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Clinical and imaging findings, treatment details and outcomes in foals with extensor tendon rupture – a multicentre retrospective study

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Summary

Background: Forelimb extensor tendon rupture (ETR) in foals is sparsely documented.

Objectives: To describe clinical and imaging findings, treatment details and long-term outcome in foals with ETR.

Study design: Multicentre retrospective case-series.

Methods: Clinical record review of foals with ETR, presented to Faculty of Veterinary Medicine at Ghent University (Belgium), the Clinic for Horses at the University of Veterinary Medicine Hannover (Germany), and Rossdales Equine Hospital (UK) between 2009-2021. Long-term outcome based on structured telephone interview with the owner at the university hospitals and on future Ratings from a public racing results archive at Rossdales Equine Hospital.

Results: Eight foals (28%; 95%CI: 11.7-44.3%) presented with ETR only, whereas 21 foals (72%; 95%CI: 55.7-88.3%) presented with ETR and concurrent flexural limb deformity Foals with ETR only were older (median 20 days; Interquartile range (IQR) 13-22) than foals with ETR and flexural limb deformity (median 5 days; IQR 3-11; p=0.001). Treatment included medical support, immobilisation, and box rest. Hospitalisation time was longer for foals with ETR and flexural limb deformity (median 26

days; IQR 16-44) than for ETR-only foals (median 11 days; IQR 6-16; p=0.03). Total rehabilitation time was longer for foals with ETR and flexural limb deformity (median 58 days; IQR 42-91) than for foals without flexural limb deformity (median 32 days; IQR 12-39; p=0.03). Six foals (21%; 95%CI: 6.3-35.7%) were euthanased within seven months: three because of problems with limb protraction and progressive flexural limb deformity. Long-term follow-up (>18 months) was available for two cases with ETR only, and 7 cases with ETR and flexural limb deformity. Both ETR-only foals had a positive cosmetic outcome but only one a positive functional outcome. Foals with ETR and concurrent flexural limb deformity suffered limitations regarding cosmetic appearance (5/7 negative), and limb function (7/7 negative).

Main limitations: Small sample size, retrospective study, no clinical follow-up.

Conclusions: Extensor tendon rupture is a rare condition in this sample of foals treated under hospital conditions often requiring prolonged care, especially with concurrent flexural limb deformity. Further research should investigate potential associations with future athletic performance.

Introduction

Rupture of the extensor tendons (ETR) at the dorsal aspect of the carpus has been described in newborn foals and may involve the common digital extensor tendon (CDET), or according to Hunt (2011) more rarely, the lateral digital extensor tendon (LDET), resulting in distention of the corresponding tendon sheath. Normally, this condition occurs shortly after birth or within the first three to four days of life. Less frequently, a rupture may not occur until three weeks post-partum.[1,2] Tendon rupture can occur as a primary problem or may be associated with an underlying flexural limb deformity (i.e. contraction of the flexor tendons).[3] Knuckling forward at the metacarpophalangeal joint can be observed in foals with an ETR and can therefore be mistaken as a flexural limb deformity at the level of the fetlock or carpus.[1,3,4] A characteristic clinical sign of ETR is the presence of a soft swelling on the dorsolateral aspect of the carpus, which corresponds to distention of the affected tendon sheath. Often it is also possible to palpate the enlarged ends of the ruptured tendon.[3,5] If left untreated, the foal can develop secondary flexural limb deformity. Rupture of the extensor tendon can occur uni- or bilaterally[3] and in reports from the early 20th century, prognosis was regarded as unfavourable[6] to hopeless.[7] Stevenson and Stevenson (1942) stated that outcome was improved for foals that were able to walk a few steps, and following a surgery in which the tendon sheath was opened and the proximal part of the tendon resected. In the original description of this technique the wound was left open to heal by second intention[8], whilst a later report recommended primary closure.[9] Here prognosis was referred to as fair, in terms of ability to achieve normal limb function, but sample size was limited to eight cases and follow-up did not extend long-enough to observe horses entering active work.[9] In more recent literature, surgical treatment is no longer recommended and therapy is tailored dependent on severity of the clinical signs observed: in mild cases restriction of movement is considered sufficient, whilst immobilisation with a bandage, splint, or cast is

recommended for more severe cases. In the current literature, prognosis is stated as good but, to the best of our knowledge, data on long-term outcome is lacking.[1,3,4,10]

Accordingly, this exploratory retrospective study aimed to describe the clinical findings, treatment details and long-term outcomes of foals with ETR presented to three large referral centres. A secondary objective was to compare outcomes between foals with and without concurrent flexural limb deformity.

Material and Methods

Medical records from the Faculty of Veterinary Medicine at Ghent University (Belgium), the Clinic for Horses at the University of Veterinary Medicine Hannover (Germany), and Rossdales Equine Hospital (UK), from 2009 to 2021, were reviewed. A convenience sample of foals were included in the study if they received a diagnosis of ETR within the first three months of life. Data on signalment and age at first presentation was collated as well as the foal's case history to include: all birth- and development-related information, details of clinical sign evolution (particularly any angular or flexural limb deformity), and the treatment initiated by the referring veterinarian. Clinical examination at the referral centres included subjective visual and digital evaluation of the extensor tendon sheath(s) and, if present, of any flexural (manually assessing the range of motion of the different articulations of the limb) or angular limb deformity (assessment in the standing foal as well as during locomotion). All foals underwent additional examination, as deemed appropriate, for the assessment of any other concurrent diseases. The foals were categorised as either: ETR without flexural limb deformity or ETR with flexural limb deformity. The second category was further subdivided into those cases with initial ETR and subsequent development of flexural limb deformity (ETR_FD), or initial flexural limb deformity with subsequent development of ETR (FD_ETR). If it was not possible to distinguish between ETR_FD and FD_ETR, foals were counted in a separate group of ETR with flexural limb deformity without knowledge of the initial pathology. Cases were grouped as uni- or bilaterally affected.

All available ultrasonographic and radiographic data relating to the carpi were retrospectively evaluated by the same observers (resident ECVDI, JF, supervised by Dipl. ECVDI, KVP). Ultrasonographic examination was routinely performed in the standing foal, unless the foal was too young or unable to stand. Ultrasonographic images and reports were evaluated to determine, where possible, the proximodistal extent of the tendinous pathology, site of rupture (determined by a clear discontinuity of fibres) and whether there was undulation of the tendon or retraction of any free ends. The cross-sectional area (CSA), dorsopalmar thickness and mediolateral width of the tendon were measured in the region of maximal CSA and the echogenicity, echotexture and longitudinal fibre pattern were also noted. Normal cross sectional dimensions of the CDET were considered to be 3-5mm in thickness and 12-18mm in width.[11] The type of lesion in the CDET was categorised into four groups: a) Complete rupture = Total disruption of the tendon fibres across the whole cross section and either an interposed hypoechoic structure or anechoic space between the tendon stumps, b) Partial rupture = Hypoechoic or anechoic clefts or gaps within the tendon substance that extend to the periphery, however some intact tendon fibres remain through the lesion, c) Tendinitis = Enlarged CSA with hypoechoic regions of fibrillar disruption without interruption of the borders of tendon, and d) Normal = normal size, shape, echogenicity and fibre pattern. Presence and echogenicity of effusion within the tendon sheath, presence of synovial proliferation or thickening, and presence of intrathecal fibrinous accumulations

were also recorded. Radiographs were taken standing and assessed for the location and extent of soft tissue swelling, skeletal ossification index (SOI)[12] and, if present, the degree of angular limb deformity. Cases with ETR due to wounds were excluded. One foal with evidence of an earlier, undiagnosed ETR in which the ETR was an incidental finding during clinical examination was excluded from the study.

Methods of immobilisation were categorised as: bandage, splint bandages, or cast, and it was noted whether this included the distal limb only or incorporated the entire limb. Medical treatments were categorised as: anti-inflammatory medication, gastrointestinal protectants, antimicrobial medication, and other medications. Duration of hospitalisation, as well as, duration and type of rehabilitation programme following discharge, was recorded. Total rehabilitation time was defined as: duration of hospitalisation plus total duration of rehabilitation at home. The end of rehabilitation at home was defined as the time point when the foal was no longer restricted in movement.

To assess cosmetic and functional outcome, a structured telephone interview (Supplementary Item 1) with the owner was conducted at Ghent University and the University of Veterinary Medicine Hannover, whilst for the cases from Rossdales Equine Hospital, Racing Post Rating (RPR) was evaluated for Thoroughbred foals and siblings (Racing Post Database: (https://www.racingpost.com)). Outcome was further divided into short-term outcome for the foals treated in 2020 and 2021 (3-16 months post onset of clinical signs) and long-term outcome (18-139 months post onset of clinical signs) for all other foals. The outcome was graded on a scale from 1-10 with 10 as an excellent outcome. Outcome was positive when the owner graded it with at least 8 points. To assess whether there may be a genetic component predisposing foals to the pathology, owners were asked during the telephone survey if any other foals from the same mare had suffered from extensor tendon rupture. Finally, owners were asked if they would recommend the treatment that the foals had received.

Data Analysis

Descriptive statistics were performed for numerical variables. Statistical analysis was performed to compare foals with only ETR to foals with ETR and concurrent flexural limb deformity. Variables of interest included the age on admission (for all foals), hospitalisation time and total rehabilitation time (i.e. combined duration of hospitalisation and rehabilitation at home, limited to foals with long-term follow-up). Euthanased foals were excluded from the calculation of hospitalisation and rehabilitation time.

All analyses were conducted in Python (3.7.12). The package pandas (v.1.2.5) was used for data loading, the function mwu from pingouin (v.0.5.0) for the Mann-Whitney U test and the functions anderson and levene with center = 'median' from scipy.stats (1.7.3) for the normality and homoscedasticity tests, respectively.

Normal distribution and homoscedasticity were evaluated with Anderson-Darling and Brown-Forsythe tests, respectively. The significance level was set at 0.05. Based on the results, the non-parametric Mann-Whitney U test was used. Non normally distributed data is presented as a median and associated interquartile range (IQR).

Results

General information

In total, 29 foals (Ghent University (n=19), University of Veterinary Medicine Hannover (n=6), Rossdales Equine Hospital (n=4)) of different breeds (19 Warmblood, 3 Thoroughbred, 2 Standardbred, 1 Arabian, 1 Draught horse, 1 Friesian, 1 Quarter Horse, 1 unknown breed) met the inclusion criteria. There were 13 fillies, 13 colts and 3 foals of unknown sex. Age on admission to the hospitals ranged from 1 to 27 days (median: 7 days). Foals with ETR only were significantly older (median 20 days; IQR 13-22), than foals with a combination of ETR and flexural limb deformity (median 5 days; IQR 3-11; p=0.001).

History on presentation

Three of the 29 foals were reported to be born before term. Radiographs were available for two of these foals and showed ossification indices of Grade 3 and Grade 4 respectively.[12] Assistance during birth was reported for 2/29 births. Based on case history alone, 9/29 foals were initially diagnosed with ETR by the referring veterinarian. In contrast, 15/29 foals were diagnosed initially with a flexural limb deformity, and in 4/29 foals it was not possible to determine if the ETR or the flexural limb deformity occurred first. One foal was referred for treatment of a carpus valgus deformity and ETR had not been detected by the referring veterinarian. Worsening of the combined flexural limb deformity and ETR was observed in 3/15 cases with FD_ETR. Treatment by the referring veterinarian included: intravenous oxytetracycline (n=3/29), therapeutic shoeing (n=1/29), plasma infusion (n=1/29) and casting and splinting (n=1/29). No other treatment details could be retrieved from clinical records.

Clinical examination

All foals presented with a variable amount of fluctuant swelling at the dorsolateral aspect of the carpus, problems with limb protraction and/or obvious knuckling forward. Overall, 2/29 foals (ETR only) showed mild signs of ambulatory difficulties, in 2/29 foals (ETR only) mild to moderate signs of ambulation difficulties were observed and the remaining 25/29 foals showed moderate to severe difficulties of ambulation, which needed assistance to enable movement. No differentiation in degree of swelling was recorded. There were 16 cases with unilateral ETR and 13 with bilateral ETR. Figure 1 presents the number of foals per category (ETR versus ETR with concurrent flexural limb deformity) and differentiates the number of uni-, and bilaterally affected limbs. In cases with flexural limb deformity hyperflexion was consistently observed at the fetlock joint and in a smaller proportion of foals the carpus was involved. However, this latter observation was not consistently recorded in the clinical records and degree of flexural limb deformity was not noted in detail. One foal was diagnosed with a lateral digital extensor tendon rupture, whereas all other foals had clinical signs of CDET rupture.

Concurrent disorders

The following concurrent diseases were reported: a carpus valgus conformation in 5/29 foals (4/5 on the contralateral limb, 1/5 on the affected limb), incomplete ossification of the carpal bones in 5/14 foals in which radiographs were performed (SOI Grade 3), umbilical infection in 5/29 foals and neonatal maladjustment syndrome in 2/29 foals. The following diseases each occurred once in a foal: varus of the metacarpophalangeal joint of the affected limb, digital hyperextension of a hindlimb, tarsal varus,

hoof abscess in the hindlimb, failure of passive transfer, diarrhoea, pneumonia, entropion, and vaginal prolapse.

Diagnostic imaging

During the initial evaluation and/or hospitalisation period, ultrasonography of the dorsal carpus was performed in 13/29 foals (8/13 bilaterally) and carpal radiographs were acquired in 14/29 foals (10/14 bilaterally). Five of the 29 foals had both ultrasonographic and radiographic examinations performed, 8/29 foals underwent only ultrasonographic examination, 9/29 had only radiographs taken, and 7/29 foals did not have any imaging performed.

Complete rupture of the CDET was identified with ultrasonography in 8/13 foals (2/8 bilaterally) and partial rupture was identified in 5/13. In the foals with partial rupture the residual intact fibres bridging the ruptured part compromised an estimated 10% (3/5), 25% (1/5) and 50% (1/5) of the CSA. In one foal with a partial ETR, there was a CDE tendonitis in the contralateral limb with a heterogeneous hypoechoic region occupying roughly 40% of the CSA; this corresponded to a short fibre pattern on longitudinal examination.

There was undulation of the affected CDETs in 12/13 foals, which was best appreciated on longitudinal examination. The ruptured tendon ends were observed to retract over variable distances in the same 12/13 foals, with the stumps observed to fold over themselves by 180° in one of the 8 foals with a complete rupture bilaterally. The gap between the ruptured tendon ends was filled with different amounts of heterogeneous hypoechoic material, interspersed with anechoic regions compatible with haematoma, fibrinous material and/or synovial fluid. Proximal and distal to the rupture, the CDETs had a heterogeneous hypoechoic echotexture in all foals (13/13) which extended over varying distances. In all cases which had longitudinal section images available (9/13), the fibre pattern of the tendon stumps was mixed, consisting of regions of fibre absence, pinpoint, and short linear echos. As the distance from the stumps increased, there was an increased quantity of long linear parallel echos.

The CDET adjacent to the rupture site was enlarged in 11/13 cases. Maximum CSA of the abnormal CDET ranged from 0.5 - 2.7cm^2 (measured in 5 limbs of 5/13 foals). Maximum dorsopalmar thickness ranged from 0.4 - 0.9cm (measured in 15 limbs of 13/13 foals,) and maximum lateromedial width from 1.5 - 3cm (measured in 9 limbs in 9/13 foals). The proximodistal range of abnormal CDET tissue extended from the mid or distal radius, to the proximal or mid metacarpus in 7/13 foals. In 3/13 foals it was abnormal only at the level of the carpus and in 1/13 only at the level of the distal radius. In 2/13 foals the proximodistal extent could not be determined. Anechoic CDET sheath effusion, synovial thickening of the tendon sheath wall and fibrinous accumulations, strands or loculations of varying severity, were present in 13/13 foals with complete and partial ETR, and in the limb with tendonitis.

Follow-up ultrasonographys were performed within two months of the initial examination in 3/13 foals and showed decreased echogenicity of the tendon ends (n=1), a large volume of hyperechoic material filling the rupture gap (n=1) or an unaltered appearance of the tendon (n=1). Subjectively, the degree of

sheath effusion had decreased in 2/3 foals and remained static in the other foal. The amount of fibrinous material in the tendon sheath had: decreased (n=1), increased (n=1) and remained static (n=1).
One foal underwent repeat ultrasonographic examination after 15 months (Figure 2). The CDET, which was previously partially ruptured with just 10% residual fibres, showed no evidence of a discontinuity or anechoic gap and the maximal CSA of the CDET had markedly reduced in comparison to the initial ultrasonographic examination. There was moderate heterogeneous hypoechogenicity of the tendon in transverse section and sparse short and medium length linear echos present in longitudinal section. There was minimal anechoic effusion and mild synovial thickening of the tendon sheath.

In terms of radiography, bilateral acquisition of the carpi was performed in 10/14 foals and unilateral acquisition in 4/14. Radiographically visible soft tissue swelling which could be attributed to ETR and/or CDET tenosynovitis was present in 14/14 foals (Figure 3). This was visualised laterally in all foals undergoing dorsopalmar projections (14/14) and dorsally in 5/6 foals which had lateromedial projections. The proximal extent of the soft tissue swelling was observed at varying points between the distal radius and carpometacarpal joint, and the distal-most aspect varied from the carpometacarpal joint to the mid-diaphysis of the third metacarpus, some extending past the distal margin of the radiograph. The maximum point of swelling was most commonly identified at the level of the distal row of carpal bones (6/14) or the carpometacarpal joint (4/14).

Skeletal ossification index was Grade 4 for 9/14 foals and Grade 3 for 5/14 foals. Carpal valgus was present in 7/14 foals with the deviation from the longitudinal axis ranging from 2-20 degrees. The carpal valgus deformation was present in an ipsilateral limb to the ETR in one foal and in the contralateral limb without ETR in 5/14 foals. In one foal with bilateral ETR, carpus valgus also occurred bilaterally.

Agreement between history, clinical and diagnostic imaging examination

Clinical findings at the clinic corroborated with the case history in 25/29 foals. In four cases, additional or even contradictory clinical findings were observed. In two foals referred for ETR, a concurrent flexural limb deformity was diagnosed, one foal was referred for flexural limb deformity instead of the subsequently diagnosed ETR and one foal was referred for carpus valgus on the contralateral limb without a prior diagnosis of ETR.
Of the 16 foals with clinically suspected unilateral ETR, six underwent ultrasonography and in all cases (6/6) unilateral ETR was diagnosed.
Thirteen foals had clinical signs compatible with a bilateral ETR, and in seven of these an ultrasonography was conducted. Among those seven, three were confirmed to have an ETR or at least pronounced tenosynovitis. In 2/7 foals unilateral signs of ETR were confirmed and in the last two foals, despite signs of bilateral ETR, only unilateral ultrasonography was performed which confirmed the ETR.
A carpal valgus was clinically present in 5/29 (17.2%) foals (in 4/5 foals in the contralateral limb), whereas radiographically a carpal valgus was diagnosed in 7 of the 14 foals (50%) (5/7 in the contralateral limb) in which radiographs were available.

Treatment

Therapy was initiated in all foals and most of them (26/29) were hospitalised for treatment. One foal with an ETR and flexural limb deformity was euthanased after one day of treatment due to financial constraints. Of the two foals treated at home, one foal had ETR without flexural limb deformity and one foal presented with ETR and flexural limb deformity. The latter was euthanased at home.

Information regarding bandaging was available for all 29 foals. The exact type of bandaging protocol utilised depended on the severity of clinical signs (no bandage: possible ambulation without assistance and without risk of injury, bandage: possible ambulation without assistance and risk of injury, splint or cast: ambulation only possible with help, foal cannot stand independently) and varied between hospitals. All foals with flexural limb deformity received bandaging (21/21). In 9 of the 21 foals with an additional flexural limb deformity, treatment was initiated with casts (distal limb casts or full limb casts) and subsequently changed to splints and/or bandages at a later stage. In the remaining 12/21 foals, treatment was initiated with splints.

In foals with ETR only, treatment was initiated in 1/8 foals with a distal limb cast (from foot to the proximal metacarpus). In 3/8 foals, treatment began with splints, in 2/8 it began with bandages and in the remaining 2/8 foals bandaging was deemed unnecessary.

Casts and splints were used distally (from foot to the proximal metacarpus) or as full limb casts. Splints were often applied dorsally, but detailed information on this aspect was not consistently recorded. If treatment was initiated by casts or splints, the subsequent change to splints or bandages respectively, was dependant on clinical evolution. The foals were able to move without assistance with the help of the bandages.

Five of the 29 foals developed complications as a result of bandage therapy, which included pressure sores on the dorsal aspect of the metacarpophalangeal joint. Two of these five foals had been treated with casting followed by splinting; the remaining three foals had been treated with splinting only. Digital hyperextension occurred in one foal which was primarily treated with a cast. This foal also developed elongation of the flexor tendons in the hindlimbs, which had not been casted.

Of the hospitalised foals, 22/26 were treated with non-steroidal anti-inflammatory drugs (most often meloxicam), 18/26 received gastrointestinal protectants, 12/26 received oxytetracycline infusions and 14/26 received antibiotics for concurrent diseases. Other medications included: plasma infusion (n=3), anti-thrombotic medication (n=2), ophthalmic ointment (n=2) and corticosteroids (n=1).

The hospitalisation time was significantly shorter for foals with ETR only (median 11 days; IQR 6-16) compared to foals with ETR and flexural limb deformity (median 26 days; IQR 16-44; p=0.03).

Data regarding rehabilitation after discharge was available for 20/29 foals. Fourteen of the 20 foals still needed bandaging after hospital discharge and were stabled for variable amounts of time (2 days – 7 months). Six of 20 foals, however, had immediate paddock or field access. Total rehabilitation time was significantly shorter for foals with ETR only (median 32 days; IQR 12-39) compared to those foals with additional flexural limb deformity (median 58 days; IQR 42-91; p = 0.03).

Case outcome

Data regarding survival rate was available for 26/29 foals. Six foals were euthanased within seven months of hospital admission. Aside from the single foal which was euthanased after one day of treatment, three foals were euthanased because of worsening of ETR-associated clinical signs (development of severe flexural limb deformities), and two for an unrelated reason of colic.

Information about cosmetic and functional outcome was available for 20/29 foals based on structured telephone interviews with the owners (Figure 4). For 20 foals with available follow-up information, intended use was compared to the performance level actually achieved. Eleven foals were bred for showjumping. In the short-term follow-up, three owners were satisfied with the result of the treatment, whilst two owners stated that results were below expectations. With regards to long-term follow-up, one horse (ETR without flexural limb deformity) fulfilled the expectations of the owner and competed at 135 cm level, whilst four owners stated they were not satisfied with their horses' performance. For one foal, no further information was available. Of the three dressage horses, two foals were still too young to make a performance assessment on at the time of short-term follow-up. One owner was satisfied, while another owner noticed difficulties in the movement of the foal. Long-term follow-up was available for one horse who was competing at Novice level by 6 years of age. Of the three Thoroughbred foals, all were five years or older at the time of follow-up. Two horses could not be found on the Racing Post Database and had no available racing record. One of these foals had five siblings with RPR values between 61 and 104 (median: 81.5), whilst the other foal did not have registered siblings. The third foal was six years old at the time of manuscript submission and had raced once, achieving an RPR rating of 78. It did not have registered siblings. The one included Standardbred foal (ETR without flexural limb deformity) was born in 2009 and had the longest rehabilitation time (18 months). The horse never raced and was retired from training because of a lack of performance which the owner attributed to the ETR. One eventing foal and one reining foal were included in the short-term follow-up. Within the short-term, the owners reported a good functional outcome. None of the foals seen at Ghent University or the University of Veterinary Medicine Hannover had any other reported musculoskeletal injuries that could be associated with performance-limitation.

Potential genetic component of an extensor tendon rupture

Ten mares of the treated foals were multiparous and 3/10 were reported to have had at least one other foal with limb deformity in the past. It was not possible to discern whether this referred to ETR, flexural limb deformity or a combination of both.

Recommendations for treatment

Information on whether the owner would recommend the treatment their foal received was available for 22/29 foals. In total, 77% (17/22) of owners would recommend the treatment but 52% (9/17) would only recommend it for foals of high genetic value or for pleasure horses. Of the foals with ETR only, 83% (5/6) of owners would recommend the treatment. For foals with ETR and flexural limb deformity, 75% (12/16) of owners recommended treatment, although 50% (8/16) of them had reservations about the treatment.

Discussion

This retrospective study is the first systematic investigation into the clinical findings, treatment, and outcome of foals with ETR for at least 26 years. In the literature, it has been reported that an ETR is a common finding and occurs in 1.33% to 1.5% of all new-born foals.[8,10] Therefore it was surprising that in the current study, where medical records from three large referral hospitals located in important breeding areas across Europe were utilised, only 29 foals met the inclusion criteria. In preparation for this study, personal communication with clinicians from additional hospitals around Europe revealed that this pathology is also not common in other locations. A reason for this discrepancy might be that foals are more commonly treated at home rather than in a clinic environment. However, Ghent University (Belgium) and the Clinic for Horses at the University of Veterinary Medicine Hannover (Germany) have also monitored births. Another potential reason for the discrepancy in incidence rates could be that some foals suffering from ETR remain undetected and/or are misdiagnosed as flexural limb deformity, as discussed in literature.[1,3,4]

Most of the included cases were; Warmblood foals (19/25) at the university hospitals, and Thoroughbred foals (3/4) at Rossdales Equine Hospital. This is in agreement with the normal breed distribution of the patient populations seen in each hospital. No sex predisposition could be detected.

We have shown a close link between ETR and flexural limb deformity, as only 27.6% (8/29) of the ETR cases occurred in isolation, and a combination of an ETR and flexural limb deformity was present in most of the cases (21/29). In contrast to the existing literature, foals which suffered from a FD_ETR were not the exception but rather the most common scenario (12/29 foals, see Figure 1).[4]

It has been stated that ETR occurs in the early stages of the peri-partum period; often associated with the foals' first attempts to stand.[1,4] However in the current study, the age at hospital admission was significantly older for foals with ETR compared to those with a combination of ETR and flexural limb deformity. Although this was not proven directly in this study, this could be an indication that most cases of ETR develop later in the peri-partum period. A possible explanation for this observation could be that stresses acting on the extensor tendons increase as the foal's bodyweight and speed of locomotion increases with advancing age; these increased forces in turn lead to ETR. Another rationale could be that the foals with ETR only, initially show mild locomotor problems, perhaps as the tendon is only partially ruptured, and this delays owners in seeking veterinary attention. In contrast, a foal with a combination of ETR and flexural limb deformity is usually unable to stand unaided and thus alerts the owner to the need for timely veterinary attention. They usually also require a level of intensive care that is difficult to achieve at home, potentially leading to earlier hospital admission. On the other hand, owners recognised a swelling on the dorsolateral aspect of the carpus in 7/9 foals with suspicion of an ETR.
A carpal valgus was present clinically in 5/29 and radiographically in 7/14 foals. Some of the foals with a radiographically diagnosed carpal valgus had only mild angular limb deformities which might have been missed during clinical examination or which might be a result of positioning of the foals for radiography. Contrary to what is reported in the literature, in this study most cases of carpal valgus occurred in the contralateral limb to that affected by ETR. The reason for this remains unclear. However,

delayed ossification of the carpal cuboidal bones in dysmature foals can lead to a carpal valgus deformity. This may be associated with the anatomical localisation of the extensor tendons on the lateral side of the limb, leading to increased forces and thus to collapsing of the cuboidal bones mainly on the lateral side.[3] This however remains speculative as the skeletal ossification index in the foals which were radiographically examined were not indicative for dysmaturity.

Whilst the pathology of extensor tendon rupture in foals appears to be largely unique to the CDET, this case series also contained one foal with clinical signs of a lateral digital extensor tendon rupture. Unfortunately, this foal did not undergo ultrasonography. Lateral digital extensor tendon rupture has been described in literature[1] but predisposing factors for this specific type of pathology remain elusive. Anatomical differences could play a role as the lateral digital extensor is more laterally located and therefore may be less likely to be affected by blunt trauma to the dorsal aspect of the limb or any alteration in biomechanics created by flexural limb deformity. Alternatively, a predisposing weakness may be present which could be investigated histologically in future studies. Moreover, in the absence of confirmation by ultrasonography, we cannot exclude an error in the clinical diagnosis, although cases were examined by experienced clinicians.

The most common location for radiographically identifiable swelling was between the distal radius and proximal metacarpus on the dorsal and lateral aspect of the limb; an area that corresponds to the anatomical location of the CDET and its associated sheath. On ultrasonography the degree of effusion varied from mild to significant, but this variable could not be reliably determined due to the retrospective nature of this study: the degree of probe pressure elicited, in turn displacing the synovial fluid, could not be determined from the images but is likely to vary between ultrasonographers. In this case series, CDET sheath effusion was anechoic in all cases during the initial ultrasonography, although there were variable amounts of fibrinous material present. In foals with an echogenic effusion, other differential diagnoses should be considered such as: septic tenosynovitis and haemorrhagic effusion. In the three foals where follow-up ultrasonography was performed within 2 months, variable changes were detected. Due to the small number of cases, it is unclear whether these variations could relate to: the chronicity of ETR prior to presentation, severity of the rupture, degree of stabilisation of the limb achieved or the type of treatment pursued. The foal with follow-up ultrasonographic examination 15 months post-diagnosis showed re-joining of the free tendon ends with a heterogenous hypoechoic appearance in transverse section and some short linear fibres in the longitudinal examination. The tendon had not completely healed but may remodel further with additional time.

Agreement between anamnesis and findings of the clinical examination was good. In 86.2% (25/29) of the cases, the anamnesis corresponded to the clinical examination. In the four previously misdiagnosed cases, two cases included an overlooked flexural limb deformity, whilst the other two incorporated a missed ETR. This suggests that the low number of recorded ETR cases, in the three different hospitals within the last 13 years, may be a realistic assessment of ETR prevalence. Agreement between clinical and ultrasonographic examination was good. In 9/13 foals the ETR was correctly identified by clinical examination. In 2/13 foals, ultrasonography confirmed just a unilateral ETR whilst clinical examination

indicated the condition to be bilateral. In the remaining 2/13 foals, ultrasonography was only performed unilaterally; although it diagnosed ETR unilaterally in all these cases, clinical examination had identified a bilateral condition.

All foals which were euthanased in association with ETR suffered from a concurrent flexural limb deformity. In all these cases clinical signs were gradually deteriorating and prognosis was regarded as poor. The worse prognosis for foals which have a flexural limb deformity in addition to ETR is in agreement with previously published reports.[2] The majority (26/28; 92.9%) of foals which received treatment were hospitalised; indicating that often severity of clinical signs precludes treatment on the stud.

The exact type of bandage therapy utilised was dependent on both the severity of clinical signs and clinician preference/hospital policy, which likely differed between the 3 centres of study. Splinting was the most common type of bandaging to be used and only one hospital used casts as a first line treatment. The other two hospitals were concerned about potential side effects of flexor tendon elongation with prolonged application of splints or casts; accordingly, their policy was to only use these types of external coaptation for limited periods, on an hourly basis in some cases. However, of the 10 foals (9/10 were ETR with concurrent flexural limb deformity foals) treated with casts, only one foal developed a forelimb flexor tendon elongation. Interestingly, in the same foal flexor tendon elongation was also developed in a hindlimb which had not been casted. This indicates that casts, if properly applied and carefully monitored, can be a safe treatment option at least in foals with ETR and concurrent flexural limb deformity.

Most hospitalised foals received NSAIDs in combination with gastrointestinal protectants. An integral component of therapy for flexural limb deformity, is pain management. Data from this study indicates that 50% of the foals with a primary occurring ETR, subsequently developed a flexural limb deformity. This highlights the importance of a quick start of supportive immobilisation of the limb, to minimise the chance of subsequent flexural limb deformity.
On the other hand, 12 foals were reported to develop ETR after initial flexural limb deformity. Therefore, it can be recommended to start early with bandage support and NSAIDs in these foals as well.

Elongation of the flexor tendons is a risk of limb immobilisation in young foals and should therefore be performed judiciously. In the authors' experience, even short intervals of cast immobilisation may be very useful. In 1981, Fackelman described superior results after three weeks of full-limb cast therapy compared to no bandage therapy.[15] Prolonged casting in foals however, may be associated with weakening and elongation of flexor tendons and pressure sores.[16] As a result, it is not part of our current therapeutic strategy.

Hospitalisation and total rehabilitation time were significantly shorter for ETR only foals compared to those with an ETR-FD combined pathology. This was an expected finding.

At the start of the last century, the prognosis for an ETR was regarded as unfavourable, whereas in more recent literature and textbooks, the prognosis is described as good.[1,4,6] Based on the information obtained from our structured telephone interviews with owners, the short-term functional outcome of cases with isolated ETR was good. No conclusions can be drawn regarding the long-term results due to the small sample size. In contrast, for foals with an ETR and concurrent flexural limb deformity, the short-term as well as the long-term outcome was poor for both cosmetic appearances. The long-term functional outcome for Thoroughbred foals was also negative. This negative outcome in foals is unlikely to be attributable purely to the presence of a flexural limb deformity, as outcome for flexural limb deformities have been described as moderate (for horses competing at an international level) to good (for riding horses).[13] A recent multicentre retrospective matched cohort study showed that desmotomy of the accessory ligament of the deep digital flexor tendon to correct flexural limb deformity did not reduce the probability of horses entering competition.[14] Therefore it seems plausible to assume that the ETR itself is an important factor in the reduced functional outcome identified in this study. To improve prognosis in the future, it may be important to focus on preventing secondary flexural limb deformity and accordingly treatment should be implemented quickly after clinical signs are noticed.

In the literature, the possibility of a genetic component to the pathogenesis of ETR has been discussed.[4,8] The current study only investigated whether other offspring from the mare suffered from ETR or not. Offspring of the sire were not included in the analysis due to lack of available information on the sires and their offsprings. This study does not allow for further exploration of this association due to the small sample size and limitations of a retrospective study with owner-directed follow-up.

Half of the owners surveyed found the treatment to be expensive and suggested that they would only invest this amount into a foal that they determined to have a high genetic value, which was a surprisingly high number of owners. This decision is most likely to be associated with the poor long-term outcome of the foals with an ETR and flexural limb deformity.

The main limitations of this study were the small sample size with a convenience sample of cases from the participating centres, and that follow-up was carried out by structured telephone interview with the owner. Data pertains to a specific hospitalised population and the prognosis may be better for milder cases which may be managed without referral and hence, are not included in this study. Some specific details of the clinical examination (palpation of tendon stumps and potential crackling sound, etc.) were not consistently noted in the clinical records. Diagnostic imaging studies varied in extent and dynamic ultrasonography studies were not performed. Treatment procedures differed between different hospitals. Due to the retrospective character of this study, further influences on the development of ETR discussed in literature, such as hypothyroidism could not be investigated. However, the skeletal ossification index in the foals which were radiographically examined was Grade 4 in most cases (9/14) and Grade 3 for the remainder (5/14), indicating that these foals were minimally/not skeletally underdeveloped. As such, it is less likely that hypothyroidism played a role in these cases.[17]

In conclusion, this retrospective study on ETR details clinical findings, treatment, and outcome of foals with ETR, providing evidence to suggest that the outcome is mainly affected by the presence or absence of a concurrent flexural limb deformity and seems to be less favourable than claimed in earlier reports. As data pertained to a specific hospitalised population, it cannot be excluded that the prognosis may be better for milder cases which may be managed without referral. Limitations with regard to the retrospective nature of the study must be considered when interpreting the data of the present study.

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Competing Interests
No competing interests have been declared.

Ethical Animal Research
Research ethics committee oversight not required: retrospective study of clinical records and data from a structured telephone interview at Ghent University and University of Veterinary Medicine Hannover. Retrospective review of clinical records at Rossdales Equine Hospital and racing records obtained from a public database.

Informed consent
Owner's consent for use in this specific study was obtained at Ghent University and University of Veterinary Medicine Hannover. At Rossdales Equine Hospital all owners signed a consent form on hospital admission which highlighted that records may be used anonymously for research purposes.

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Data availability statement
The data which supports the findings of this study are available from the corresponding author upon reasonable request

Author Contributions
A. Mokry, U. Delling and M. Oosterlinck contributed to the study design. A. Mokry, C. Bernhard, U. Delling, J. Faulkner, K. Vanderperren, V. Colgate and M. Oosterlinck contributed to the study execution, data analysis and interpretation. All authors contributed to drafting and revision of the manuscript and approved the final version. A. Mokry had full access to all the study data and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Figure legends

Figure 1: Flow chart of the classification of foals based on clinical examination after admission in the referral centre (ETR = extensor tendon rupture, FD = flexural limb deformity, ETR_FD = initial ETR with subsequent development of FD, FD_ETR = initial FD with subsequent development of ETR).

Figure 2: Ultrasonographic images at the level of the dorsal aspect of the distal row of carpal bones in a 20-day-old colt with a common digital extensor tendon partial rupture, obtained at the initial examination (A) and 15 months later (B). A1) transverse image showing marked enlargement of one of

the tendon stumps, hypoechoic to anechoic heterogeneous echogenicity and anechoic sheath effusion. A2) Longitudinal image showing loss of fibre pattern and undulating appearance of the tendon secondary to retraction of the ruptured tendon ends. B1) transverse image showing a decrease in the cross-sectional area, decrease in the heterogeneity of the echogenicity and decreased sheath effusion. B2) longitudinal image showing mixed short and medium fibre pattern. Lateral and proximal are to the left of the images. Ultrasonographic examination was initially performed in the recumbent foal, and the control examination (15 months later) in the standing horse.

Figure 3: Dorsopalmar (A) and lateromedial (B) radiographs of the carpi of a 21-day-old colt with unilateral rupture of the common digital extensor tendon and moderate to severe tenosynovitis, visualised radiographically as a soft tissue swelling at the dorsal and lateral aspects of the carpus and proximal metacarpus with the maximal point at the level of the distal row of carpal bones (arrowheads). Skeletal ossification index is Grade 4. Lateral and dorsal are located on the left of A and B respectively. Radiographs were taken in the standing foal.

Figure 4: Flow chart of the short- and long-term follow-up information for 20/29 of the included foals, divided by cosmetic and functional outcome and by categories (with and without concurrent flexural limb deformity). The number of foals is indicated in the brackets. A cosmetic negative outcome was indicated if a flexural limb deformity, swelling at the level of the dorsolateral aspect of the carpus, or white hairs were present. A negative functional outcome was indicated if the owner reported poor performance or other locomotor problems.

Supporting Information

Supplementary Item 1: Example of the structured telephone interview with the owner conducted at Ghent University and the University of Veterinary Medicine Hannover.

References

1. Hunt RJ. Flexural Limb Deformities in Foals. In: Diagnosis and Management of Lameness in the Horse, Second Edition., Eds: M.W. Ross and S.J. Dyson, W.B. Saunders, Saint Louis. 2011: 645–649.

2. Myers VSJ, Gordon GW. Ruptured common digital extensor tendons associated with contracted flexor tendons in foals. Proc Am Assoc Equine Pract. 1976:2167–2174.

3. Tatarniuk DM, Trumble TN, Baxter GM, Ernst NS, McIlwraith CW, Hunt RJ. Lameness in the Young Horse. In: Adams and Stashak's Lameness in Horses, 7th Edition., John Wiley & Sons, Ltd. 2020:1033–1090.

4. Fürst A, Auer JA, Kaegi B. Rupture of the common digital extensor in a foal. Prakt Tierarzt. 1996;77:69-72

5. Embertson RM. Congenital abnormalities of tendons and ligaments. Vet. Clin. N. Am.-Equine Pract. 1994;10(2):351-364.

6. Williams WL. Veterinary Obstetrics. Published by the author. 1909. 1070.

7. Williams WL. Diseases of the Genital Organs of Animals. Published by the author. 1939. 553.

8. Stevenson WL, Stevenson WG. Rupture of the Common Digital Extensor. Can J Comp Med Vet Sci.1942; 6:197–203.

9. Arnbjerg J, Smith M, Sonnichsen HV. Ruptur af musculus extensor digitorum communis hos fol. Nordisk Veterinaer Medicin.1970;22:452–455.

10. Yovich J, Stashak T, Mcilwraith C. Rupture of the Common Digital Extensor Tendon in Foals. Compend Contin Educ Pract Vet. 1984;6(7): S373-S378.

11. Tnibar M, Kaser-Hotz B, Auer JA. Ultrasonography of the Dorsal and Lateral Aspects of the Equine Carpus: Technique and Normal Appearance. Vet. Radiol. Ultrasoundy. 1993; 34(6):413–425.

12. Adams R, Poulos P. A Skeletal Ossification Index for Neonatal Foals. Vet Radiol Ultrasound. 1988;29(5):217–222.

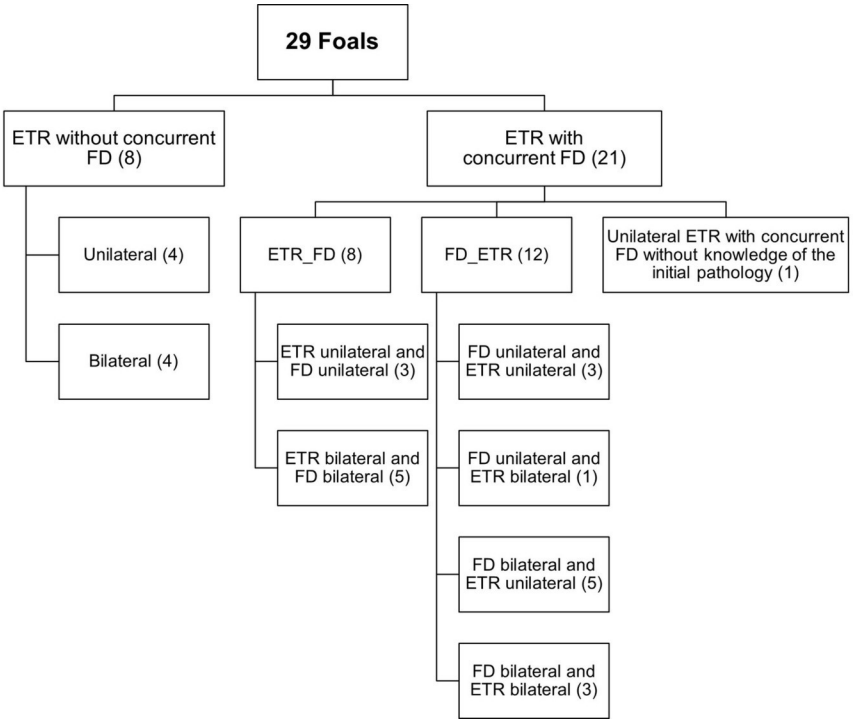
13. Carlier S, Oosterlinck M, Martens A, Pille F. Treatment of acquired flexural deformity of the distal interphalangeal joint in the horse: a retrospective study of 51 cases. Vlaams Diergeneeskd Tijdschr. 2016;85: 9–14.

14. Wismann ES, Jacobsen S, Thøfner M, Ladefoged S, Ekstrøm C, Lindegaard C. Long-term athletic performance in sport horses after desmotomy of the accessory ligament of the deep digital flexor tendon. Equine Vet J. 2022;54(3):495-501.

15. Fackelman G. Equine flexural deformities of developmental origin. Proc Am Assoc Equine Pract.1981:97–105.

16. Bischofberger AS. Drains, Bandages, and External Coaptation. In: Equine Surgery. 2019:280–300.

17. Koikkalainen K, Knuuttila, A, Karikoski N, Syrjä, P, Hewetson M. Congenital hypothyroidism and dysmaturity syndrome in foals: First reported cases in Europe. Equine Vet. Educ. 2014; 26(4): 181–189.



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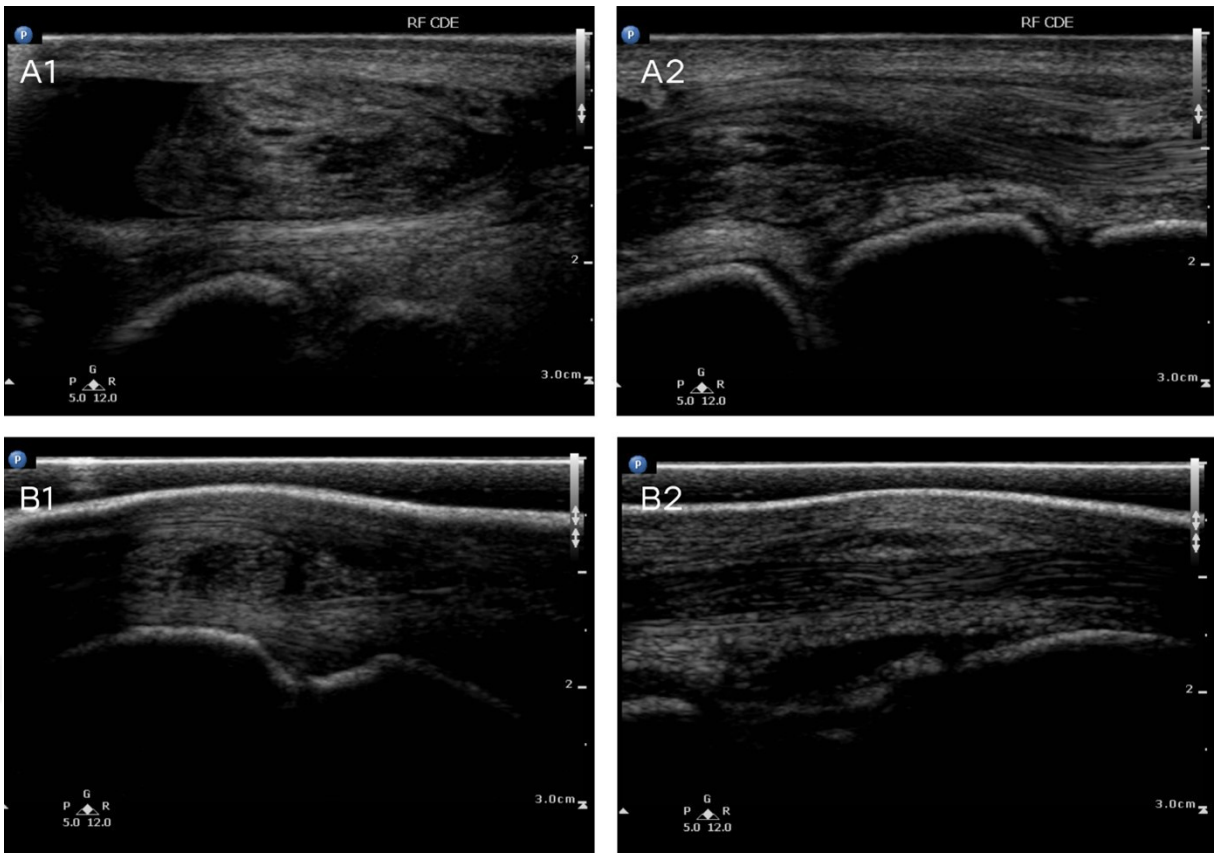

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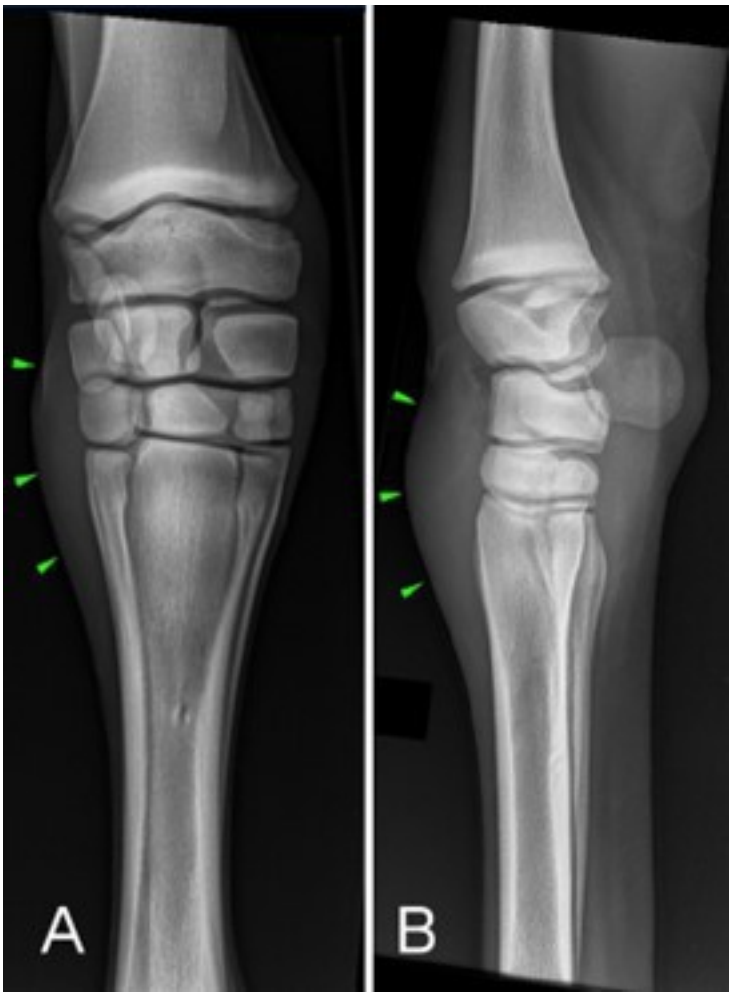

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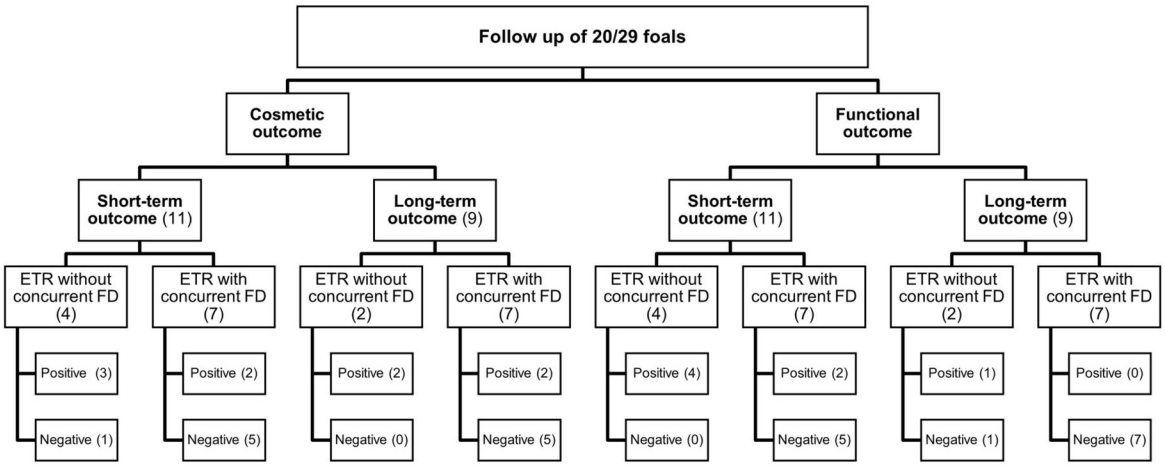

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