A new approach to treatment selection in dogs with cranial cruciate ligament rupture: patient-specific treatment recommendations

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Abstract

Cranial cruciate ligament rupture is one of the most important diseases in canine orthopedics. Despite the frequent occurrence of the disease and the extensive literature available, there is still controversy about the best treatment method. The aim of this review article is to present a new, more specific approach to treatment selection in dogs with cranial cruciate ligament rupture. Patients are divided into different groups and particular treatment methods are then recommended according to group membership.

In order to develop the treatment recommendations, the patient groups were initially defined based on criteria that are important for treatment selection, such as type of cranial cruciate ligament rupture, chronicity, degree of instability, size and weight of the patient, stage of osteoarthritis, the presence of bone deformities, concurrent medial patellar luxation or rotational instability. A detailed literature search was conducted through MEDLINE/PUBMED; CAB Abstracts, Google Scholar and in conference proceedings abstracts from 1990–2019. Based on the available literature, treatment recommendations were developed for each patient group. These patient group-specific recommendations based on best available evidence are intended to simplify the decision-making process for treatment selection in dogs with cranial cruciate ligament disease.

Keywords: cranial cruciate ligament, dog, treatment, tibial osteotomies, extracapsular stabilization

Ein neuer Ansatz für die Therapieauswahl bei Hunden mit Kreuzbanderkrankung: Patientenspezifische Behandlungsempfehlungen

Die Ruptur des kranialen Kreuzbandes ist eine der wichtigsten orthopädischen Erkrankungen des Hundes. Trotz der Häufigkeit der Erkrankung und der umfangreichen vorhandenen Literatur, herrscht immer noch Uneinigkeit über die beste Therapiemethode. Ziel dieses Übersichtsartikels ist es daher, einen aktuellen, spezifischeren Ansatz für die Therapieauswahl bei Hunden mit kranialem Kreuzbandriss vorzustellen. Hierbei werden die Patienten in verschiedene Gruppen eingeteilt, für die dann jeweils eine bestimmte Therapiemethode empfohlen wird.

Für das Erarbeiten der Behandlungsempfehlungen wurden zunächst anhand verschiedener, für die Therapieauswahl wichtiger Kriterien verschiedene Patientengruppen definiert (Typ des Kreuzbandrisses, Chronizität, Grad der Instabilität, Grösse und Gewicht des Patienten, Arthrose-Stadium, Vorhandensein von Knochendeformationen, gleichzeitige mediale Patellaluxation oder Rotationsinstabilität). Anschliessend wurde eine ausführliche Literatursuche über MEDLINE/PUBMED; CAB Abstracts, Google Scholar und in Konferenzbänden von 1990–2019 durchgeführt. Anhand der verfügbaren Literatur wurden dann Behandlungsempfehlungen für jede der Gruppen formuliert.

Diese Patientengruppen-spezifischen Empfehlungen sollen dem Kleintierpraktiker den Prozess der Entscheidungsfindung für die Therapieauswahl bei Hunden mit Kreuzbandriss erleichtern.

Schlüsselwörter: Hund, Kreuzbanderkrankung, Behandlungsempfehlung, Tibiaosteotomien, extrakapsulärer Bandersatz

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Introduction

Cranial cruciate ligament rupture (CCLR) is one of the most common causes of hind limb lameness in dogs.[98,204] The cranial cruciate ligament (CCL), which is covered by synovial membrane, originates axially from the lateral femoral condyle and inserts at the cranial intercondylar area of the tibia.[6,89,208] It consists of two macroscopically distinct fiber bundles, which are loaded independently during flexion and extension due to their slightly different origins and insertions.[6,89] The smaller, craniomedial part is taut in extension and flexion, while the larger caudo-lateral part is taut in extension but loose in flexion. The counterpart of the CCL is the caudal cruciate ligament, which originates axially from the medial femoral condyle and attaches at the caudal intercondylar area and the popliteal incisura.[6,89] The CCL is essential for stifle joint stability.[6,89,110,181,188] It limits cranial tibial translation and prevents hyperextension. In addition, together with the caudal cruciate ligament, it contributes to rotational stability and, in extension, to the varus-valgus stability of the stifle by restricting internal rotation.[6,129] If the CCL is ruptured, the femoral condyles slide caudodistally on the tibial plateau slope during weightbearing. The shear force that causes this cranial translation of the tibia is referred to as "cranial tibial thrust".[110,173,181] During swing phase of gait, the tibia slides back into its starting position.[110] This forward and backward movement of the tibia leads to shear stress on the articular cartilage and may cause meniscal injuries[74,181], leading to synovitis and osteoarthritis.[4,19,55] Therefore, CCLR is not simply a ligament tear, but rather a whole-joint disease.[43,136,138]

There are conservative and surgical treatment options to treat CCLR. The goal of treatment is the restoration and long-term maintenance of joint function, pain reduction, stabilization of the joint, and the treatment of existing meniscal damage. Treatment should also slow down the progression of osteoarthritis and reduce the occurrence of late meniscal damage.

In most cases, several treatment methods can be successful.[8,112] However, there is often one method that is superior to others for a specific group of patients when evaluated in studies with objective outcome measures.[20,81,114,197] The aim of this review is to define different patient groups based on criteria that influence the treatment decision making. These criteria include chronicity, degree of instability, size and weight of the patient, stage of osteoarthritis, and presence of bone deformities. Based on current scientific evidence, we developed treatment recommendations for each patient group. In this article, different clinical presentations of canine CCLR are presented, followed by specific treatment recommendations for the corresponding patient group. This approach is new and may allow a more individual and practical approach to the treatment selection for CCLR.

Degenerative cranial cruciate ligament rupture

The majority of CCLR (99% in large- and medium-sized dogs) are a result of CCL degeneration without substantial trauma. For this reason, CCLR is often referred to as CCL disease rather than just as a ligament tear.[79,86,145,191] All dogs can suffer from a degenerative CCLR. However, middle aged, large dogs (body weight >15kg) are typically affected, with Newfoundland, Bulldog, Boxer, Labrador Retriever, Saint Bernard and American Staffordshire Terrier being over-represented.[61,182,199,204] In 22%–54% of cases the disease is bilateral.[22,32,39,51,56,139]

The causes for CCL degeneration are controversial, but mechanical overload seems to play an important role.[42,87,112] Other risk factors are a genetic predisposition (proven in Newfoundland and boxers),[10,143,201] body weight and low activity level,[25,199] castration,[199,204] inflammatory processes in the joint[19,55] and certain hind limb conformations.[83,84,95,97]

Two stages of degenerative CCLR can be differentiated, making these cases clearly different from acute traumatic CCLR (Figure 1). The early degenerative stage is characterized by synovitis, first signs of osteoarthritis and progressive CCL degeneration.[19,39] However, there are no substantial fiber ruptures, which is why the joint is stable during palpation.[19,165] Clinical symptoms during this stage are subtle, such as intermittent or mild lameness, varying degrees of joint effusion, and pain on stifle palpation, especially in extension. Radiographs show joint effusion and mild degenerative changes in the early stages.[39]

Late degenerative stage cranial cruciate ligament disease (CCLD) is characterized by marked degenerative changes in the stifle joint, joint effusion, synovitis, and peri-articular fibrosis.[87] This is also evident on radiographs (Figure 1). Clinical symptoms of the late stage include more severe lameness, especially after exercise, medial peri-articular fibrosis ("medial buttress"), joint effusion, muscle atrophy, and pain on stifle manipulation.[135] A meniscal click may be palpated in some cases. If the CCL is completely ruptured, a positive cranial drawer and tibial compression test complement the findings.[89,135] These tests should be performed in sedated animals to increase their accuracy, especially in case of large or nervous dogs.[35] For the majority of cases, CCLR can be diagnosed by clinical evaluation. However, or-

thogonal radiographs are always recommended to rule out other pathologies and to evaluate tibial plateau angle (TPA) and bone alignment.[52]

Treatment

In most cases, CCLR should be treated surgically.[190,206] This results in rapid pain reduction and early return to normal limb function.[190,206] Physical therapy has been shown to improve the treatment outcomes, no matter if the dog was treated surgically or conservatively.[128,130,163] Physical therapy after CCLR repair aims at decreasing inflammation and pain, maintaining or improving joint range of motion, restoring muscle flexibility, strength, endurance and mass, and normalizing proprioception and neuromuscular patterning.[126]

Surgical treatment of degenerative CCLD usually involves arthroscopy or arthrotomy for evaluation and treatment of the intra-articular structures, followed by stabilization of the stifle joint. There are various methods of stabilization, which can be classified into extracapsular techniques, intracapsular techniques and tibial osteotomies. While intra- and extracapsular techniques intend to replace the CCL, tibial osteotomies alter the biomechanics of the joint to eliminate "cranial tibial thrust", thus restoring craniocaudal stability.[21,106,107,131,183] Extracapsular techniques and tibial osteotomies are the most commonly used techniques.[59,196]

Joint evaluation

The scientific evidence shows that a joint evaluation is highly recommended in any case of CCLR, because it is the gold standard to assess the intra-articular structures, first and foremost being the menisci.[38,160,161,186] The damage caused by the intervention is negligible in a joint that has already been affected by secondary degenerative changes.[11,147,152]

Arthroscopy has many benefits in comparison to conventional or minimally invasive craniomedial arthrotomy. The magnification and the small diameter of the arthroscope allows a complete visualization of the joint. Arthroscopy therefore permits a more precise evaluation and treatment of menisci, cartilage and cruciate ligaments. In a study with 9 weeks follow up after arthroscopy or arthrotomy and subsequent joint stabilization, patients from the arthroscopy group recovered faster after the procedure.[92] Disadvantages of arthroscopy are the high costs for equipment and the expertise required. Craniomedial sub-patellar arthrotomy is another approach to decrease post-operative morbidity associated with arthrotomy. However, with this method a complete evaluation of the joint is not possible and meniscal tears can be overlooked, especially in the lateral joint compartment.[11,113,152] Furthermore, the treatment of meniscal damage and debridement of the cruciate ligament remains difficult due to the small approach, which increases the risk of cartilage damage.[11] In conclusion, arthroscopy is currently the most accurate method for stifle joint evaluation.[147,152,158,200]

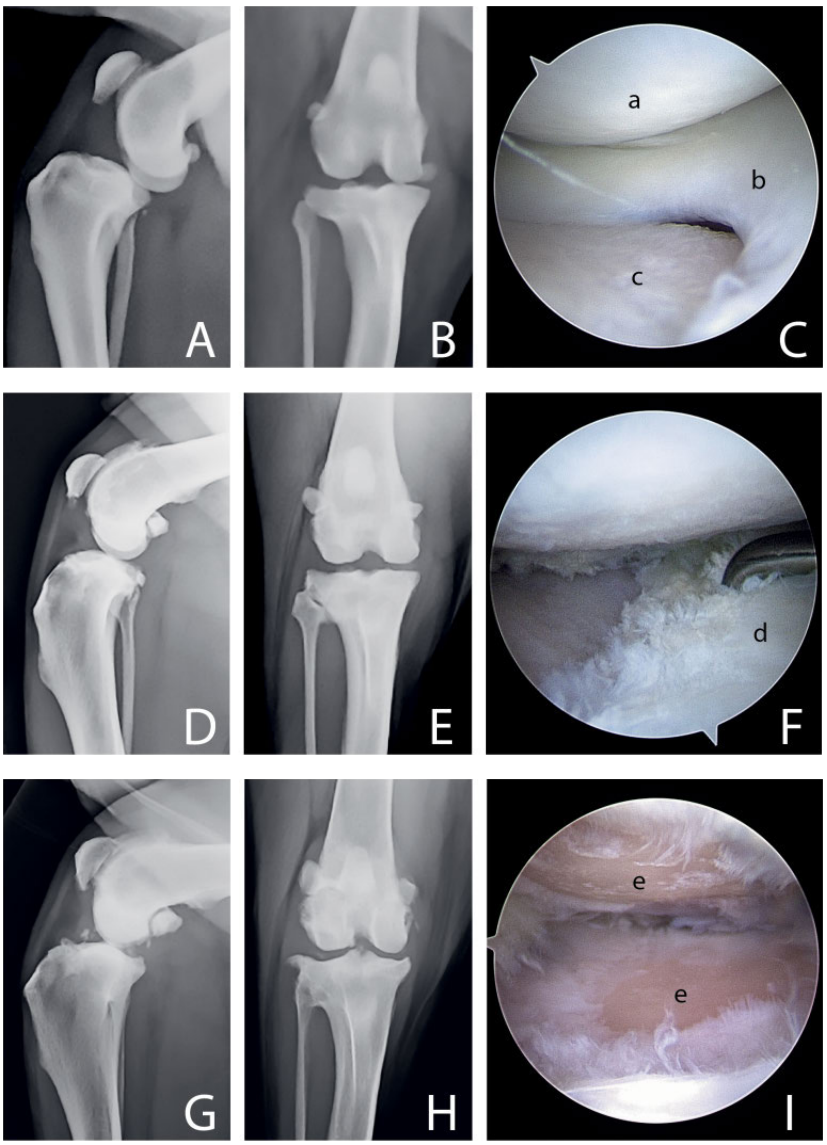

Figure 1: Mediolateral and craniocaudal stifle joint radiographs with corresponding arthroscopic images of three dogs with different CCLR-types. **A, B, C Acute traumatic CCL rupture:** The radiographs show marked cranial tibial subluxation and a massive joint effusion without signs of osteoarthritis. (A, B). The arthroscopic image (C) shows a normal meniscus (b) and normal cartilage of the femur (a), while the tibial cartilage (c) appears slightly irregular. **D, E, F Early degenerative CCL rupture:** The radiographs show joint effusion and moderate degenerative changes of the joint. (D, E). In the arthroscopic image (F) both the cartilage of the tibia and of the femur have an irregular surface. The rim of the meniscus (d) is examined with a meniscal probe and looks abnormal, which indicates a degenerated meniscus. **G, H, I Late-degenerative CCL rupture:** The radiographs show severe osteoarthritic changes, joint effusion, peri-articular new bone formation and intra-articular mineralization (G, H). The arthroscopic image (I) shows fibrillation and full thickness erosion (e) of the articular cartilage with exposed subchondral bone on both tibial plateau and femoral condyles. The meniscus is is no longer visible, most likely because of the chronicity of the disease.

Cranial cruciate ligament debridement

CCL debridement is a controversial procedure with little evidence to support it. Hulse et al. were able to show that the tibial plateau leveling osteotomy (TPLO) has a protective effect on the intact fibers in partial functional CCLR. This effect may be due to a reduction in cranial tibial thrust force and a concomitant reduction of the load on the CCL.[94] A similar effect was also demonstrated for the tibial tuberosity advancement (TTA).[171] The remaining intact fibers in a partial functional CCLR are important, because they contribute to joint stability and may prevent meniscal and cartilage damage.[94,158] Therefore, in partial functional CCLR treated by TTA or TPLO only torn CCL fibers should be debrided.[94,171]

With complete CCLR, however, a complete debridement of the CCL remnants is recommended, since the CCL remnants are a possible source of inflammation mediators and pain and because their removal facilitates exploration of the joint.[44,112,176]

Treatment of meniscal damage

Thirty-three to eighty-three percent of dogs with CCLR already have meniscal damage at the time of initial surgery.[36,68,70,71,78,115,144,158,161] Although repeatedly questioned, the available literature shows that the diagnosis and treatment of meniscal injury at the time of initial surgery leads to a better outcome, faster recovery, and a lower risk of late meniscal damage.[31,160] In addition, an accurate meniscal evaluation decreases the risk of late meniscal injuries and the need for a second surgery to treat them. For those reasons, a thorough evaluation of the menisci with subsequent treatment of meniscal injuries is highly recommended.[65,73,96,160,161] The first and most important step for the successful treatment of meniscal injuries is a careful and detailed examination of both menisci. The menisci should be assessed with arthroscopy and probing to evaluate meniscal appearance, integrity, and consistency.[82]

The caudal pole of the medial meniscus is most frequently affected by injuries.[13,158] The lateral meniscus can be injured alone or in combination with damage to the medial meniscus in association with CCLR.[113,119,158,203] A study by Ralphs et al., 2002, reported lateral meniscal tears in 77% of dogs with CCLR undergoing stifle arthroscopy.[158] However, the clinical significance of these lateral tears remains unknown.[113,158] Meniscal injuries are classified based on the type of injury, the time of occurrence, and their location.[70,73] The most important factor for treatment selection is the location of injury. Meniscal tears that affect only the axial part of the meniscus should be treated differently to injuries that involve the axial and the periphery of the meniscus. The goal of meniscectomy is to remove abnormal tissue that contributes to the inflammatory and degenerative processes in the joint, thereby reducing pain and lameness, while still maintaining meniscal function. It is therefore recommended to remove as little meniscal tissue as possible, but as much as necessary.[74,156,185] In selected cases, meniscal repair might also be an alternative to meniscectomy.[45,184]

Meniscal injuries that occur after initial surgical stabilization of the stifle are referred to as late meniscal tears. The frequency of occurrence of late meniscal tears depends on the stabilization method used (TPLO: 3%–12%,[68,101] TTA: 6%–21%[49,115,178]). However, "meniscal release", introduced as a prophylaxis for late meniscal tears, is not generally recommended. Meniscal release involves axial or abaxial transection of the intact meniscus at time of the initial surgery.[123,151,154,172] Even if meniscal release reduces the occurrence of late meniscal tears, this advantage has to be weighed against its negative effects.[155] Meniscal release leads to complete loss of meniscal function, which results in cartilage damage and a faster progression of osteoarthritis.[123,153,154]

Which treatment methods are recommended for large dogs (> 15 kg)?

Based on the available evidence, tibial osteotomies, especially the TPLO, appear to be the most appropriate treatment method for large dogs with CCLR.[17,21,23,43,46,49,64,81,93,104,114,115,121,124,131,132,141,144,157,162,170,174,177,178,197,206] A recently published systematic review concluded that the available literature shows, that the TPLO has a lower complication rate, less osteoarthritis progression and a better clinical-functional outcome than the TTA.[12,132] However, there are significantly fewer studies evaluating the TTA than the TPLO. The only direct comparative study reported TPLO to be superior to the TTA, but that study involved only relatively few cases.[114] Nevertheless, TTA is widely used and leads to good or very good clinical results.[64,115] Further prospective comparative studies with larger sample sizes are required to confirm the superiority of one technique over the other. Conservative management has also been described in large dogs, but with a less favorable treatment outcome than surgical treatment.[206]

In several prospective studies, large dogs treated with TPLO had better outcomes and less progression of osteoarthritis compared to dogs managed conservatively or treated with extracapsular techniques.[17,20,81,114,121,141,206] However, extracapsular techniques have been reported to be successful in selected cases.[38,43,121]

Even so, it has to be kept in mind that none of the currently available techniques are capable of restoring normal stifle joint kinematics after CCLR. This explains late meniscal tears, cartilage damage and progression of osteoarthritis occurring after joint stabilization.

Which treatment methods are recommended for small dogs (<15 kg)?

In small, older and inactive dogs, conservative management is widely used with good success in some cases.[41,148,190] However, there is a longer recovery period (four to five months) than after surgical stabilization. During that time the osteoarthritis progresses unhindered.[43,190]

Therefore, surgical treatment is often recommended for small dogs as well, to achieve a faster return to normal limb function.[14,48,66,205] A surgical technique often used in small, older or less active dogs is extracapsular stabilization.[59] The lower body weight may be one of the reasons for the decreased complication rates in comparison to large dogs.[14,36]

However, the tibial plateau is often steeper in small dogs than in large dogs, particularly in West Highland White Terriers, Yorkshire Terriers and Bichon Frisés.[72] This steeper tibial plateau results in higher cranial tibial thrust, which might lead to premature loosening of the extracapsular stabilization.[1,37,72,174,192] The load on the suture can also be increased due to a high activity level of the dog in the postoperative period.[36,52,187,205] Dynamic techniques such as TPLO or TTA are therefore better suited in small dogs with steep tibial plateau and for small dogs expected to be very active in the postoperative period. The available studies evaluating these techniques in small dogs show acceptable to excellent treatment results.[14,48,63,66,146,193,205] A study comparing TPLO and extracapsular stabilization techniques demonstrated a lower degree of lameness after 6 months, shorter convalescence and a higher level of owner satisfaction in the TPLO treatment group.[14] Studies in small dogs directly comparing TTA and TPLO are not yet available.

Which treatment methods are recommended for large dogs with an excessive tibial plateau angle?

TPA of > 34 ° are termed "excessively steep".[174,175,180] Since excessive TPA results in high cranial tibial thrust, treatment techniques that eliminate this shear force, such as TPLO, are recommended.[58,180] However, correction of excessive TPA with TPLO requires a large rotation of the osteotomy fragment, which potentially increases the risk of tibial tuberosity fractures.[16,198] This risk is particularly high when the osteotomy fragment is rotated below the insertion of the patellar tendon.[85] This problem is less significant in small dogs with excessive TPA, since good treatment results were achieved in a study with this patient group with only TPLO.[48,205]

For large dogs with excessive TPA, correction can be achieved with standard cranial tibial closing wedge osteotomy (CTWO), a modified CTWO or TPLO in combination with CTWO.[76,106,180] The TTA is not commonly used in dogs with excessive TPA, since sufficient cranialization of the tibial tuberosity is often not possible with the available implants.[21,194]

Which treatment methods are recommended for dogs with cranial cruciate ligament rupture and end-stage osteoarthritis without palpable instability?

Some dogs with CCLR present with advanced osteoarthritis induced by chronic instability and continuous inflammation and degeneration of the joint.[4,187] In these cases, joint adaptation, including peri-articular fibrosis and osteophyte formation can be so advanced that instability may not be detectable at palpation.[53,127,135,181] In such cases, surgical stabilization may be less likely to improve function, since the main cause of pain is the osteoarthritis rather than the joint instability.[91,181,189] These dogs may be candidates for conservative management, which can be combined with arthroscopy or arthrotomy for the treatment of meniscal tears, if meniscal injury is suspected.[91,181,189]

Conservative management of dogs with stifle osteoarthritis is not different from the treatment of osteoarthritis in other joints. It is a multimodal treatment with weight reduction being one of the key components.[27,100,102] Depending on the stage of osteoarthritis, medications such as non-steroidal anti-inflammatories can be used to relieve pain and reduce inflammation.[100,120,125] The use of tramadol, however, has been questioned in a recent study.[29] The intra-articular injection of corticosteroids is also a controversial topic.[99] On one hand, corticosteroids are very potent anti-inflammatories that effectively act on the inflammatory processes in osteoarthritic joints.[62,75] On the other hand, they are also known to be chondrotoxic.[57,99,140,168] The advantages and disadvantages of steroid injections should be carefully weighted before their use. Other therapeutic options are disease-modifying drugs or nutraceuticals (e.g. chondroitin sulfate, polysulfated glycosaminogylcane or omega 3 fatty acids), intra-articular injection such as injection of hyaluronic acid or orthobiologics, which include biological substances such as mesenchymal stem cells or platelet-rich plasma. Unfortunately, most of these substances lack validation by controlled, randomized clinical trials, but results to date are promising in terms of pain relief and reduced progression of osteoarthritis.[28,34,40,47,62,75,90,134,137] When conservative management fails, surgical options such as total knee replacement or stifle arthrodesis should be considered. Both procedures are invasive and complications can be severe, thus a risk-benefit assessment should always be done by the surgeon. Unlike in human medicine, total knee replacement is not yet routinely used in veterinary practice.[2]

Acute traumatic cranial cruciate ligament rupture

Acute traumatic ruptures of the CCL are rare.[135,145] In medium and large breed adult dogs, acute traumatic CCLR accounts for only about 1% of cases.[135] An intact CCL without previous degeneration only ruptures as a result of severe trauma. Possible traumatic mechanisms are hyperextension (e.g. the dog steps into a hole while running), excessive internal rotation of a flexed stifle, or severe blunt trauma (e.g. car accidents, high-rise syndrome), with the latter often accompanied by multiligament injuries or joint luxation.[5,26,133] In skeletally immature dogs, severe trauma often results in CCL avulsion, as the juvenile bone is weaker than the bone-ligament interface.[112,159] In adult dogs, despite the acute occurrence, there is often pre-existing degeneration of the CCL usually in the core of the ligament.[52] The classification of CCLR as acute traumatic or degenerative is difficult in these dogs.

Clinically, the degree of lameness observed after acute traumatic CCLR tends to be more severe than after degenerative CCLR. On palpation, severe pain, soft-tissue swelling, marked joint effusion and pronounced instability can be found.[26,52,111,112,135,159] Concurrent collateral ligament injuries can be detected with varus or valgus stress.[116] The integrity of the caudal cruciate ligament should always be evaluated.[21,116] Radiographs usually show acute soft tissue swelling, joint effusion with no signs of osteoarthritis. In immature dogs an avulsion fragment may be detectable in both orthogonal radiographs. The most important radiographic difference between degenerative and acute traumatic CCLR is the lack of degenerative joint disease secondary changes (Figure 1).[52,112]

Treatment

In acute traumatic CCLR with an avulsed fragment, a repair can be attempted using suture material, Kirschner wires or a lag screw if the fragment is of sufficient size.[159] Unfortunately, in most cases the avulsed fragment is too small to allow a strong repair, requiring other techniques as described for the treatment of degenerative CCLR.[52,159,195] These techniques should also be employed in adult dogs suffering from acute traumatic CCLR. Skeletally immature dogs with sufficient growth potential in the proximal tibial physis can be treated with cranial tibial epiphysiodesis, a technique that can achieve tibial plateau leveling without an osteotomy.[195] A screw is inserted into the cranial part of the tibial plateau in order to stop the growth from the most cranial aspect of the physis, while allowing continuous growth at the caudal aspect. This eccentric growth leads to a decreased TPA. Proximal tibial epiphysiodesis is a good alternative to TTA or TPLO, especially in large young dogs, where these techniques should not be used because of an actively growing proximal tibial physis.[195] For dogs in which the proximal tibial physis still has growth potential, but not enough for proximal tibial epiphysiodesis, techniques such as the closing tibial wedge osteotomy (CTWO) or the CORA based leveling osteotomy (CBLO) can be used. With these techniques, the osteotomy is performed below the proximal tibial physis.[106,108]

Acute traumatic CCLR are usually associated with increased rotational instability, which should be considered in the treatment selection (see the section "Rotational instability - a new criterion for the choice of treatment in CCLR").[109,166]

Cranial cruciate ligament rupture and medial patellar luxation

Concurrent medial patellar luxation (MPL) and CCLR have been reported in 6% to 20% of dogs, most commonly in smaller breeds.[7,33,52,80,202] Although the exact mechanism is unknown, the abnormal limb conformation and increased joint rotation in MPL may lead to higher stress on the CCL, which might accelerate its degeneration and ultimately result in CCLR. This is particularly important with MPL grade 3 and 4 since the stabilizing effect of the patellar tendon on the stifle joint may be absent most or all the time.[7,33,52] Another mechanism is the increased internal tibial rotation after a CCLR that may favor the development of MPL because of medial translation of the tibial tuberosity.[117]

Dogs that suffer from both CCLR and MPL usually show the typical clinical signs of CCLR. In addition, there is often a history of chronic, intermittent lameness due to MPL, which becomes acute due to the CCLR.[33,52] The grade of MPL in dogs affected by both conditions is often higher than before the CCLR.[33]

Treatment

The goal of surgical treatment of concurrent CCLR and MPL is to eliminate cranial tibial thrust caused by CCLR and to realign the extensor apparatus to reduce patellar luxation.[69,118] The standard techniques for MPL treatment (e.g. sulcoplasty, tibial tuberosity transposition (TTT) or soft tissue techniques like fascia imbrication or muscle release) are combined with suitable techniques for joint stabilization for CCLR (Figure 2).[118]

The deformities existing in some dogs with MPL should be corrected in combination with the treatment of CCLR.[54,112,164] Mild deformities of the proximal tibia may be treated with TTT in combination with an extracapsular suture. For dogs with severe deformities or for dogs with high activity levels, modified TTA or

TPLO techniques can be used. The modified TTA includes lateralization of the tibial tuberosity in addition to the cranial transposition to realign the quadriceps mechanism. This technique is called "tibial tuberosity transposition – advancement" (TTTA).[142,207] For the modified TPLO, the semicircular osteotomy fragment is shifted medially, resulting in lateral transposition of the distal rest of the tibia, which also includes the tibial tuberosity, therefore achieving realignment of the extensor apparatus.[67,69,117]

For severe femoral deformities, a corrective osteotomy is recommended in addition to treatment of CCLR.[24,179] The outcome after combined treatment of CCLR and MPL is generally good to excellent.[117,118,207] However, cases with MPL grade 4 or cases with severe deformities have a higher risk of complications.[60]

Rotational instability – a new criterion for treatment selection in canine cranial cruciate ligament rupture

In 33% of dogs treated with TPLO and 70% of dogs treated with TTA, there is persistent cranial tibial translation during postoperative weightbearing.[103,170] While the reasons behind this persistent instability are multifactorial, a combination of rotational instability and incomplete elimination of cranial tibial thrust may be a significant factor in some dogs.[103,170] Stifle rotational instability, defined as an excessive rotation of the tibia relative to the femur, is poorly described in dogs. The shear forces resulting from rotational instability have devastating effects on the articular cartilage.[3] Furthermore, it has been suggested that a minimal, clinically undetectable rotational instability could be responsible for the occurrence of late meniscal tears.[166]

Predisposing factors for rotational instability may be hyperlaxity of the stifle joint, conformation anomalies of the limb, and muscular deficits. Hyperlaxity is found in dogs with acute traumatic CCLR with or without damage to other stifle ligaments, or in dogs with complete, degenerative CCLR without significant peri-articular fibrosis.[166] Conformational anomalies that are thought to promote rotational instability include both femoral and tibial deformities.[16,21,78] Muscular deficits, particularly when affecting the caudal thigh region, are believed to be another reason for rotational instability or increased internal rotation of the stifle. It has been described in humans that the thigh musculature is able to compensate for rotational instability up to a certain extent.[122,169] This may also apply to the dog, which is why muscular deficits in this region are likely to favor rotational instability.[109] Other causes for rotational instability in dogs that underwent TPLO are insufficient

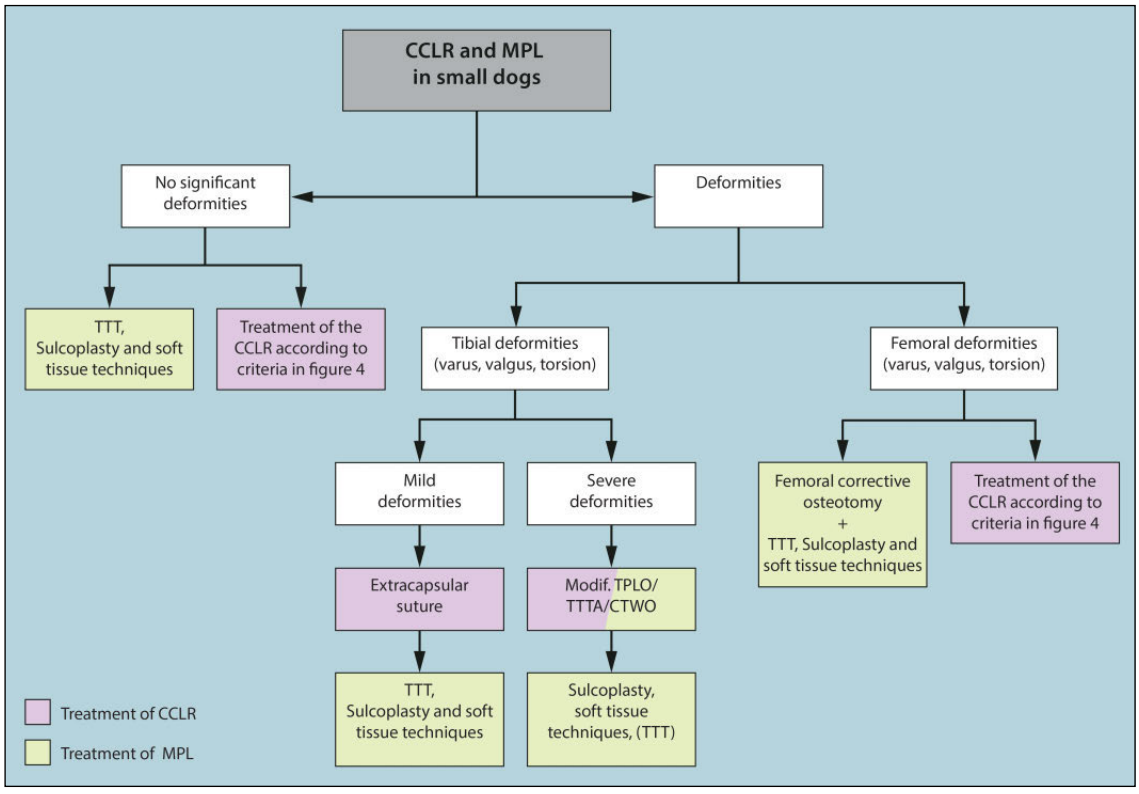

Figure 2: Recommended decision-making steps in dogs with cranial cruciate ligament rupture and concurrent medial patellar luxation. (TTT = tibial tuberosity transposition, TTTA = tibial tuberosity transposition-advancement)

rotation or a postoperative rock back of the osteotomy fragment.[15] A phenomenon associated with rotational instability is "pivot shift" (PS). In humans, PS is described as anterior subluxation of the tibia from below the lateral femoral condyle combined with a sudden external rotation.[30,77] Patients also describe it as a "giving way" of the knee when weightbearing.[77] In veterinary medicine, 0.3%–3.1% of dogs treated with TPLO demonstrate the same phenomenon postoperatively.[68,78] Pivot shift in dogs occurs as a combination of cranial tibial translation and internal tibial rotation, resulting in a sudden lateral change in direction of the stifle joint during weight bearing.[166] Apart from an incorrectly performed TPLO or postoperative rock back, insufficient correction of both femoral and tibial deformities is suspected to be one of the main causes of PS in dogs, as the TPLO mainly stabilizes the joint in the craniocaudal plane.[15,68,78,105] So far, PS has not been described after TTA, although there is evidence of persistent instability after TTA.[167,170]

During preoperative clinical examination, it is often difficult to assess how much rotational instability contributes to the overall instability of the stifle joint, since craniocaudal instability is usually very prominent. Therefore, it is recommended to reevaluate rotational stability after stabilization.[166] For detecting rotational instability, the authors have used a modified tibial compression test by combining a rotational stress to the compression force applied to the stifle. For this test, the observer's hands are placed as for a standard tibial compression test and the stifle is held at a 135° angle (standing angle) with the stifle joint and paw aligned sagittally. Then, before applying tibial compression by flexion of the tarsal joint, the paw is externally rotated 10 degrees and a valgus stress is applied. After compression is established, external rotation is gradually released, allowing the tibia to internally rotate and eventually subluxate. The test is positive if there is a visible and palpable jerky subluxation, and internal rotation of the tibia in the transverse plane, which is more pronounced laterally than medially.[149] After TTA, it is more challenging to assess craniocaudal and rotational instability intraoperatively, since the TTA requires contraction of the quadriceps muscle to stabilize the stifle joint.[21] In theory, it would be possible to pull the patella proximally during the tibial compression test in order to simulate quadriceps contraction. In practice, however, this is almost impossible as not enough force can be generated manually (Boudrieau, Kowaleski, Kim, personal communication, 2018).

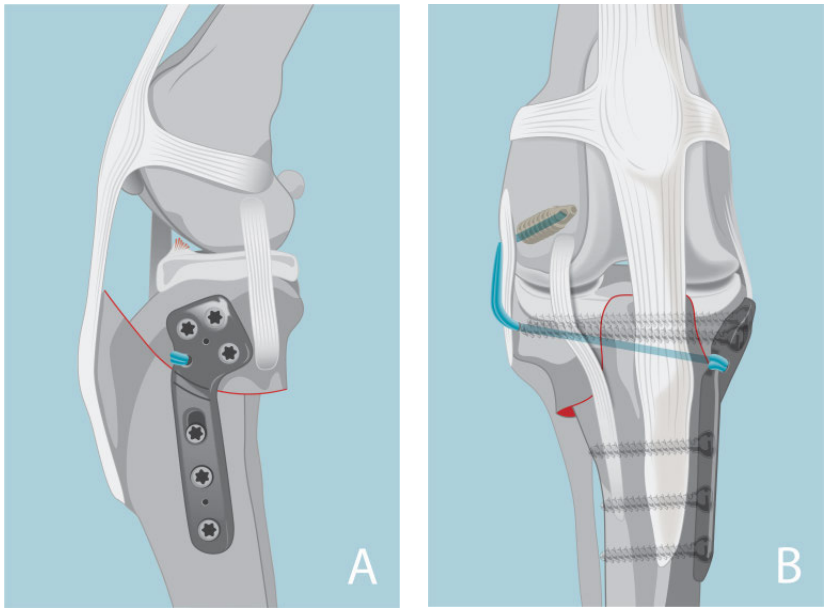

Figure 3: Combination of tibial plateau leveling osteotomy (TPLO) and extracapsular suture for the treatment of rotational instability with a new type of TPLO plate (TPLO Internal Brace, Arthrex, Munich). **A** medial view, **B** cranial view

Treatment

Because the significance of rotational instability in dogs has only been recognized recently and extensive literature and clinical experience in this area are still lacking, it is difficult to make evidence-based treatment recommendations. Conservative management with physical therapy has been described, but with varying degrees of success.[68,78] Schaible et al. treated dogs with rotational instability successfully using TPLO and an extracapsular suture.[166] With this combination, the tibial osteotomy ensures craniocaudal stability, while the extracapsular suture eliminates excessive internal rotation.[88] To simplify the placement of an extracapsular suture next to the TPLO plate, a new plate type has been developed, which allows to directly attach the suture to the plate (TPLO Internal Brace, Arthrex, Munich) (Figure 3).[150] For smaller, less active dogs without conformational anomalies suffering from CCLR with rotational instability, treatment with an extracapsular suture only may be sufficient. The advantage of extracapsular suture techniques for the treatment of CCLR with rotational instability is their ability to eliminate both cranial translation and excessive internal rotation of the tibia.[9,18,50]

Conclusions

This article introduces a new, clinically applicable approach to treatment selection in dogs with CCLR. The treatment recommendations given in the article were developed in three steps. In the first step, patient groups were defined based on the criteria chronicity, degree of instability, size and weight of the patient, stage of osteoarthritis and the presence of bone deformities. The following patient groups were defined: large dogs

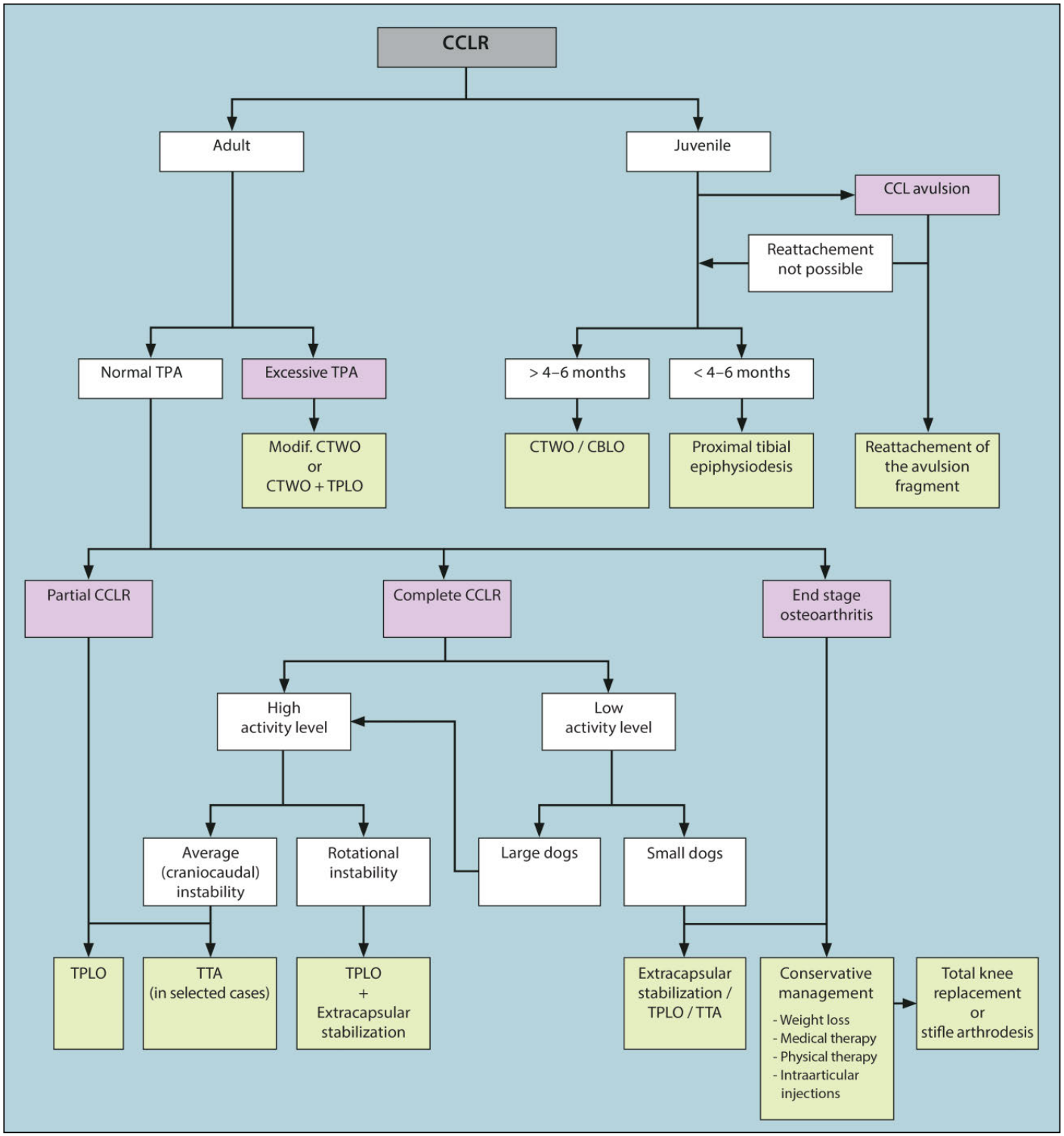

Figure 4: Algorithm for treatment selection in canine cranial cruciate ligament rupture based on best available evidence and personal experience. (Purple boxes = CCLR-types, green boxes = treatment recommendations)

(> 15 kg), small dogs (<15 kg), dogs with excessive TPA, dogs with CCLR and advanced osteoarthritis without palpable instability, dogs with acute traumatic CCLR, dogs with CCLR and MPL and dogs with CCLR and rotational instability of the stifle joint.

In the second step, several databases (MEDLINE / PUBMED; CAB Abstracts, Google Scholar) were searched for evidence (keywords: canine, cranial cruciate ligament rupture, treatment). The findings from the retrieved literature were then combined to formulate

treatment recommendations for each patient group. Figure 4 summarizes the treatment recommendations supplemented by our experience, where there was no available evidence. The approach with patient-specific recommendations is a new, more refined method for treatment selection in dogs suffering from CCLR. The treatment recommendations are intended to facilitate the decision making for treatment selection in canine CCLR for small animal practitioners. However, they are not intended to be strict guidelines. Additional factors such as costs, owner expectations and surgeon's experience have to be taken into account before selecting a treatment method.

Scientific studies that examine the safety and efficacy of a treatment method should form the basis of all treatment recommendation. However, a recent review article stated that for most treatment methods, except for the TPLO, there is not sufficient evidence to adequately evaluate them.[17] It is therefore possible that other techniques, when applied to a suitable patient, lead to treatment results comparable to the TPLO. Therefore, future studies should consider reporting results using patient groups. This will make it possible to establish patient-specific treatment guidelines that are completely based on high-quality evidence.

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Conflict of interest

A. Pozzi and S. Knell are consultants of Arthrex®.

Une nouvelle approche du choix thérapeutique chez les chiens atteints de pathologie des ligaments croisés: recommandations de traitement spécifiques au patient

La rupture du ligament croisé antérieur est l'une des affections orthopédiques les plus importantes chez le chien. Malgré sa fréquence et la vaste littérature disponible, il existe toujours un désaccord sur la meilleure méthode de traitement. Le but de cet article de revue est donc de présenter une approche actuelle et plus spécifique pour la sélection de traitements chez les chiens présentant une déchirure du ligament croisé antérieur. Les patients sont divisés en différents groupes, pour lesquels une méthode spécifique est alors recommandée. Afin d'élaborer ces recommandations de traitement, différents groupes de patients ont été initialement définis sur la base de plusieurs critères importants pour la sélection de la méthode (type de déchirure du ligament croisé, chronicité, degré d'instabilité, taille et poids du patient, stade de l'arthrose, présence de déformations osseuses, luxation patellaire médiale simultanée ou instabilité rotationnelle). Par la suite, une recherche documentaire détaillée a été effectuée via MEDLINE/PUBMED; CAB Abstracts, Google Scholar et dans les actes de conférences de 1990 à 2019. Des recommandations de traitement ont ensuite été formulées pour chacun des groupes sur la base de la littérature disponible. Ces recommandations spécifiques aux groupes de patients sont destinées à permettre au praticien des petits animaux de prendre plus facilement sa décision lors de

Un nuovo approccio per la scelta della terapia per i cani affetti da malattie del legamento crociato: raccomandazioni di trattamento specifiche per il paziente

La rottura del legamento crociato craniale è una delle piu'comuni malattie ortopediche del cane. Nonostante la frequenza della malattia e la vasta letteratura disponibile, c'è ancora disaccordo sul miglior metodo di trattamento. Lo scopo di questo articolo è quello di presentare un approccio aggiornato e più specifico alla selezione della terapia per i cani con rottura del legamento crociato craniale. I pazienti saranno divisi in diversi gruppi, per ognuno dei quali sarà raccomandato un metodo di trattamento specifico. Per elaborare le raccomandazioni terapeutiche, sono stati dapprima definiti diversi gruppi di pazienti sulla base di vari criteri importanti per la selezione della terapia (tipo di rottura del legamento crociato, cronicità, grado di instabilità, dimensioni e peso del paziente, stadio di artrosi, presenza di deformazioni ossee, lussazione della rotula mediale o instabilità rotazionale contemporanea). Successivamente, è stata condotta un'ampia ricerca bibliografica tramite MEDLINE/PUBMED; CAB Abstracts, Google Scholar e negli atti di conferenze dal 1990 al 2019. Sulla base della letteratura disponibile, sono state poi formulate raccomandazioni di trattamento per ciascuno dei gruppi.
Queste raccomandazioni specifiche per i gruppi di pazienti hanno lo scopo di facilitare il processo decisionale del veterinario di piccoli animali per la selezione

la sélection des méthodes thérapeutiques chez les chiens présentant des déchirures des ligaments croisés.

Mots clés: Chien, affection des ligaments croisés, recommandations de traitement, ostéotomies du tibia, remplacement extracapsulaire du ligament

della miglior terapia per i cani con rottura del legamento crociato.

Parole chiave: Cane, malattia del legamento crociato, raccomandazione di trattamento, osteotomie tibiali, sostituzione del legamento extracapsulare

A new approach to treatment selection in dogs with cranial cruciate ligament rupture: patient-specific treatment recommendations

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