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The existence of intertransverse joints in young warmblood foals

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OBJECTIVE
To verify the existence of intertransverse joints (ITJs) in young foals.

ANIMALS
11 warmblood foals.

PROCEDURES
Postmortem examination of the lumbar area in foals < 200 days old using CT, MRI, dissection, and histomorphology. Data were analyzed with descriptive statistics.

RESULTS
Age of foals varied between 1 and 200 days (median, 11 days). Ten foals had 6 lumbar (L) vertebrae, and 1 foal had 5. All 11 foals, irrespective of age, had ITJs between the first sacral and last lumbar vertebrae and between the last and second-to-last lumbar vertebrae. In 6 foals (all with 6 L vertebrae), ITJs also existed between the fourth and fifth L vertebra. One foal, also with 6 L vertebrae, additionally had a unilateral (right) ITJ between the transverse processes of the third and fourth L vertebra. Based on CT, width of ITJs was seemingly greater in young (< 1 month old) foals because of the incomplete ossification of the transverse processes. The ITJs were confirmed and further characterized by MRI, dissection, and histomorphology.

CLINICAL RELEVANCE
ITJs already exist in very young warmblood foals and are present at birth. During the first months of life, these juvenile ITJs develop similarly to other synovial joints with increasing ossification and concomitant decrease of thickness of the cartilage layer. Knowledge of the presence of these ITJs in young animals is clinically relevant, as they should be recognized as nonpathologic when for instance a young foal is presented for presumed arthropathy and examined with advanced imaging techniques.

Intertransverse joints (ITJs) are joints that are localized between the transverse processes of caudal lumbar vertebrae. These joints, which also have been described as lateral joints, are unique to horses and rhinoceroses[1] and have thus far been found in all horse breeds examined, including domestic, wild, and prehistoric specimens.[1–3] They increase stability in the lumbar region, specifically by limiting axial rotation and lateral bending.[1,2,4,5] Generally, the number and size of ITJs decrease in a cranial direction, and ITJs are non-existent between the transverse processes of the most cranial lumbar vertebrae.[1,2,6] The number and condition (ankylosed [nonfunctional] or normal [functional]) of ITJs vary between warmblood horses, Konik Horses, and Shetland ponies.[6] In Shetland ponies, more than half of all ITJs were ankylosed; in warmblood horses, the number was far less.[6] Asymmetry between the left and right side, in presence and in condition, is common[2,6] and variable between breeds.[6] Differences between breeds in cranial extension exist also. In Konik horses, no ITJs were located cranial to the second-to-last lumbar vertebrae, in contrast to 22% in Shetland ponies and 23% warmblood horses.[6] In the early 1960s, Stecher[1] reported that the development of these lateral joints started after birth. Stecher examined horse bones macerated by the weather, fresh skeletal material from an abattoir, and specimens from numerous zoological museums. In that study, he stated that these ITJs (lateral joints) were not present at birth in "very young" (< 6 weeks) skeletons. In 8 very young skeletons recorded as 36 hours, 4 days, or 6 weeks old, ITJs could not be discerned.[1] From the 1960s on, later reports[5,7] referenced this finding, and no specific research concerning ITJs has since been conducted. Recent research on anatomical variation and breed differences between warmblood horses, Konik horses, and Shetland ponies makes this finding questionable when lumbar areas of young specimens are examined using CT.[6] As whole-body CT imaging in young foals is implemented more and more for presurgical planning of foals with, for example, polyarthritis, possibly in combination with umbilical (remnant) infection,[8] being familiar with detailed CT anatomy becomes crucial. When performing dissection of newborn foals, the first author (TJPS) observed the presence of ITJs.

The aim of this study was to evaluate the presence of ITJs in young warmblood foals to clarify whether ITJs exist at birth or develop with time and more specifically at which age. Our hypothesis was that ITJs already exist in newborn foals and continue to develop after birth as other synovial joints do.

Materials and Methods

Foals

Eleven very young to young warmblood foals that died or were euthanized for reasons unrelated to this study (ie, foals for which no axial skeletal abnormality was clinically visible) were collected and included for postmortem examination after getting the owner's written informed consent. Postmortem examinations of the intertransverse regions consisted of advanced diagnostic imaging (CT, MRI) and dissection followed by macroscopic and histomorphologic examination. Data were analyzed with descriptive statistics in a spreadsheet program (Excel version 16.43; Microsoft Corp).

Advanced diagnostic imaging

The lumbar spines were subjected to CT and MRI within 24 hours after euthanasia. For CT examination, the lumbar spines of 9 intact foals (Nos. 1 through 5 and 8 through 11) were scanned in ventral recumbency in a custom-designed CT tray. A 64-slice sliding gantry CT (Somatom Definition AS; Siemens) was used (kVp, 100 mAs; automated exposure control [Care-for-Dose] rotation time, 1 second; slice thickness, 0.6 mm; spiral pitch factor, 0.8; convolution kernel, B30 or B60; matrix, 512 X 512; scan field of view, variable according to cadaver size).

Contrast CT was used to outline the ITJ joint cavities in foal 8. For this purpose, the soft tissue mass surrounding the lumbar vertebrae was further reduced, and 1 to 2 mL of contrast medium (Iobitridol; 350 mg/mL) was injected in the intertransverse space under CT guidance.

For MRI, performed in 3 foals (Nos. 2, 4, and 8), muscular tissue of the lumbar spines was reduced to improve image quality. A 1.5-T MRI (Philips Ingenia) was used, and images were acquired in ventral recumbency with an extremity coil surrounding the remaining soft tissues. Sequences applied were dorsal short tau inversion recovery (repetition time, 4,338 milliseconds; echo time, 60 milliseconds; inversion time, 165 milliseconds; slice thickness, 2.5 mm; interslice gap, 2.5 mm; field of view, 250 mm; matrix, 280 X 207), sagittal T2-weighted turbo spin echo (repetition time, 3,053 milliseconds; echo time, 115 milliseconds; slice thickness, 2 mm; interslice gap, 2 mm; field of view, 160 mm; matrix, 400 X 275), and dorsal proton density turbo spin echo with fat saturation (repetition time, 3,614 milliseconds; echo time, 30 milliseconds; slice thickness, 0.8 mm; interslice gap, 0.88 mm; field of view 187 mm; matrix, 424 X 321). Acquired images were evaluated for visibility of the ITJs and components (such as synovial fluid and cartilage lining) in the picture archive and communication System (Enterprise; Agfa Healthcare) in DICOM format. Volume-rendering and multiplanar reconstruction was also performed in the mentioned picture archive and communication system.

Dissection and macroscopy

All 11 lumbar areas were dissected completely and examined for the presence of ITJs. During dissection of 6 foals, images and videos (Lumix DMC-FZ 30 GT; Panasonic) were made of the lumbar areas with special focus on the intertransverse region between the transverse processes of all lumbar vertebrae.

Histomorphology

After macroscopic imaging, samples of 4 lumbar areas (foals 1, 3, 6, and 11) were prepared for histomorphology. Samples were fixed in neutral-buffered 10% formalin and decalcified in 10% EDTA before routine processing and staining with H&E and subsequent light microscopic evaluation (BX45; Olympus).

Results

Foals

The 11 foals consisted of 7 males and 4 females, with a median age of 11 days (range, 1 to 200 days) and median body mass of 70 kg (range, 40 to 250 kg). Four foals were younger than 1 week, 5 foals were between 1 and 4 weeks of age, and the 2 oldest foals were 131 and 200 days, respectively. Detailed information of all 11 warmblood foals with corresponding examinations of advanced diagnostic imaging, dissection, macroscopic imaging, and histomorphology is provided **(Supplementary Table S1)**.

Advanced diagnostic imaging

All 9 intact foals subjected to CT had 6 lumbar vertebrae **(Supplementary Table S2)**. Irrespective of age, ITJs were bilaterally present between the last lumbar and first sacral vertebra in all specimens. All foals also had bilateral ITJs between the fifth and sixth lumbar vertebrae. Five foals had bilateral ITJs between the fourth and fifth lumbar vertebrae. One foal (No. 11) had a unilateral (right) ITJ between the third and fourth lumbar vertebrae **(Figure 1)**.

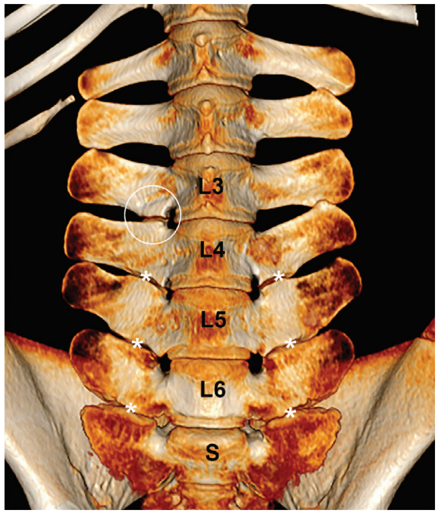

Figure 1—Volume-rendering reconstruction of the ventral aspect of the lumbar region of a warmblood foal (No. 11) with 6 lumbar vertebrae. Intertransverse joints (ITJs; asterisk) between sacrum (S), sixth lumbar (L6), fifth lumbar (L5), and fourth lumbar (L4) vertebrae are clearly visible. There is also a unilateral ITJ present between the right transverse processes of L4 and L3 (circle). Note the rib remnant in the extension of the right transverse process of L1.

In the younger foals (< 1 month), the ITJ spaces appeared very wide in combination with almost undefinable joint margins while evaluated with CT due to incomplete/ partial ossification at birth **(Figure 2)**.

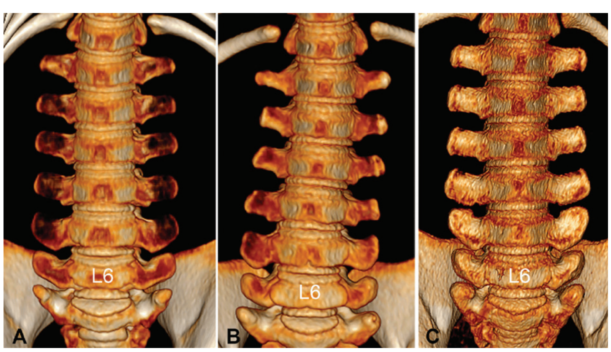

Figure 2—Volume-rendering reconstruction of the ventral aspect of the lumbar region of 3 warmblood foals (A, No. 1 [1-day-old female]; B, No. 4 [4-day-old male]; C, No. 8 [14-day-old female]), all with 6 lumbar vertebrae. In these very young foals, the areas of the ITJ spaces appeared to be very wide in combination with almost undefinable joint margins while evaluated with CT due to incomplete or partial ossification at birth.

With increasing age, these ITJs could be better defined as ossification proceeded. Injection of contrast medium into the synovial cavities of the ITJs between the left transverse processes of L4 and L5 and L5 and L6 was performed in a 14- day-old foal (No. 8). Thin lines of contrast were visible between the L4 and L5 and L5 and L6 transverse processes **(Figure 3)**. Soft tissue to cartilage-attenuating tissue of 2 to 2.2 mm was present between the ossified parts of the latter.

On all 3 specimens that underwent MRI, ITJs were visible between the nonossified parts of the transverse processes and were best visualized as thin, hyperintense lines due to presence of synovial fluid on proton density images **(Figure 4)**. Separate visualization of joint cartilage versus synovial fluid or the cartilaginous (nonossified) part of the transverse processes was not possible in any of the sequences, as less detail of the ITJs was noted in the short tau inversion recovery or T2-weighted turbo spin echo sequences compared with the detail in proton density images.

Figure 3—Dorsal plane CT image of the caudal dissected lumbar region of a warmblood foal (No. 8 [14-day-old female]; ***see*** also Figures 2 and 5) after contrast arthrography of the left ITJs between L6, L5, and L4 (arrows). Note the thick cartilage layers of the ITJs, and because of the dissection, multiple air artifacts are visible.

Figure 4—Dorsal plane MRI image of a warmblood foal (No. 8 [14-day-old female]; ***see*** also Figures 2 and 3) depicts both the cartilaginous or nonossified (NO) part as well as the ossified (O) part of the transverse processes of lumbar vertebrae and the associated ITJs (asterisk).

Dissection and macroscopy

At dissection, CT and MRI findings were confirmed. The 2 foals (Nos. 6 and 7) that were not examined with advanced imaging had 5 and 6 lumbar vertebrae, respectively. In both foals, ITJs between the first sacral (S1) and the last lumbar vertebra and between the last and second-to-last vertebrae were encountered. Macroscopically, in younger foals (< 1 month old) in which the ossification of the transverse processes was still incomplete, the ITJs contained thick layers of cartilage with a fissure-shaped synovial cavity in between **(Figure 5)**. These ITJs appeared to be normal (functional) synovial joints in all dissected foals except one (foal 3). In this 2-day-old foal, both ITJs between transverse processes of L5 and L6 (left and right) contained opposing joint facets that were only partially separated **(Figure 6)**. The other ITJs identified between L4 and L5 had a regular appearance, as in the other foals.

Figure 5—Dissected warmblood foal number 6 (11-day-old male). Right view (cranial to the right) of transverse cut transverse processes of L3, L4, L5, L6, and S1, visualizing clearly the ITJs between L5 and L6 (asterisk) and between L6 and S1 (double asterisk) with their thick cartilage layers. Note the absence of ITJs between L3, L4, and L5.

Histomorphology

The histological findings of the 4 foals (Nos. 1, 3, 6, and 11, which were respectively 1, 2, 11, and 200 days old) corresponded with both advanced diagnostic imaging and macroscopy. On histology, the ITJs showed as 2 facets featuring a relatively thick layer of epiphyseal cartilage with underlying subchondral bone, a synovial cavity in between, and a joint capsule (Figure 6). The thickness of the epiphyseal and articular cartilage decreased with age of the foal (from approx 21 mm at day 1 and 2 to approx 17 mm at day 200), consistent with progression of the ossification front. The partially separated ITJs between L5 and L6 of foal 3 showed largely nonseparation of the articular cartilage of the opposite facets with focal presence of a small joint space, partially filled with eosinophilic fibrillar proteinaceous material. Both facets of the L3 and L4 ITJs of the 200-day-old foal (No. 11) had focally necrotic epiphyseal cartilage, consistent with osteochondrosis latens **(Supplementary Figure S1)**.

Discussion

ITJs appear to be already present at birth in warmblood foals and do not develop in the early neonatal period (after 6 weeks) as suggested earlier.[1] The ITJs, which have the characteristics of juvenile synovial joints, can be visualized by CT and MRI, which provide more detail on the soft tissues of these joints in which ossification is still incomplete. As whole-body CT imaging is increasingly employed in the workup of foals with, for example, polyarthritis or trauma, being familiar with the normal anatomy is essential for correct CT image interpretation. Results of the present study unequivocally showed that the presence of ITJs in very young horses should be considered physiologic rather than pathologic and therefore will help in avoiding incorrect interpretations.

The main reason the existence of ITJs in the horse at the very young stages was not noted in the earlier work is most likely the source of the material that was used. Specimens consisted of "horse bones macerated

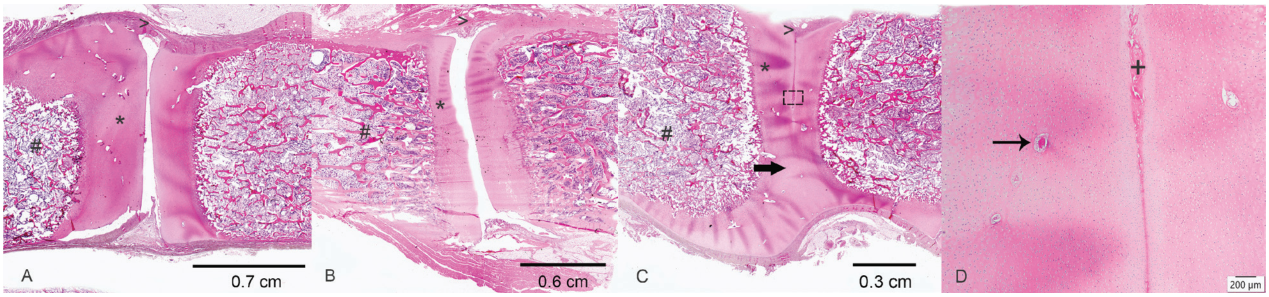

Figure 6—Microscopic images of H&E-stained ITJs. A—The ITJs were composed of 2 facets featuring a thick layer of vascularized epiphyseal cartilage (*) with underlying subchondral bone (#) with a synovial cavity in between and a joint capsule (>). The thickness of the articular-epiphyseal cartilage complex decreased with the age of the foal, from approximately 21 mm at days 1 and 2 (A) to approximately 17 mm at day 200 (B), consistent with the gradual progression of the ossification front. C—The right L5-L6 ITJs of foal number 3 showed for the better part nonseparation of the articular cartilage (thick arrow) of the opposite facets with focal presence of a small joint space (rectangle). D—The reduced joint space in this area was partially filled with eosinophilic fibrillar proteinaceous material (+). The thin arrow indicates a blood vessel (enlargement of area indicated with rectangle in C).

by the weather, fresh skeletal material from a horse butcher, and specimens examined personally in numerous zoological museums in America and Europe."[1] In the juvenile joints, large parts are cartilaginous, which will not survive either maceration due to weather conditions or processing for making a skeletal preparation as they are on display in zoological museums. It is not known which specimens in Stecher's report[1] came from an abattoir, but it is uncommon to slaughter very young foals, so it is likely that the neonatal animals he examined did not come from this source.[1]

Histological examination of the ITJs from the foals showed, as could be expected, that these synovial joints are still in development with vascularized epiphyseal cartilage present and endochondral ossification still in progress. For this reason, the joints did not materialize in the 3D volume-rendered CT reconstructions (Figure 2) of this manuscript. Of course, this condition will change after further maturation and termination of the process of endochondral ossification.

In one of the ITJs, the joint space was incomplete. One explanation for this nonfunctionality could be ankylosis of the ITJs, which has been noted frequently in adult specimens.[1,2,6] Another explanation could be an incomplete separation through a delay in the cavitation process, which is part of the developmental process of synovial joints.[9] By both gross and histological examination, no signs of inflammation or degeneration could be seen, and therefore a pathologic cause for ankylosis could not be determined. Hence, delayed separation of the joint surfaces seems more likely to be the cause for the lack of a complete joint space. Osteochondrosis latens, which is only detectable ex vivo, has been reported in many equine joints,[10,11] but not in ITJs. Further research might be warranted to determine the importance of this finding.

It can be concluded that ITJs between lumbar transverse processes are already existent at birth in warmblood horses, which has been overlooked in the past. The observation is relevant, as it means the anatomical feature is constitutive for the species, rather than an anomaly. One could conjecture that the adaptation has evolved as a stabilizer of the equine spine, and it may be interesting to closely examine both fossilized equids from the evolutionary tree of the horse and equids that are close to *Equus caballus ferus*, such as donkeys, zebras, and onagers. From a clinical perspective, it is important to classify these joints as normal for the species.

Acknowledgments

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Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org