Knee dislocation: The Pittsburgh approach

Introduction:

The dislocation of the knee is a relatively uncommon but severe injury to the knee joint. The frequent combination of knee dislocation with multiple trauma, associated fractures, multiple ligament injuries and most importantly the frequent neuro-vascular injuries to the popliteal artery and the peroneal nerve make this injury a true surgical challenge. Critical is an early diagnosis of the knee dislocation in order to be prepared for early complications such as complete ruptures of the popliteal artery or intimal lesions which may surface subacutely. Whereas the neurovascular status after a knee dislocation needs to be instantly addressed, fractures and ligamentous lesions play a significant role for the outcome and the functionality of the knee joint. In order to ensure the reestablishment of a functional knee joint the multiple ligament injuries need to be treated. However, rationales for the treatment of knee dislocations are still subject of controversy. The range of treatment protocols advocated range from non-operative treatment with immobilization up to immediate surgical restoration and repair of the multiple ligament tears although most recent reports have recommended early ligament repair or reconstruction (Frassica1991, Marks1993, Montgomery1987, Taft1994). During the last ten years we have developed a treatment protocol which allows for early rehabilitation and subacute surgical restoration of the ligamentous structures. In this article we will describe the Pittsburgh protocol for the treatment of knee dislocations.
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Examination:

Initially a brief history of the accident should be taken including the mechanism of injury. An inspection of the knee joint usually indicates the severe soft tissue damage around the knee joint. If the knee joint is still in a dislocated position it needs to be reduced immediately and held in reduction using a splint or a brace. If the history and inspection is unclear as to whether a knee dislocation has happened, a brief examination of the collateral ligaments and a Lachman test should be revealing the ligamentous instability instantaneously. Another helpful test in the acute setting is to assess the step-off of the medial tibial plateau with respect to the medial femoral condyle. These steps should be performed within minutes after admission. Since knee dislocations have a very high rate of neurovascular injuries it is essential to immediately examine the neuro-vascular status of the leg. Associated peroneal nerve injuries are common in knee dislocations. Particularly in posterolateral knee dislocations the peroneal nerve is injured in up to 50% of the cases (Taft 1994). The pulse of the popliteal artery and the pedal pulses should be checked several times and compared to the contralateral side. Any side to side difference in pulse quality should make the use of a doppler-sonography mandatory. A “warm” leg is no clear cut sign of normal perfusion. If there is any doubt about an adequate perfusion of the leg a single-shot arteriogram should be obtained immediately and a consultation with a vascular surgeon needs to be arranged in the ER. Once the vascular status has been determined and vascular injury has been ruled out an x-ray should be obtained. A posterior splint is usually sufficient for the reduction. In case of severe soft tissue trauma, or if the reduction can not be held in a splint, an external fixateur can be helpful. The reduction needs to be controlled radiographically. In our practice we have
found early MRI a critical examination. Physical examination can be obscured by pain, muscle spasms, soft tissue swelling, vascular injuries, ipsilateral fractures or polytrauma. A MRI may identify ligament and meniscal tears, occult osteo-chondral fractures, capsular ruptures, muscle lacerations and intra-osseous contusions. Furthermore MRI helps with detailed surgical planning of the incisions, extent of exposure, necessity of reattachment or reconstruction of ligaments, number and type of grafts needed and the order of repair and reconstruction.

The treatment has to be modified in case of an open knee dislocation. The incidence has been reported to be between 20 and 30% of all knee dislocations (Taft 1994). The principles of open fracture treatment should be applied in these cases. This includes immediate cleaning of the wound area, sterile wrapping and subsequently thorough surgical irrigation and debridement under sterile conditions in the operating theater. After 2-3 weeks the surrounding soft tissues have recovered and the immediate danger of infection is minimized such that ligament surgery can be performed.

The ligament surgery is usually performed after 10 days to allow for capsular healing and recovery of the soft tissues.

**Treatment:**

The goals of treatment are to restore the anatomy, the stability and the range of motion of the knee, aiming for the return to pre-injury level of function. Factors which may affect these goals and the overall treatment outcome comprise patient age and expectations and importantly the presence of associated injuries. Significant surgical
considerations include timing, approach, graft selection and rehabilitation. With the injuries of collateral ligaments, we ideally perform surgery within 2 weeks to prevent excessive scarring which may make the identification of anatomical structures difficult and interfere with ligament repair. One of the potential disadvantages of acute ligament surgery is the development of postoperative knee stiffness. In our experience, some patients have required manipulation under anesthesia, but reoperation for stiffness has been rarely necessary. We generally delayed surgery for ten days to two weeks after the injury to allow soft tissue recovery, capsular healing and restoration of range of motion. Patients are placed in a long-leg hinged knee brace and start preoperative rehabilitation aiming at the restoration of range of motion and quadriceps contraction. There are times when the acute reconstruction is not possible (open knee dislocations, arterial injury, unstable polytraumatized patient). In this situation, non-operative treatment may be conducted and consist of 4 weeks immobilization in extension before the mobilization is started. However, the non-operative treatment does not result in acceptable outcome in our experience.

Surgical management begins with an examination under anesthesia to complete or finalize the diagnostic of the different ligamentous injuries. This examination under anesthesia is also a critical step to determine the final surgical strategy. The most common combinations of injury include lesion of the ACL, PCL, and MCL, or ACL, PCL, LCL, and postero-lateral corner. Less commonly, the PCL is intact or partially torn and does not require repair (Cooper). Our approach is to repair or reconstruct all the injured ligaments. Intrasubstance tears of the MCL and avulsed ligaments are usually...
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repaired while intrasubstance tears of the ACL, PCL, and LCL are commonly reconstructed. Peripheral meniscus tears and capsular avulsions are directly fixed.

With the patient supine, a well-padded tourniquet is adjusted on the upper thigh. Before and during the surgery, frequent checks of the pedal pulse are performed either digitally or with a sterile doppler. The surgical approach is essentially determined by the injury to the collateral ligaments. We always begin with an arthroscopy performed with gravity inflow. The arthroscopic pump is never utilized for these cases and the calf turgor is repeatedly controlled during the operation. An arthroscopic approach is advocated to reduce the large dissection and exposure due to medial and lateral approaches, thereby decreasing the risk of skin necrosis. However, you should always be ready to do it open in case of fluid extravasation in the calf. Surgeons involved in this surgery should have the experience of both approaches: arthroscopic and open surgery. The ACL is usually reconstructed using a bone-patellar-tendon-bone allograft and the PCL with an Achilles tendon allograft. Knee dislocations are good indications for allografts, because of the reduction of surgical trauma associated with the harvesting of autografts in a knee already traumatized. The details of the operative techniques for ACL and PCL reconstruction have been already discussed (Harner-Marks). There are however important considerations to address in regard to combined cruciate ligament reconstruction. The ACL tunnels have to be placed at the anatomical insertions of the ACL. When a bone-patellar-tendon-bone graft is used, the tibial drill guide is set at 55 degrees, thereby allowing an increase in the length of the tibial tunnel, which will prevent the bone plug to be fixed outside the tunnel. The PCL tibial drill guide is positioned parallel to the proximal tibio-fibular joint line. The tibial tunnel should be drilled from the antero-
medial incision leaving a bone bridge of at least 1 cm between the ACL and PCL tunnels. The PCL tunnel should be placed at the distal and lateral aspect of the PCL footprint. An intra-operative lateral radiograph is always taken to verify the tunnel position (figure…). The PCL femoral tunnel is placed 8mm proximal to the distal articular cartilage at the anterior half of the PCL femoral footprint. The bone blocks of the PCL Achilles allograft and the ACL bone-patellar-tendon-bone allograft are fixed at the femur using titanium interference screws.

When the cruciate ligaments and the MCL are torn, a medial ”hockey stick” incision is performed starting at the anteromedial tibia, continuing to the medial femoral epicondyle until the vastus medialis is reached. Through this approach, the MCL and the medial joint line can be exposed and capsular as well as meniscal repair can be performed. If an open reconstruction of the ACL or PCL is performed, the knee joint can be accessed through this incision via a medial parapatellar mini-arthrotomy. The meniscal tears are fixed with nonabsorbable sutures and capsular repair is achieved using suture anchors. Avulsions of the MCL are addressed by reattachment to the bone with the use of suture anchors while intrasubstance tears are fixed primarily using a Bunnel stitch and nonabsorbable sutures.

When the cruciate ligaments and lateral structures are torn, we use a curvilinear incision starting midway between the fibular head and Gerdy’s tubercle, continuing towards the lateral femoral epicondyle, and ending parallel to the posterior edge of the ilio-tibial band for an approximate length of 15cm. The peroneal nerve is identified at the proximal end of the incision, posterior to the biceps tendon and followed distally to the point of entrance in the anterior tibial muscular compartment. We usually release the
fascial hiatus located a few millimeters proximal to the entry of the nerve into the muscular compartment. Dissection is pursued between the posterior edge of the ITB and the biceps tendon. Then, the ITB is split longitudinally and retracted posteriorly and anteriorly to access the proximal insertion of the LCL and popliteus tendon. A vertical capsular ligament incision is performed at the posterior border of the LCL giving access to the joint line, lateral meniscal rim, popliteus tendon, and popliteofibular ligament. A systematic evaluation of the structures of the posterolateral corner is undertaken. Peripheral tears of the lateral meniscus are repaired using non-absorbable sutures and capsular avulsions are fixed using suture anchors. Avulsion injuries of the LCL and popliteus tendon are repaired using transosseous sutures or suture anchors. More frequently, the tear occurs in the mid-substance of the ligament or tendon, or at the musculo-tendinous junction requiring reconstruction. An Achilles tendon allograft of 7 to 8 mm width is used for the reconstruction of the LCL. First, the stretched or torn LCL is detached and elevated of its distal insertion, then a short tunnel is drilled following the longitudinal axis of the fibula and the allograft bone block is secured in the tunnel using a titanium interference screw (figure). The allograft tendon can be passed through a femoral tunnel beginning at the anatomical femoral insertion of the LCL and fixed on a button on the other side of the femur or attached directly onto the femoral insertion using suture anchors (figure). The native LCL is then reattached and tensioned on the graft (figure). In case of a significant injury of the popliteus, the reconstruction aims at the reestablishment of its static component, the popliteofibular ligament, using a semitendinosis autograft. The graft is fixed on the femoral side through a tunnel drilled in the anatomical insertion of the popliteus using an Endobutton (Acufex, Boston, MA) set at
the medial femoral condyle (figure). A tunnel is then drilled through the fibula head parallel to the proximal femoro-tibial joint line with great care to protect the peroneal nerve. In case of previous reconstruction of the LCL, the tunnel should be placed lateral to the interference screw. The graft is then passed beneath the LCL graft and from posterior to anterior through the fibular tunnel where it is sutured to the periosteum (Figure). The graft can also be secured in the fibular tunnel using a bioabsorbable interference screw (Bioscrew, Linvatec, Largo Florida).

Before the final fixation of the repaired/reconstructed collateral ligaments, the PCL graft is tensioned at 90 degrees of flexion. The reproduction of the normal step-off of the medial tibial plateau (approximately 1 cm) should be achieved. The graft is fixed on the tibial side using a screw and soft tissue washer. The ACL is then tensioned in extension and fixed on the tibial side using a titanium interference screw. Post-operative radiographs are obtained to confirm proper reduction and to check the fixation position.

After the fixation of the ACL and PCL, the sutures of the repaired/reconstructed collateral ligaments are tied. The LCL is tensioned at 30 degrees of flexion, the posterolateral corner at 30 degrees with the tibia maintained in internal rotation, the MCL at 30 degrees of flexion, and the POL near extension. The knee is moved through a range of motion from 0 to 90 degrees of flexion. Then the tourniquet is released and a meticulous hemostasis is achieved. Suction drainage is used in case of a lateral incision or medial arthrotomy incision. The knee is finally braced in full extension with a bolster placed beneath the tibia to prevent posterior sagging of the tibia on the femur.
Rehabilitation:

Initially, the knee is maintained in full extension for 2 to 4 weeks. The patients ambulate non-weightbearing with crutches in order to protect the collateral ligament repair. Quadriceps isometric contraction sets are undertaken in the brace from the first post-operative day. After this initial period, passive range of motion is started under the permanent supervision of a physical therapist to prevent posterior subluxation of the tibia. The brace may be unlocked for ambulation and sleeping. Ambulation is progressed to weightbearing if the quadriceps is functional, except in case of a posterolateral repair or reconstruction was performed. In this case, partial weightbearing ambulation is maintained for three month. Active hamstring exercises are avoided for 4 months in order to prevent posterior translation stresses.

Discussion:

The optimal treatment of knee dislocations is still controversial. The neurovascular injuries after knee dislocation are of primary concern and have to be addressed accordingly. The incidence of popliteal artery lesions has been found to be in the magnitude of 16%-33% (Green 78, Kendall 93) leading to amputations in as much as 88% if ischemia exceeds the first 8 hours (Green78). It therefore is critical to diagnose vascular injuries immediately. Our treatment protocol therefore focuses on the early diagnosis of vascular injuries and thus, ensures a thorough assessment of the vascular situation (fig: x).
Peroneal nerve lesions occur variably in 14% (Roman 1978) to 63% (Wright 1995) of the cases depending on the injury mechanism. The severity of the neural injury ranges from slight irritation (neuropraxia) to complete disruption of the nerve (neurotmesis). The recovery from the neural damage is variable. Current literature suggests recovery rates as low as 50% (Sisto85, Taft94). According to recent observations the neural injury is no indication for an early surgical intervention since exploration and neurolysis did not show improved recovery rates of peroneal nerve function (Sisto85). We therefore recommend the observation of peroneal nerve function for 3 months. If no progress is detected, arrangements for reconstructive procedures should be made.

Once the neurovascular status is clear we allow 10 days for soft tissue recovery and capsular healing. This allows for detailed preoperative planning and early range of motion exercises can be performed.

The critical step of our concept is the anatomic reconstruction of all injured ligamentous structures. Avulsion injuries of the cruciate and collateral ligaments can be refixed in order to restore the normal anatomy. Intrasubstance tears however have a limited ability to recover to normal function and should therefor be reconstructed. The isolated reconstruction of the central pivot or the collateral ligaments neglects the complex biomechanical importance of the combination of these ligaments towards knee joint function. We know from literature and biomechanical studies that the isolated stabilization of the central pivot is not sufficient in order to provide stability to the knee joint if the posterolateral corner has been injured. We therefore advocate the reconstruction of cruciate ligaments, lateral collateral ligament and the posterolateral corner complex.
In order to avoid additional soft tissue damage to an already traumatized knee joint we prefer to use allografts for ligament reconstructions. Secondly the quality of a patellar tendon autograft might be diminished by an occult injury to the patellar tendon during the accident. The use of patellar tendon allografts for ACL reconstruction and Achilles tendon allografts for PCL reconstruction has been reported to produce consistently good results in large series of patients (Noyes96). In our own practice we have used allografts for ACL/PCL reconstructions with excellent functional outcome as reported earlier (Harner98, Shapiro 95).

The postoperative rehabilitation is done in a brace in order to protect the multiple ligament reconstructions. We consider the early muscular rehabilitation of the quadriceps important. Isometric quad contractions and guided range of motion exercises after 2 - 4 weeks provide the base for early neuro-muscular recovery. The early return to range of motion by passively guided motion and the return to ambulation under progressive weight bearing within the first six weeks is critical for the early reestablishment of knee joint function and mobility.

We have reviewed the results of 25 out of 30 patients (84%) which have been treated between 1990 and 1993 according to the above treatment rationale. The follow-up was 36 months on average, KT-1000 ratings and the IKDC score was used for evaluation. Acute ligament reconstruction was performed on 15 patients. At the time of examination 9 patients rated their knee subjectively as normal, 13 patients felt their knee to be nearly normal and three patients rated their knee as abnormal. The mean corrected anterior translation was 0.1mm (SD +2.2) and the total antero-posterior translation was 2.6 mm (SD+2.6). No patient lost more than 3 degrees of extension, the mean flexion loss
compared to the contralateral side was 11.2 degrees. Using this technique we could reduce the amount of manipulations under anaesthesia to a minimum, re-operations due to impaired range of motion was not necessary in any of the followed cases.

Some authors have suggested to postpone surgery for up to 3 weeks in the case of a combination of ACL/PCL and MCL injury (?). With respect of the favorable non-operative treatment results of MCL healing a period of 3 weeks would allow the MCL to heal before ACL/PCL surgery is performed. This option in our view is feasible provided that the knee joint is perfectly reduced. A subluxation of the knee joint is not tolerable since the MCL would heal in an non-appropriate length. If there is any involvement of the lateral side however, we discourage delayed surgery due to the high degree of instability present during the MCL healing response. Additionally we find surgery after 10 days considerably more difficult due to soft tissue scarring.

Much controversy exists concerning the use of arthroscopy in the treatment of knee dislocations. Our approach to this problem is based upon the believe that an arthroscopic reconstruction of the cruciate ligaments poses less surgical trauma to the already traumatized knee than an additional parapatellar incision. However, great care has to be taken that there is no major extravasation into the surrounding soft tissue which might lead to a rise in compartmental pressure and eventually to a compartment syndrome. We therefore do not use an arthroscopic pump. As soon as swelling of the calf compartment is noted the arthroscopy is stopped and the procedure is performed using a mini-arthrotomy. A surgeon operating on knee dislocation has to be experienced in
arthroscopic and mini-open replacement techniques in order to be able to change the technique if necessary.

According to the results of our technique we feel that the reconstruction of the multiple ligament injured knee provides satisfactory subjective functional assessment, range of motion and stability. However, the ability of the patient to return to high demand sports and heavy manual labor is less predictable.