11) of cases. Dimple sign is pathognomic of IKD and was reported to be present in 69.8% (79) of cases.

A number of different structures were reported as a block to reduction in IKD, which was reported in 103 cases (90.4%). MCL ± medial structures were reported to cause a block to reduction in over half the cases (52.4%) followed by medial retinaculum ± capsule. Other less common causes included vastus medialis (6.8%) and patella (4.9%). A concise summary of injury characteristics is provided in Table 2.

3.2. Structures involved

Injuries to any ligament was reported in 96.5% (110) cases. The most common pattern of injury to ligament was ACL, PCL, MCL ± other structures which was present in 80% (88) of cases. Of these 86.3% (76) cases were isolated ACL, PCL, MCL. The second most common injury pattern was ACL, PCL, MCL, LCL ± other structures reported in 10% (11) of cases. Isolated MCL injury was only reported in 2.7% (3) cases. Only one case was reported to have no ligamentous injury at all. A summary of injuries to structures is presented in Table 3. Menisci injury were present in only 17.6% (19) cases. Medial meniscus was the most commonly injured structure in 11.1% (12) cases. Lateral meniscus was injured in only 3.7% (4) cases while both menisci were injured in 2.8% (3) cases.

Neurovascular status was reported in 111 (97.4%) cases. Overall incidence of neurovascular injury was 9% (10). The incidence of vascular injury was 3.6% (4). There were two cases of isolated popliteal artery injury (1.8%) and two cases (1.8%) of injury to both nerve and vascular structures. Of the four cases of vascular injury, one had a popliteal artery thrombosis in a chronic dislocation patient; one had popliteal artery tear requiring repair and two initial injuries on presentation had resolved on reduction of knee without any surgical intervention to artery, but one required four compartment fasciotomies.

The overall incidence of nerve injury was 5.4% (6). Of the six cases, four were in acute and two were in chronic patients. This isolated group included the peroneal nerve in one case, the sciatic nerve in one case, both the tibial and peroneal nerves in two cases. Two patients had resolution of symptoms in acute group while other two had no resolution of symptoms. The two patients with chronic nerve injury had no clear documentation of outcome. A summary of injuries to structures around the knee is presented in Table 3.

3.3. Management

All one hundred and fourteen cases of IKD required surgical intervention to achieve joint reduction. Time taken from injury to surgery was reported in 76.3% (87) cases and 65.5% (57) patients went to theatre in less than 72 hours. Two patients went to theatre in over a year (Table 4). One was initially treated non-operatively in above knee plaster but continued to complain of instability and

Table 2
Summary of injury characteristics.

Injury characteristics	Number of cases
Mechanism of injury	
n = 114	
Fall	49 (44.5%)
Fall	14
Skiing	8
Twist	7
Sports tackle	6
Hole	6
Height	3
Horse	1
Slip	2
Snowboarding	1
Bicycle	1
RTA	36 (32.7%)
Motorcycle	13 (11.8%)
Work related	3 (2.7%)
Rotor tiller	4 (3.6%)
Rolling down the hill	2 (1.8%)
Trapped	1 (0.9%)
Paragliding	1 (0.9%)
Hit by box	1 (0.9%)
Total	110
Not reported	4
Dislocation type	
n = 114	
PL	79 (85%)
Lateral	9 (9.7%)
Posterior	4 (4.3%)
AM	1 (1.1%)
Total	93
Not reported	21
Dimple sign	
n = 114	
Yes	60 (70%)
No	26 (30%)
Total	86
Not reported	28
Blocks to reduction	
n = 114	
MCL ± medial structures[a]	54 (52.4%)
Medial retinaculum and/or capsule	31 (30.1%)
Vastus medialis	7 (6.8%)
Patella	5 (4.9%)
Accessory gastrocnemius head	1
Extensor retinaculum	1
Medial menisci	1
Patella tendon	1
Posterolateral capsuloligamentary structures	1
Multiple structures[b]	1
Total	103
Not reported	11

RTA: road traffic accident; MCL: medial collateral ligament; PL: posterolateral; AM: anteromedial.

[a] Medial structures, vastus medialis, capsule, retinaculum, medial femoral condyle fracture.

[b] Medial patellar retinaculum, capsule, medial patellofemoral ligament (MPFL), vastus medialis, meniscotibal and meniscofemoral ligaments were found incarcerated within the intercondylar notch.

Table 3
Injuries to structures around the knee.

Structures injured	Number of cases
Ligaments	
Intact ligaments	1
MCL only	3 (2.7%)
ACL, MCL	4 (3.6%)
ACL, PCL, MCL ± other structures	88 (80%)
ACL, PCL, MCL	76
+ Vastus medialis	3
+ Adductor longus	1
+ MPFL	1
+ MPFL, PMC	1
+ Pes Anserinus, medial gastrocnemius	1
+ PMC	1
+ Popliteus, adductor magnus	2
+ Quadriceps tendon	1
+ Semimembranosus tendon	1
ACL, PCL, MCL, LCL ± other structures	11 (10%)
ACL, PCL, MCL, LCL only	6
+ popliteus	1
+ vastus medialis	2
+ MPFL	1
+ PLC	1
ACL, PCL, patella tendon	1
ACL, PCL, PLC, LCL, QT, VMO	1
ACL, PCL, LCL, popliteus, VMO, QT, patella	1
Total	110
Not reported	4
Meniscal injury	
No	89 (82.4%)
Yes	19 (17.6%)
Medial meniscus	12 (11.1%)
Lateral meniscus	4 (3.7%)
Medial and lateral menisci	3 (2.8%)
Total	108
Not reported	6
Bony injuries around the knee	
No	82 (81.2%)
Yes	19
Patella injuries	14 (13.9%)
Dislocations	7
Dislocations + tibial plateau fracture	1
Fractures	3
Tibia condyle	1
Avulsion fracture of deep MCL	1
Avulsion of LFC	1
MFC and proximal tibia fracture	1
Intracondylar eminence fracture	1
Total	101
Not reported	13
Vascular injury	
Yes	4 (3.6%)
No	107 (96.4%)
Total	111
Not reported	3
Nerve injury	
Yes	6 (5.4%)
No	105 (94.6)
Total	111
Not reported	3

pain after 14 months while the other patient was a multiple trauma patient involved in RTA and had pelvic fracture, head injury, fracture of right tibia, left knee IKD with vascular compromise. She underwent multiple surgeries for vascular complications and was then found to have pain, instability and a stiff knee. Open only reduction was performed in 73.7% (84) cases whereas arthroscopic only reduction was performed in 14.9% (17) cases. A diagnostic arthroscopy and attempted reduction followed by open reduction was performed in 11.4% (13) patients (Table 5). For those patients that underwent open technique, an approach to the knee was described in 90% (87) patients. The most common open technique was direct medial approach in 36.8% (32) cases, followed by anteromedial approach in 19.5% (17).

Table 4
Summary of cases and time to surgery.

Timing to surgery	Number of cases
< 72 hours	57 (65.5%)
3 days to 3 weeks	16 (18.4%)
3 weeks to 3 months	7 (8%)
3 months to 12 months	5 (5.8%)
1–3 years	2 (2.3%)
Total	87
Timing not reported	27

Table 5
A summary of reduction techniques used and different approaches to the knee.

Reduction technique	Number of cases	Approach
Open	84 (73.7%)	DM = 32 (36.8%) AM = 17 (19.5%) MPP = 12 (13.8%) DA = 9 (10.3%) DM + DL = 9 (10.3%) DM + MPP = 2 (2.3%) DM + PL = 1 (1.2%) DA + DM = 1 (1.2%) DA + PM + PL = 1 (1.2%) PM = 2 (2.3%) Ilizarov frame[a] = 1 (1.2%) Not reported = 10
Arthroscopy followed by open	13 (11.4%)	
Arthroscopic only	17 (14.9%)	–
Total	114	97

DM: direct medial; MPP: medial parapatellar; PL: posterolateral; AM: anteromedial; DAA: direct anterior.
[a] No open surgery was performed in this case at all.

Ligament surgery was performed in 71% (81) patients, whereas 24.7% (20) patients had no ligament surgery. The most common ligament repair was of MCL in 32.3% (34) cases, which included 3 MCL reconstructions. Two of these repairs included a gastrocnemius repair and semimembranosus repair in addition to MCL repair. The second most common ligament surgery pattern was MCL, ACL, PCL ± other structures in 27.6% (29) cases. Four patients in this group had MCL repair and augmentation with reconstruction. All four-ligament (MCL, ACL, PCL, LCL) surgery was performed in 5.7% (6) patients. Table 6 shows further breakdown of which ligaments were repaired or reconstructed as well as other patterns of ligament surgery. Five patients underwent meniscal surgery.

External fixators were utilised in six cases in order to maintain reduction of the joint. Three were removed at 6 weeks but remaining three did not have further information on the outcome. Ilizarov frame was used in two cases. First case was a 3-month delay in presentation utilised an Ilizarov frame followed by arthroscopic ACL and PCL reconstruction in a second surgery. The second case had a chronic dislocation of more than 3 years with patella dislocation and required Ilizarov frame and medial tibial tubercle transfer. Ilizarov frame was removed at 3 months and quadricepsplasty at 12 months for 0–20° ROM.

3.4. Postoperative rehabilitation and outcomes

Post-operative weight bearing status was reported for 75% (85) cases. The majority of these were non-weight bearing 56.5% (49) ranging from 2 days to 3 months. Hinge brace was applied in 14.1% (12) cases with varying degree of flexion. Above knee plasters were used in 22.4% (19) cases. A small proportion of patient, 9.4% (8) were placed in external fixators (6) and Ilizarov frame (2).

Post-operative range of motion (ROM) was reported in 64% (73) cases. 35.6% (26) had descriptive assessment of ROM. 64.4% (47) had a range documented. Table 7 shows a summary of results. 11 patients had flexion between 80 to 90 degrees, 31 patients had flexion greater than 90 degrees, 5 patients had flexion less than 60 degrees. Postoperative stability on clinical examination was reported in just over half the patients 52.6% (60) cases. PROMs were reported in only 15.8% (18) patients with IKDC being the most common (Table 7).

Complications were reported in 14.4% (15) cases (Table 8). Medial sided skin necrosis occurred most commonly in 6.7% (7) and only two of these cases requiring return to theatre. This was followed by postoperative stiffness affecting 4.8% (5) of patients, 4 of whom returned to theatre.

Table 6
The pattern of knee ligament repair and/or reconstruction.

Ligament repairs	Repair[a]	Reconstruction	Total
No ligament repairs = 20 (19%)	–	–	20
MCL = 34 (32.3%)	MCLr only = 28 MCLr + gastrocnemius repair = 1 MCLr + semimembranous repair = 1 MCLr, MPFLr = 1	MCLR only = 3	34
MCL, ACL, PCL = 29 (27.6%)	MCLr, ACLR, PCL-R = 16 MCLr, ACLr, PCLr = 2 MCLr, ACL-R, PCLr = 1 MCLr, ACLr, PCLr, QTr, VMO advancement =1 MCLr, ACL-R, PCL-R, LMr =1 MCLr, ACLr, PCLr, pLM, PHMMr = 1 MCLR, ACL-R, PCL-R, PMC-R, pMM = 1 MCLr, ACL-R, PCL-R, popliteus tendon recon = 1	MCL-R, ACLR, PCLR = 2 MCLr + R, ACLr, PCLr = 1 MCLr + R, ACLR, PCLr, MPFLr, PLCr, oMMr + LMr = 1 MCLr + R, PCLR = 1	29
MCL, ACL, PCL, LCL = 6 (5.7%)	MCLr, ACL-R, PCL-R, LCLr = 6	–	6
MCL, ACL = 6 (5.7%)	MCLr, ACLr = 3 MCLr, ACLr, MMr = 2 MCLr, ACL-R = 1	–	6
ACL, PCL = 1	–	ACL-R, PCL-R = 1	1
ACL, PCL, LCL = 2	ACLr, PCLr, LCLr, LMr = 1	ACL-R, PCL-R, LCL-R = 1	2
MCL, PCL = 1	MCLr, PCL-R, Lateral release = 1	–	1
Miscellaneous = 6 (5.7%)	ACLr = 1 MPFLr = 1 Patella tendon repair = 1 QTr + fasciotomies = 1 VMOr = 1	PCL-R = 1	6
Not clearly reported = 9	–	–	9
Total = 114	–	–	114

r: repair; R: reconstruction; p: partial; o: open; ACL: anterior cruciate ligament; PCL: posterior cruciate ligament; MCL: medial collateral ligament; LCL: lateral collateral ligament; PLC: posterolateral corner; PMC: posteromedial corner; MPFL: medial patelo-femoral ligament; MM: medial meniscus; LM: lateral meniscus; QT: quadriceps tendon; VMO: vastus medialis obliquus.
[a] Repair is based on MCL.

Table 7
Summary of post-operative weight bearing status and range of motion.

Range of motion	Number of cases	Weight bearing status
Reported	47	85
	Flexion < 60 = 5	Ex-fix = 6
	Flexion 80–90 = 11	Ilizarov = 2
	Flexion > 90 = 31	Hinge brace with
Subjective	26	varying degree of
	Full ROM = 10	flexion = 12
	Normal = 7	FWB with knee in
	Satisfactory = 4	extension and ROM
	Reduced = 2	after 2/52 = 15
	Functional ROM = 1	NWB 0–8 weeks = 18
	Good ROM = 1	NWB for 2/52 in hinge
	Walking	brace and gradual ROM
	independently = 1	an WB = 13
PROMs	18	NWB in POP 2 to 10
	IKDC 75.42 ± 3.86 = 14	weeks = 17
	IKDC 48.2 = 1	POP in 10 deg
	IKDC 49.4 = 1	flexion = 2
	IKDC 56.3 = 1	
	IKDC 62 = 1	
Not reported	23	29

IKDC: International Knee Documentation Committee; ROM: range of motion; FWB: Full weight bear; NWB: non-weight bear; POP: plaster of Paris.

Table 8
Summary of complications and their treatment.

Complications	Number of cases	Treatment
Yes	15	15
	Stiffness = 5	Stiffness
	Skin necrosis = 7	1 requiring excision of
	Compartment	heterotropic
	syndrome = 1	ossification
	Wound infection = 1	3 requiring release of
	Sinus track = 1	arthrofibrosis
		1 requiring
		manipulation
		Wound infection–no
		further information
		Sinus track–healed.
		Fasciotomy for
		compartment
		syndrome
		Skin necrosis
		4 non-operative
		treatment
		2 skin flaps
		1 failed skin flap,
		requiring patellectomy
No	89	–
Not reported	10	–

4. Discussion

The main finding of this review is that all 114 cases of IKD required surgical intervention to achieve joint reduction. Posterolateral dislocation was the most common type seen in 85% of cases. Interestingly, overall incidence of neurovascular injury was 9% with the incidence of nerve injury being 5.4% and of vascular injury 3.6%. The majority of injuries occurred as a result of fall in 44.5% cases with road traffic accidents and motorcycle related injuries accounting for other 44.5% of cases.

A review by Xu et al., on IKD had the average age of 43.4 ± 15.5 years [55]. They reported low energy injuries accounting for 44.2% cases and high energy accidents for 55.8%. This is similar to the findings of this SR. The rate of neurovascular injury in their review was 4.8%, which is lower than our SR which could be down to low number of patients in their study ($n = 45$). Overall, the rate of neurovascular injuries remain lower than reported in for knee dislocations which has be reported as 18% for vascular and in up to 40% multi-ligament knee injury (MLKI) for common peroneal injury [67,68]. In a study of 42 patients with MLKI reconstruction, 59.5% sustained high energy injuries (including motor vehicle accidents) and 40.5% sustained low energy sports related injuries [69]. Same study reported nerve and arterial injury rate of 16.6% and 4.7%, respectively [70]. Billières et al., reported nerve injury in 15% of MLKI treated by one stage reconstruction with allograft [70]. In another study by SOFCOT vascular lesions were present in 12% of cases [71]. While another study of 72 knee dislocations, rate of popliteal artery injury was 16.7% [72]. Of these, one patient underwent amputation, two resection graft and one underwent endovascular treatment. Our SR suggests that IKD are much likely to occur in low energy injuries in comparison and rate of neurovascular injuries remains relatively low. We hypothesise that the low incidence of neurovascular injury in this SR, is secondary to the mechanism by which IKD is sustained. IKD commonly arises following valgus force, which is less likely to significantly stress the neurovascular bundle that lies laterally in the popliteal fossa.

The MCL ± medial structures were the most common structures blocking the reduction in just over the half the cases (52.4%) followed by medial retinaculum and or capsule (30.1%). Vastus medialis was involved in 6.8% cases. The majority of cases with damage to these structures can be explained by the mechanism of injury in IKD, which is normally a valgus force in a flexed knee, while the tibia and femur pivot around each other in opposite direction. This results in tearing and damage to anteromedial structures, including capsule and retinaculum. The rotational forces lead to damage of cruciate ligaments. Xu et al., reported the two most frequent structures in their review were MCL (43.1% and medial retinaculum (31.8%) followed by vastus medialis (9.1%) [55]. These findings are consistent with our SR.

In this SR, 96% of cases involved 2 or more ligament damage with 80% of these involving ACL, PCL, MCL ± other structures. The incidence of meniscal injuries in this SR was 19% with medial meniscus injury reported in 11.1%. Interestingly, there were no chondral injuries recorded in this SR. Xu et al., reported the most common injured ligament pattern was also ACL, PCL, MCL in 81.8% with meniscal injury rate of 25% [55]. In a study by Lee et al., the rate of meniscal injury was 42.6% in patients undergoing MLKI reconstruction [69]. Majority of these were combined medial and lateral menisci injuries. They reported cartilage injury rate of 19% majority of which were on femoral condyle. Billières J et al., reported meniscal injury rate of 30%, of which the medial meniscal injury rate was 25% [70]. They did not report any chondral injury. However, where there are combined meniscal and chondral injuries present, outcome has been shown to be inferior [73].

The surgical approach to reduction varied, dependent on interposing structures within the joint and injury pattern. However, open reduction remained the most common method of reduction in 73.7% cases. In more recent years, a hybrid approach of diagnostic arthroscopy followed by open reduction has been utilised (11.4%). With open technique, direct medial approach was described in 36.8% cases. Arthroscopic reduction of IKD was first described by Dubberley et al. and in this SR, only 15% of cases underwent arthroscopic reduction [15].

The overall complication rate in this SR was 14.4%. The most common complication in this SR was the medial side skin necrosis, occurring in 7.3%, which occurs from pressure of the medial femoral condyle buttonholing through the soft tissues. Clinically this can be seen as skin puckering with ecchymosis over the medial joining line. This is the 'dimple sign'which often can be pathognomonic of IKD and was present in 70% of the knees in this SR. Lee et. al., reported a complication rate of 36.4% (12 of 33) in MLKI reconstruction of which arthrofibrosis, graft failure, hardware irritation and infection were all equally reported (9.1%) [69]. Angelini et al.,

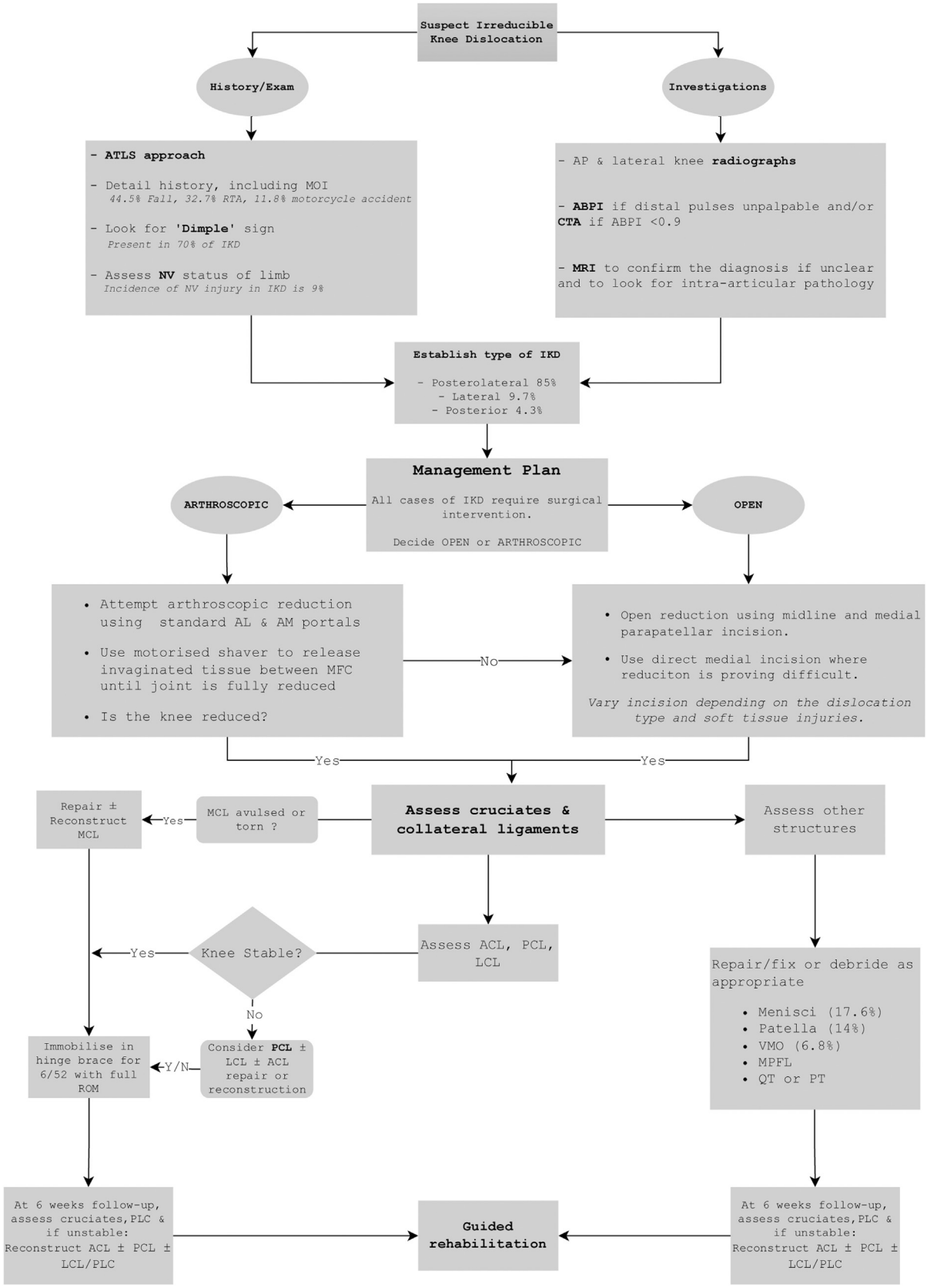

Fig. 2. A proposed management algorithm for the irreducible knee dislocation.

reported a complication rate of 35.7% (5 of 14) in patients undergoing ligament reconstruction following knee dislocations treated with hinged external fixator. Four of these patients had superficial skin infection [74].

This SR describes the outcomes of clinical studies and case reports on IKD. To our knowledge this is the largest review on IKD with 114 patients. A previous review looked at the outcome in 34 studies with 45 patients. Based on this SR we proposed management algorithm as described in Fig. 2. Once a knee dislocation is recognised as irreducible, patients should promptly proceed to the operating theatre. In order for adequate preoperative planning patients should undergo magnetic resonance imaging following plain radiographs, to identify associated soft tissue injury. CT scans, including CT angiogram, should be considered as part of a trauma series if a high mechanism of injury is suspected. Although vascular injury is uncommon in IKD, ankle brachial index (ABI) of < 0.9 is indicative of a possible vascular injury. In the first instance it is reasonable to attempt arthroscopic reduction before open reduction. Where MCL is torn, it is best to repair or reconstruct it at initial surgery along with medial retinaculum and/or capsule. Other soft tissue or ligamentous injuries may be addressed in a one or two staged procedure. We recommend early range of motion with a hinge brace where needed. Close patient follow-up is crucial for monitoring skin breakdown or stiffness and at six weeks for assessment of stability clinically to appropriately progress post-operative restrictions. Not all patients will need ligament reconstruction and therefore further treatment should be based on individual patient factors.

This SR has several limitations including studies reviewed provided level IV evidence, with common limitations including low study numbers and a lack of control group. There is heterogeneity in the cases, with no consistency regarding patient assessment, investigation, intervention or follow-up. Appraisal of the nonrandomized clinical studies using the MINORS tool demonstrated a variety of limitations, which are summarized in Tables 1a and b. The MINORS scores ranged from 3 to 12 for noncomparative studies (maximum score, 14) and the single comparative study scored 18 (maximum score, 24).

5. Conclusion

Based on the findings of this SR we conclude that:

- the most common type of IKDs are PL dislocations and;
- the MCL, medial retinaculum and capsule and vastus medialis oblique form the most common structures involved in block to reduction and often will require open reduction and repair in acute setting if arthroscopic reduction fails. The most common pattern of injury to ligament is likely to be ACL, PCL, MCL ± other structures but the MCL will be the most commonly repaired ligament. The dimple sign is often present and is highly pathognomonic of IKD. The incidence of neuro-vascular injury is uncommon;
- the most common postoperative complications likely to be encountered is medial skin necrosis and postoperative knee stiffness. Therefore, patients should be mobilised as early as possible with ROM in hinge brace.

Disclosure of interest

The authors declare that they have no competing interest.

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Authors contribution

S.S. Malik: Conceptualisation of study. Data acquisition and analysis, drafting and acquisition of manuscript.

J. Osan: Data analysis and interpretation.

R. Aujla: Data acquisition & drafting and of manuscript.

N. Aslam: Data acquisition and interpretation, drafting and revision of manuscript.

P. D'Alessandro: Drafting and of manuscript.

P.B. MacDonald: Data analysis and interpretation, drafting and revision of manuscript.

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