Clinical and imaging assessment in decision-making of complex patella luxation cases: surgical application of 3D planning and 3D guides

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Complications following surgical correction of medial patella luxation (MPL) have been reported to occur in up to 44% of cases (Gibbons, Macias et al. 2006, Cashmore, Havlicek et al. 2014, Kalff, Butterworth et al. 2014, Gallegos, Unis et al. 2016, Brower, Kowaleski et al. 2017, Willauer and Vasseur 1987). Complications occur at a higher frequency in larger breed dogs, and dogs with lateral patella luxation. Informed clinical and radiographic +/- CT assessment allows informed surgical decision-making and may be expected to improve outcomes following surgery.

The aim of this session is to improve clinical and imaging assessment of patella luxation cases in the frontal, sagittal and axial planes, review the components of a "standard" surgical repair for MPL, and identify cases that are *not* suitable for standard repair.

WHAT CAUSES PATELLA LUXATION?

Patella luxation most commonly results from malalignment of the quadriceps mechanism and the trochlea groove in the frontal plane such that weight-bearing results in medial (more common) or lateral displacement of the patella from the trochlea groove. Frontal plane malalignment can result from a combination of both frontal plane deformities and axial plane deformities of the femur and / or the tibia(Brower, Kowaleski et al. 2017, Zilincik, Hluchy et al. 2018).
Femoral varus and tibial valgus deformities are associated with MPL with more severe grades having significantly higher anatomic lateral distal femoral angles (aLDFA) and femoral varus angles (FVA)(Brower, Kowaleski et al. 2017, Zilincik, Hluchy et al. 2018) (Newman and Voss 2017).
Patella luxation can also be the result of axial or transverse plane malalignment. Medial patella luxation is commonly associated with a decreased angle of anteversion of the femoral neck with more severe grades of MPL having reduced femoral anteversion angles (FAA)(Zilincik, Hluchy et al. 2018). The acetabulum is typically retroverted approximately 15^0 and corresponds to the femoral neck which is anteverted to meet the acetabulum. Various FAA have been reported with normal values ranging from 16^0 to 31^0. Reduction in the femoral anteversion angle leads to external torsion (supination) of the distal femur and femoral trochlea. This effectively positions the trochlea lateral to the tibial tuberosity and increases the likelihood of MPL.

Patella luxation less commonly results from malignment of the patella in the sagittal (proximodistal) plane, such that at some point in the stifle joint range of motion, the patella luxates medially (more common) or laterally from the trochlea groove. Sagittal plane luxation on extension is associated with patella alta, where the patella is located relatively proximal to the trochlea groove(Johnson, Broaddus et al. 2006, Drew, Glyde et al. 2018). Sagittal plane luxation on flexion is associated with patella baja, where the patella is located relatively distal to the trochlea groove.(Mostafa, Griffon et al. 2008, Pugliese, Pike et al. 2015)

Tibial deformities can also contribute to malalignment leading to patella luxation. More severe grades of MPL may have a proximal valgus deformity +/- an axial / transverse plane deformity where the distal tibial is torsed externally which realitvely internally torses the proximal tibia.

Assessment of the tibia in the frontal and axial planes has been previously described. Joint reference angles for the tibia include:

- mMPTA mechanical Medial Proximal Tibial Angle 93^0.
- mMDTA mechanical Medial Distal Tibial Angle 96^0.
- Tibial torsion angle -3^0 (internal torsion)

WHAT IS "CLINICALLY SIGNIFICANT PATELLA LUXATION"? / WHICH GRADES OF PATELLA LUXATION REQUIRE SURGICAL CORRECTION?

Most cases of grade 1 MPL are not clinically significant, do not cause clinical signs, and do not require surgical correction. In some cases, most commonly obese dogs that progress to cruciate instability, a previously asymptomatic grade 1 MPL will progress to be clinically significant. Femoral varus +/- torsional deformities, can uncommonly result in significant patella maltracking without patella luxation, leading to clinical problems requiring correction.

Grade 2, 3 and 4 MPL should be surgically corrected.

Patella luxation reduces the efficiency of the quadriceps mechanism which requires more work from the animal for ambulation. The patella is a sesamoid that acts as a fulcrum in a pulley (the trochlea) which increases the moment arm of the patella tendon thereby decreasing the effort needed from the quadriceps.

Patella luxation also causes several detrimental secondary effects(Campbell 2010). These include:

- severity dependent secondary skeletal deformity. It is important to recognise that patella luxation is developmental not congenital. Hueter-Volkmann law largely explains the secondary skeletal developmental deformities. Bone growth is retarded by increased compression and accelerated by reduced loading
- full thickness cartilage erosion
- secondary osteoarthritis
- cruciate disease has been reported to occur in 40% of dogs with untreated MPL(Campbell 2010). Campbell et al (2010) found that grade 4 MPL cases were significantly more likely to have concurrent cruciate disease than lower grades. This is likely due to a combination of luxation reducing the patella tendon moment arm thereby increasing cranial tibial thrust, increased internal rotation of the tibia, and the presence of osteoarthritis.

DECISION-MAKING: HOW DO YOU DETERMINE WHICH CASES NEED WHAT SURGERIES FOR CORRECTION?

Assessing the frontal plane offset of the trochlea axis from the tibial tuberosity while the animal is weight-bearing is a critical part of the decision-making process. This is performed as part of the standing orthopaedic examination. It is important that this determination is performed when the quadriceps mechanism is loaded as the dynamic “bowstring” effect of the quadriceps mechanism is lost under general anaesthesia. Unloading of the quadriceps mechanism nearly always results in under-estimation of the magnitude of the offset and is a key source of decision-making error and consequent surgical failure.
The tibial tuberosity (TT) should be positioned immediately distal to the axis of the trochlea groove. Frontal plane offset between the trochlea groove and the TT results in some degree of patella malalignment with the groove ranging from patella mal-tracking in mild cases through to patella luxation. A subjective estimation of the offset distance should be recorded as this will be the amount of correction that is necessary.
It is important to remember that frontal plane offset between the trochlea and the TT can result from either single deformities or a combination of deformities. For MPL these include:

- distal femoral varus
- distal femoral external torsion (supination) / decreased femoral anteversion angle
- medial translation of the tibial tuberosity
- proximal tibial valgus
- distal tibial external torsion (supination) / proximal tibial internal torsion (pronation)

Full assessment for these deformities is best made with a combination of patella tracking CT scans from the hip to the pes and femoral and tibial radiographs. Various methods for measuring both radiographs and CT scans to assess for femoral and tibial deformities has been previously published and won’t be reviewed in this session. Being able to measure the relevant femoral and tibial angles are an essential skill to maximise success in managing cases of patella luxation.

Correction of the frontal plane offset by transposition of the TT, without surgical correction of the underlying or causative deformities, is achievable in nearly all grade 2 MPL cases and most grade 3 MPL cases. Some grade 3 cases and all grade 4 cases require that the individual causative deformities responsible for the frontal plane offset are identified and resolved, as treatment with TT

translation alone in these cases may fail. Increased degree of femoral varus (increasing aLDFA) has been shown to increase the risk of poor outcome and major complications(Perry, Adams et al. 2017). It would be rare to be able to effectively correct a grade 4 MPL using standard surgical correction of trochleoplasty, lateral fascial imbrication, medial desmotomy and tibial tuberosity transposition. Grade 4 cases nearly always have significant femoral +/- tibial deformities that makes patella mal-tracking (patella tracks obliquely or unevenly through the trochlea groove) and recurrence of luxation highly likely if standard surgical correction is used and the individual angular limb deformities are not also corrected.

No objective metric exists for determining how much translation of the TT is possible in an individual animal. Using CT, it is possible to measure the translation width of the tibia at the level of Gerdey's tubercle. My approach is to not translate the TT greater than 50% of this width. Translation greater than 50% probably reduces stability of the fixation but more importantly is usually associated with significant distal femoral varus +/- external torsion of the distal femur / reduced angle of anteversion. In these cases, correction of the femoral varus and femoral torsion in combination with translation of the TT is indicated in preference to a major / non-anatomical translation of the tuberosity.

Patella luxation can also result from relative sagittal plane (proximodistal) malalignment of the patella. This should also be assessed as part of the standing orthopaedic examination, however, can also be accurately assessed under general anaesthesia. Sagittal plane assessment is not affected by the quadriceps mechanism being "unloaded" under general anaesthesia, unlike frontal plane malalignment which is likely to be underestimated under GA.

Examination under GA should also be performed to assess for trochlea depth, whether the patella is captured by the trochlea groove throughout the range of motion, and for evidence of concurrent cruciate instability.

Various methods for trochleoplasty have been described. Trochlea block recession is more difficult than trochlea wedge recession however both are acceptable methods of deepening the trochlea and maintaining articular cartilage. Block recession has been shown to be superior to wedge in that it obtains better trochlea depth proximally and maintains more articular cartilage.
Cartilage elevation to maintain articular cartilage with resection of subchondral cancellous bone in immature animals is an acceptable method although infrequently used.
Trochlea resection where the articular cartilage is destroyed by being rasped away with the subchondral bone has been shown to create much greater morbidity, much greater OA and worse outcomes that methods that maintain articular cartilage. Trochlea resection is contraindicated, is unacceptable and has no place in veterinary surgery.
Patella groove replacement is commonly used particularly for salvage surgery after trochlea resection, and in some cases is used as a primary method of trochleoplasty. A retrospective case series of 35 cases with medium term follow up found 17% complications with revision surgery required in 9% of cases.
Ridgestop™ is a polyethylene synthetic trochlea ridge designed as a "cost-effective" alternative to trochleoplasty that is claimed to be minimally invasive and "more effective" than other trochleoplasties. Peer-reviewed published evidence on this procedure is currently lacking. It is promoted as a sole procedure or in combination with other procedures to resolve MPL. My experience with Ridgestop™ is limited to revision of complication cases.

Tibial tuberosity (TT) transposition is best achieved with a sagittal saw and can be achieved with a complete or a partial osteotomy. Cashmore et al (2014) showed that subsequent avulsion of the TT was 11 times more likely when a single K wire rather than 2 K wires were used. They also showed that avulsion did not occur in complete osteotomies when a tension band wire was used. Based on their retrospective study, the use of 2 K wires and a TBW is recommended if a complete osteotomy is performed.
We recently reviewed 208 cases of grade 2 and 3 MPL corrected with a partial osteotomy for a tibial tuberosity transposition. In this technique, the distal cortical bone is left intact to act as a tension band resisting the distraction force of the quadriceps mechanism. All these cases were stabilized with 2 K wires. A tension band wire was placed in 6 cases due to intraoperative fracture of the distal cortical bone bridge. In the other cases the intact distal cortical bone bridge acted as the tension band and the proximal part of the TT was pivoted laterally on the distal hinge point without fracture of the distal cortical bone. Five of these cases had postoperative recurrence of grade 2 patella luxation. Three of

these 5 cases had not received a concurrent trochleoplasty and the reluxation was resolved in these 3 cases by subsequent trochleoplasty.
For this reason, my standard approach for TT transposition in grade 2 and 3 MPL cases is a partial osteotomy stabilized with 2 K wires. If intraoperative fissure or fracture of the distal bone bridge occurs, a TBW is placed.

In conclusion, assessment of patella luxation cases should be made on each case individually with the aim of identifying the component abnormalities causing the luxation in *that case* rather than taking a “cookbook approach” to surgical decision-making.
Assessment is based on orthopaedic examination in combination with imaging to assess the frontal and axial plane deformities. Assessing the frontal plane offset between the centre of the trochlea groove and the tibial tuberosity while the dog is standing is fundamental to decision-making. A large offset would strongly suggest underlying angular deformities that require correction.
Nearly all grade 2 and most grade 3 cases can be successfully resolved with a “standard” surgical correction of some combination of trochleoplasty, medial desmotomy, lateral fascial imbrication and transposition of the tibial tuberosity with partial osteotomy and fixation with 2 K wires.
Cases with a large frontal plane offset, which includes some grade 3 cases and nearly all grade 4 cases, usually require angular limb deformity correction with distal femoral +/- tibial osteotomies or ostectomies.
Cases with a large sagittal plane offset where the patella is relatively displaced proximally or distally to the trochlea groove (patella alta or patella baja respectively) usually require a complete osteotomy of the tibial tuberosity to reposition the patella within the groove. Major distalisation of the tibial tuberosity distalises the insertion of the quadriceps mechanism and has been shown to significantly increase load through the quadriceps which may lead to complications. Consideration in these cases should be given to concurrent femoral shortening to relatively distalise the origin of the quadriceps and thereby normalize the load in the quadriceps.

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