EVALUATION OF PELVIC LIMB ANGLES IN DOGS WITH MEDIAL PATELLAR LUXATION: COMPARISON OF RADIOGRAPHY AND COMPUTED TOMOGRAPHY

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Summary

The aim of the present study was to compare the results from measurements of anatomical and mechanical angles of the femur and tibia by means of two diagnostic imaging methods – conventional radiography and computed tomography in normal dogs and dogs with medial patellar luxation (MPL). The study was done with 16 dogs (23 joints) from four small breeds (Mini-Pinscher, Chi-hua-hua, Yorkshire Terrier and Pomeranian). The results showed statistically significant differences between both imaging techniques in the values of mechanical lateral proximal femoral angle (mLPFA) and anteversion angle (AA) in joints with grade II MPL and in the anatomical lateral and medial distal femoral angles (aLDFA, aMDFA) and AA in grade III MPL. In healthy dogs, both methods differed considerably with regard to values of mechanical medial proximal and mechanical lateral distal femoral angles (mMPFA, mLDFA), the mechanical cranial proximal tibial angle (mCrPTA) and the quadriceps angle (Q-angle).

Key words: anatomical and mechanical bone angles, computed tomography, dogs, patellar luxation, radiography

INTRODUCTION
Radiographic examination in mediolateral and craniocaudal views is commonly used for diagnostics of patellar luxation in dogs (Swiderski et al., 2008). However, in dogs with serious bone deformities including excessive rotation of the femur and the tibia, the proper positioning for radiography is almost impossible. Thus, in dogs with high grade medial patellar luxation (MPL), conventional radiography presents limitations related to accurate evaluation of bone alignment and bone morphology (Mostafa et al., 2008; Mortari et al., 2009; Soparat et al., 2012). In these cases, a more objective evaluation of bone morphology could be achieved by means of computed tomography, as resulting 3D image would allow for a more accurate planning of the surgical intervention (Perry et al., 2017).
Radiography is a routine method for diagnostics of patellar luxation in dogs. The observed radiographic changes comprise displacement of the patella out of the trochlear groove – laterally or medially to femoral condyles depending on luxation type (lateral or medial), shallow trochlear groove, hypoplasia of the medial femoral condyle, medial deviation of *tuberositas tibiae*, femoral varus and stifle joint osteoarthritis (Hulse, 1981; Mostafa et al., 2008).

Compared to conventional radiograph, the computed tomography (CT) image provides over one thousand times more information (Bardet et al., 1983). This method ensures better differentiation of soft tissues and bones, and what is more, no overlapping of images is seen, which is an advantage to radiography (Bardet et al., 1983). Modern CT scanners allow reconstruction of three-dimensional models with various colour of the different anatomical structures (Soler et al., 2007; Marino & Loughin, 2010).

In human medicine, CT is used for detection of changes in femoral varus angle (FVA), anteverision angle and torsion abnormalities accompanying various hereditary diseases (Kettelkamp et al., 1988; Myers et al., 2005). In canine medicine, these changes are part of the pathogenesis of patellar luxation and coxofemoral dysplasia (Montavon et al., 1985; Palmer, 2001).

Assessment of bone deformities is more accurate through CT, which visualises three-dimensional bone morphology (Kaiser et al., 2001a,b). It was reported that the higher the grade of luxation, the stronger the deformation of the distal third of the femur (Yasukawa et al., 2016). Some of femoral angles, namely anatomical and mechanical lateral distal femoral angles (aLDFA, mLDFA) and FVA, measured by means of CT in Mini-Poodles with grade II MPL were not considerably different compared to healthy dogs from the same breed, whereas values obtained in dogs with grade IV MPL were significantly increased. The constant tension in the distal femoral epiphysis resulting from the medial displacement of the quadriceps muscle following medial patellar luxation after birth or at early age, could aggravate femoral malalignment (Yasukawa et al., 2016).

The main purpose of the present study was to compare the results from measurements of anatomical and mechanical angles of the femur and tibia by means of two diagnostic imaging methods – conventional radiography and computed tomography in healthy dogs and dogs with medial patellar luxation.

**MATERIALS AND METHODS**

This study included 16 dogs (23 stifle joints) from four small breeds (Mini-Pinscher, Chi-hua-hua, Yorkshire Terrier and Pomeranian). Thirteen dogs (17 joints) were diagnosed with medial patellar luxation (MPL) – 8 joints with MPL grade II and 9 joints with MPL grade III on the basis of clinical examination, radiography and computed tomography. Another 3 small-breed dogs (6 joints) free or orthopaedic or neurological diseases were used as controls. In them, computed tomography was performed during their referral to the clinic on the occasion of a different procedure (ovariohysterectomy, dental tartar removal, othological exam etc.) requiring general anaesthesia.

The grade of MPL was determined by the classification of Putnam (1968). Radiography and computed tomography were done after anaesthesia according to the following protocol: s.c. premedication with 0.02 mg/kg atropine sulfate (Atropinum sulfuricum, Sopharma, Bulgaria),...
and i.v. introduction in anaesthesia 15 minutes later with tiletamine hydrochloride and zolazepam (Zoletil® 50, Virbac, France) at 7.5 mg/kg. Radiographs of healthy dogs and dogs with MPL were obtained in two perpendicular views: cranio-caudal and mediolateral (PHILIPS SUPER 50 CP-D, Germany). Anatomical and mechanical angles of the femur and tibia were measured on digital radiographs by means of DICOM-compatible specialised software (iQ-VIEW/PRO v. 2.7.0 INT EN003R).

Computed tomography of dogs was done with scanner Fidex Animage (USA). Anatomical and mechanical femoral and tibial angles were measured on 3D images positioned in a plane suitable for meas-

![Fig. 1. Measurement of anatomical and mechanical femoral angles in ventrodorsal view on 3D computed tomography and 2D radiographic images.](image1)

![Fig. 2. Measurement of inclination femoral angle (IFA) and femoral varus angle (FVA) in ventrodorsal view on 3D computed tomography and 2D radiographic images.](image2)
urements by means of Cobra v. 7 software.

All femoral angles were measured as described by Hauptman et al. (1985); Paley (2003) and Tomlinson et al. (2007) (Fig. 1 and 2), and mechanical tibial angles – as per Paley (2003) (Fig. 3) and Dismukes et al. (2008) (Fig. 4). Quadr-

Fig. 3. Measurement of mechanical tibial angles in craniocaudal view on 3D computed tomography and 2D radiographic images.

Fig. 4. Measurement of cranial and caudal mechanical tibial angles in mediolateral view on 3D computed tomography and 2D radiographic images.
The quadriceps angle was measured according to Kaiser et al. (1997) (Fig. 5), and anteverision angle – as reported by Nunamaker et al. (1973) (Fig. 6).

In order to determine the femoral neck anteverision, the Rippstein-Müller axial view was used. The patient was positioned in dorsal recumbency, with both femoral bones perpendicular to the cassette and the central X-ray beam: directed towards the medullary canal. The transverse section of the latter was visualised on the radiograph.
Evaluation of pelvic limb angles in dogs with medial patellar luxation: Comparison of radiography ...
DISCUSSION

For decades, radiography has been the primary diagnostic imaging method for diseases affecting the stifle joint. A large part of bone morphology could be evaluated on radiographs. However, in some bone deformities accompanying medial patellar luxation combined with impossibility for proper positioning of patients, interpretation of images could be erroneous or subjective (Aiken & Barnes, 2014). That is why, in cases with severe bone deformities, computed tomography is superior to conventional radiography.

According to Dudley et al. (2006), there is no relevant difference between CT and radiography when used for meas-
Evaluation of pelvic limb angles in dogs with medial patellar luxation: Comparison of radiography

In this study, only small-head shape there were more important bone deformities in the distal femur. Thus, our results supported the hypothesis that bone deformities in the distal femur could differ from values obtained by means of CT or magnetic resonance imaging – gold standard in human medicine. The difference is attributed to difficult achievement of proper position of pelvic limbs (femurs in particular) in a transverse plane. The results of our study however disagreed with the cited research as we have found out statistically significant differences in three of measured angles – mL DFA, Q-angle and mCrPTA.

The contracture of m. quadriceps femoris should be furthermore considered as an important factor that could influence the results from interpretation of radiographs (Aghapour et al., 2019). In our study, all radiographic procedures were performed under general anaesthesia to reduce to minimum possible improper body positioning.

Out of the proximal angles, statistically significant difference was found only in values of the mechanical lateral proximal femoral angle in dogs with grade II MPL. This difference could not be attributed to bone deformity presence, because such difference between imaging techniques was not seen in healthy joints and those with grade III MPL, so incorrect measurements on radiographs are a possible explanation. Bone deformity was also excluded as a probable cause because the values of aLPFA measured by either CT or radiography were not different. Thus, our results supported the hypothesis that bone deformities in the distal femur were more important for the occurrence of medial patellar luxation in dogs.

Tomlinson et al. (2007) affirmed that there was a substantial difference in the shape of trochanter major and femoral head among dogs of various large breeds. In this study, only small-breed dogs were included and that is why no differences were found out in the shape of the greater trochanter or in the femoral head. Any existing difference in our opinion would be probably related to genetic predisposition to aseptic necrosis of the femoral head and neck (Legg-Calvé-Perthes disease).

In the present study, FVA tended to be higher in stifle joints with grade II and III MPL compared to healthy joints as measured by both imaging techniques, whereas aLDFA values in grade III MPL already differed significantly, probably due to difficulty obtaining a proper positioning of patients. Similar results on aLDFA, mL DFA and FVA were also reported in previous studies (Dudley et al., 2006; Yasukawa et al., 2016).

In this study, a special attention was paid on the anteverision angle, due to its importance in patellar luxation and disputable values (Campbell & Pond, 1972; Olmstead, 1981; Kaiser et al., 2001a,b; Yasukawa et al., 2016). Before the introduction of the novel diagnostic imaging methods, it has been measured directly on axial radiographs (Nunamaker et al., 1973). One of the main advantages of CT is the three-dimensional reconstruction of images and possibility for positioning of the image in a plane appropriate for measurement of anatomical and mechanical angles (Dudley et al., 2006) in cases of advanced MPL. The statistically significant differences in values of the anteverision angle obtained by either 3D CT or radiography could be attributed to the possibility to rotate the image in position, suitable for its measurement. The deviations in AA measured by radiography are supposedly due to the external rotation of the distal third of the femur and hypoplasia of the medial condyle, confirmed by the high FVA values in joints with grade II and III MPL. Similar results have been
reported also by other research teams (Kowaleski, 2006; Roch & Gemmill, 2008), allowing assuming the results from CT as more reliable.

An important precondition for axial radiographic projection is the visualisation of femoral medullary canal in transverse section (Nunamaker et al., 1973). In this study, this projection was done with difficulty in grade III MPL due to varus deformity of the distal femur, as confirmed by high values of aLDFA and FVA. The values of these angles in the present study were higher than those found out by Žilinčík et al. (2018) and Aghapour et al. (2019), yet comparable to values reported by Soparat et al. (2012).

When the anteversion angle assumes values higher than normal, femoral head and neck are directed cranially and on the contrary, if AA is lower than normal, femoral head and neck are directed more caudally than normal (Bardet et al., 1983). Lately, in dogs with MPL, this angle is evaluated by MRI or CT (Kaiser et al., 2001a; Towle et al., 2005). In healthy dogs from small breeds (Yorkshire terrier, Shi Tzu, Maltese, Poodle) the AA values range within 23.4°–27.4° (Kim et al., 2016), which are comparable to our values in normal stifle joints. In joints affected with grade II and III MPL, AA was statistically significantly higher which disagrees with the results of Žilinčík et al. (2018), but is in line with the results of Newman & Voss (2017) – both reports were done only on radiographs. In our opinion, the values measured on 3D images are more reliable due to the possibility for rotation of the image in a more suitable plane.

Kaiser et al. (2001a) established that in dogs weighing 10–20 kg, AA values were lower than those in dogs weighing < 10 kg and > 20 kg. All dogs included in the present study weighed less than 10 kg and thus, measured anteversion angles were greater.

Varus deformity of the distal third of the femur is known to occur in high grade MPL (Hulse, 1981; Schulz, 2002; Vasseur, 2003; Piermattei et al., 2006). Values of aLDFA, mL DFA and FVA determined on 3D CT images in Toy Poodles with grade II MPL did not differ considerably from those in healthy dogs from the same breed (Yasukawa et al., 2016). Our results in joints affected by grade II MPL confirmed this statement as aLDFA and mL DFA were concerned. As to FVA in joints with grade II MPL, it was greater as compared to normal joints similarly to other reports (Mortari et al., 2009).

The measurement of the inclination femoral angle (IFA) by means of CT in Toy Poodles with grade II and IV MPL did not show any significant differences (Yasukawa et al., 2016) suggesting that coxa vara was not associated to the occurrence of the disease as affirmed in earlier studies based on radiography (Bound et al., 2009; Mortari et al., 2009; Soparat et al., 2012). Similar results were reported also in English bulldogs, where IFA measured by CT did not differ substantially between healthy dogs and dogs with MPL, hence, coxa vara in this breed was not associated to patellar luxation too. In the present study, IFA values of healthy joints tended to be lower than values obtained for grade II and III MPL on both 2D and 3D images. IFA values in both MPL grades were greater as compared to reference values provided for dogs from small breeds (Kim et al., 2016). On the basis of results it could be suggested that IFA was involved in the etiology and pathogenesis of patellar luxation.

Among the studied femoral angles, statistically significant differences between values obtained by the both imaging techniques were found out for mL DFA,
mMPFA and the Q-angle, whereas in joints with medial patellar luxation: for mLpFA, aLDFA, aMDFA and the anteversion angle.

According to Piras et al. (2012), tibial malalignment is rarely involved in the etiopathogenesis of patellar luxation. Cranial and caudal tibial angles (mCrPTA, mCdPTA, mCrDTA and mCdDTA), determined in mediolateral view, have been used for detection of procurvatum or recurvatum deformity of the tibia (Fuller et al., 2014). In dogs from small breeds, caudal deformity of the proximal tibia leading to increased risk from rupture of the cranial cruciate ligament was found out (Macias et al., 2002). However, it is unclear whether the higher mCdPTA values in dogs from small breeds are associated with the prevalence of patellar luxation (Olimpo et al., 2016).

In this study, statistically significant differences in mCrPTA between both imaging techniques were found out only in healthy stifles, in line with results reported by Yasukawa et al. (2016) and Lusetti et al. (2017), but not with those of Olimpo et al. (2016). In joints with grade II and III MPL the values of mCdPTA angle were similar to those in normal joints. In our opinion, among mechanical tibial angles, mMPFA is more important. In our study, this angle tended to decrease as the MPL grade increased, due to the force exerted on m.quadriceps femoris on crista tibiae in medial direction, leading to a medial deviation clearly seen by both diagnostic imaging methods.

An interesting finding was in both grade II and III MPL, measured tibial angles were similar to those of normal joints, except for mCdPTA in joints with grade II MPL (Yasukawa et al., 2015; Kim et al., 2016; Lusetti et al., 2017). Consequently, we could affirm that tibial deformities are less important in the etiopathogenesis of grade II and III patellar luxation. Furthermore, the increase in mCdPTA could predispose to rupture of the cranial cruciate ligament.

CONCLUSION

The presented results allowed concluding that angle measurements by conventional radiography vs computed tomography resulted in different values for mLpFA and anteversion angle (in joints with grade II MPL) and in aLDFA, aMDFA and anteversion angle (in joints with grade III MPL). In healthy dogs, values of mMPFA, mLDTA, mCrPTA and Q-angle demonstrated significant differences associated with used imaging technique. Conventional radiography is appropriate for measurement of the following anatomical and mechanical angles of the femur and the tibia – aMPFA, aMDFA, mMDFA, FVA, IFA, mPPTA, mPPTA, mMPTA, mLDTA, mCrDTA, mCdPTA and mLDTA. As the evaluation of anteversion angle, aLDFA, aMDFA, mLDTA, mMPFA, mLpFA, Q-angle and mCrPTA was concerned, computed tomography is recommended due to the substantial subjectivism in patient’s positioning, the more detailed visualisation of bones and the possibility for positioning in the most suitable plane.

REFERENCES


Aiken, M. & D. Barnes, 2014. Are the fabellae bisected by the femoral cortices in a true cranio-caudal pelvic limb radiograph?


Evaluation of pelvic limb angles in dogs with medial patellar luxation: Comparison of radiography ...


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