The equine forelimb is connected to the axial region by a synsarcosis, a joint composed of only muscles (Figure 1), which provides independent mobility of the limb over the thorax and plays a role in shock absorption, owing to the elasticity and active eccentric contraction of the involved muscles.1,2 The anatomical features and roles of individual intrinsic muscles of the shoulder are extensively described in the literature.1–4 However, traumatic injuries to the serratus ventralis cervicis (SVC) and serratus ventralis thoracis (SVT) muscles have not yet been documented and described.5

The SVC muscle originates from the transverse processes of the third or fourth to the seventh cervical vertebrae (C3/C4 to C7) and attaches to the cranial facies serrata of the medial aspect of the proximal scapula. The SVT muscle originates at the level of the middle third of the first 8 ribs and is inserted on the caudal facies serrata of the medial aspect of the scapula.1,3,4 The STV and SVC contribute...
to protraction and retraction, respectively, of the thoracic limb during locomotion moving the scapula over the thoracic wall; moreover, they play a key role in suspension of the thorax between the forelimbs during locomotion and allow distribution and dissipation of the ground reaction forces, thereby acting as a shock absorber–spring complex through eccentric contraction (Figure 1).

The aim of this case series was to describe the clinical diagnoses, imaging features, treatments, and outcomes of spontaneous tears to the SVC and SVT muscles of endurance horses.

Methods

All data of horses that underwent full examinations due to onset of lameness between January 2012 and December 2020 were retrieved from a database of the ambulatory field practice of one of the authors (MP). The inclusion criteria were a clinical diagnosis and diagnostic imaging of injuries to the SVC and/or SVT that occurred during training or competition and available follow-up data for at least 24 months. Horses with an injury to the SVC and/or SVT as a consequence of a traumatic event were excluded from this study. Each diagnosis was confirmed by physical and dynamic examinations, which included walking on a firm surface along a straight line and a figure-eight pattern, trotting in a straight line, and, when safe for the horses, around circles in clockwise and counterclockwise directions. At the walk, the features of the cranial and caudal phase of the stride were considered and any changes evaluated as mild to severe. The modified lameness score of the American Association of Equine Practitioners was used to grade lameness identified during a trot in a straight line.

Ultrasonography was performed by one of the authors (MP) using a portable ultrasonography instrument (M-Turbo or Edge II; FUJIFILM Sonosite Inc) equipped with a multifrequency (3.5- to 5-MHz) convex probe. Prior to ultrasonography, the caudal neck and shoulder and cranioventral aspect of the thorax were rubbed with alcohol without clipping. The portions of the SVT and SVC muscles protruding from the caudal and cranial margins of the scapula were imaged ultrasonographically. The parts of the SVT and SVC muscles located under the scapula are impossible to image. The probe was placed on the transverse section (perpendicular to the direction of the muscle fibers) caudal to the middle third of the scapula to image the SVT, which was identified between the long head of the triceps brachii muscle and the ribs (Figure 2). More dorsally, the SVT was imaged by moving the probe proximally to follow the caudal margin of the scapula, where it was more superficial and covered by the latissimus dorsi muscle. Afterward, the probe was placed on the transverse section (perpendicular to the muscle fiber direction) cranial to the scapula and dorsal to the cervical vertebrae to image the SVC muscle between the more superficial trapezius and subclavius muscle bodies, deeper to the longissimus cervicis and semispinalis capitis muscles. For 10 of the 11 horses, the contralateral side was used to obtain reference images for comparison of the muscle size and architecture. Upon clinical and ultrasonographic confirmation of the diagnosis, treatment was initiated with the NSAID phenylbutazone at 2.2 mg/kg of body mass, administered IV once per day for 7 days.

Each horse underwent a standardized rehabilitation program adapted to the clinical condition evaluated by the clinician. The rehabilitation program consisted of approximately 2 to 4 weeks of a box-rest regimen with 10 to 20 minutes of hand walking per day.
followed by 2 to 4 weeks of a box-rest regimen with 10 to 30 minutes of ridden walking each day. Afterward, progressive increase in riding with a saddle was continued. The increase in exercise was modulated in the following weeks according to the clinical condition of the horse. Basically, the exercise was extended in duration if the horse remained stable at a given effort (ie, 30 minutes of walking and 15 minutes of trotting) for at least 10 days. Full training was resumed within 3 to 5 months from the date of the injury. Ultrasonographic reevaluation was performed in some cases at approximately 10 days and 1 month after the injury. Follow-up information about possible lameness and the progression of the rehabilitation program and training were obtained by telephone interview with the trainer; competition records were then obtained through a web database (Yamamah app; Yamama-happ) for endurance competition to determine the date the horse was able to return to competition.

Results

The cohort of 11 horses (average age, 9.8 years; range, 8 to 11 years) included 5 Arabians and 6 Anglo-Arabians, of which 10 were geldings and 1 was a mare. All participated in medium- to high-level endurance national or international competitions (100 to 160 km) in the Middle East. Of these 11 horses, 10 were diagnosed after successfully finishing a competition or elimination because of an irregular gait during an endurance competition of 160 km (n = 1), 120 km (6), and 100 km (3). In addition, 1 horse was diagnosed after a long training session on deep sand. Of the 10 horses diagnosed with a unilateral injury, 4 involved the right forelimb, 6 involved the left forelimb, and 1 was affected bilaterally. The SVT muscle was affected in 7 cases and the SVC muscle in 3 cases.

Physical examinations of horses with injury of the SVT muscle revealed the presence of moderate-to-severe edema of the sternal area, a dorsocranial displacement of the scapula with asymmetry of the height of the proximal scapula as compared to the contralateral limb (Figure 3). 1 horse had no clear asymmetry because it was affected by bilateral lesions. In contrast, horses with injury of the SVC muscle had moderate-to-severe edema cranial to the scapula in the distal third of the jugular region expanding toward the pectoral region. Passive flexion and extension of

Figure 3—Physical examination: lateral (A and B) and dorsocaudal (C) views of 3 horses with tears of the SVT (A and C) and SVC (B) muscles. A—Severe edema at the ventral aspect of the thorax (black arrows) and proximal prominence of the scapula (black arrowhead). B—Edema of the pectoral area (asterisk) in the distal third of the jugular region, expanding toward the sternal region (white arrows). C—Asymmetric appearance of the proximal margin and cartilage of the scapula (black arrow) as compared to the contralateral limb.
the affected limbs were not performed to avoid painful manipulations to the animals.

Dynamic examinations revealed moderate-to-severe reduction of the cranial phase of the stride on the affected forelimb while walking and an American Association of Equine Practitioners modified lameness score of 2 to 3/5 when trotting in a straight line.

Ultrasonography of the affected muscles revealed moderate-to-severe increases in size of the muscle body compared to the contralateral site, associated with heterogeneous echogenicity, loss of the striated muscle pattern, and varying degrees of perimuscular edema correlating to the severity of the injury (Figure 4). Moreover, well-defined, regular anechoic areas of various sizes of the muscle body were identified in 9 of the 11 horses; these areas were the result of muscle fiber disruption. All ultrasonographic findings were consistent with a diagnosis of a second-degree muscle injury as defined in human medicine (< 100% of the cross-sectional area of the muscle).  

Within 10 days after injury, improvement in the reduction of the cranial phase of the stride at the walk, in the lameness at the trot, and in the soft tissue swelling was appreciated in all horses. In 6 horses (2 SVC and 4 SVT), ultrasound evaluation at 10 days showed resolution of the perimuscular edema, but the increase in size and the abnormal echogenicity of the muscle were still clearly evident compared to the contralateral normal side. In these horses, the abnormal ultrasonographic findings were completely resolved at 1 month from the injury.

Figure 4—Dorsoventral oblique ultrasonographic images of the SVC muscles (A through C) and transverse ultrasonographic images of the SVT muscle obtained with a 3.5- to 5-MHz convex probe (D through F). Cranial is to the left. A—Normal ultrasonographic appearance of the SVC muscle (1) surrounded by the subclavius (2) and the trapezius (pars cervicalis; 3) muscles. Hyperechogenic outline of the cervical vertebra (4). B—The SVC muscle appears swollen with loss of striated muscle pattern (asterisk) and mild edema surrounding the SVC muscle body (white arrow). C—The SVC muscle appears swollen with heterogeneous echogenicity and localized anechoic areas within the muscle body in addition to loss of striated muscle pattern and irregular margins. There is severe edema surrounding the SVC muscle body (white arrow) and thickening of the perimysium (asterisk). D—Normal ultrasonographic appearance of the SVT muscle (5) between the long head of the triceps brachii muscle (6), the latissimus dorsi (7), and the ribs (8), with reverberation artifact of the lung (9). E—The SVT muscle appears swollen with loss of striated muscle pattern (asterisk), surrounded by severe perimuscular edema (arrow). F—The SVT muscle appears swollen with loss of the striated muscle pattern (asterisk) and localized, irregular anechoic areas within the muscle body (arrow).
According to the follow-up information, all horses returned to full training within 3 to 5 months from the date of the injury. The trainers or referring veterinarians of horses with injuries to the SVT reported that the asymmetry of the scapula had resolved 4 weeks after the injury. All horses were able to resume the same level of competition as before the injury in an average of 216 days (range, 74 to 362 days) for those with injuries to the SVT and 148 days (range, 112 to 309 days) for those with injuries to the SVC. No reinjuries were recorded.

Discussion

This report describes the clinical and ultrasonographic diagnosis of spontaneous SVC and SVT muscle injuries developed mainly during competitions in a group of endurance horses that showed a good outcome and return to full athletic activity after 3 to 5 months of controlled exercise. No reinjury was reported in any of the cases.

As described previously, clinical examination identified the shoulder and thorax as the anatomical regions affected by localized swelling and prominence of the proximal aspect of the scapula in cases with an injury to the SVT muscle and forelimb lameness. Dynamic manifestations were characterized by a reduction of the cranial phase of the stride on the affected limb while walking along a straight line or in a figure-eight pattern or trotting along a straight line. The clinical signs, including the soft tissue edema, improved relatively quickly within 10 days from the injury; anti-inflammatory drugs, box rest, or time may have played a role. Ultrasonography was particularly useful for identifying lesions of the SVC muscle because a diagnosis based only on clinical findings is arguable; in these lesions, there was no displacement of the scapula. Ultrasound examination enabled identification of the injury of the SVC muscle. The proximal displacement of the scapula can be considered pathognomonic for SVC injuries, and ultrasound can add information about extension of the damage.

Ultrasonography and MRI are considered the criterion standard for diagnosis of muscle injuries in human athletes. Magnetic resonance imaging is the preferred method for detection of first-degree lesions because subtle changes to the muscle are not detectable by ultrasonography. However, the use of MRI for horses is limited to the lower limb due to the size of the gantry and radiofrequency coils. In contrast, ultrasonography is useful for whole-body evaluation and diagnosis of muscle injuries of horses. Scintigraphy has also been employed for diagnosis of muscle injuries in horses, but was not necessary in this group of horses because the diagnosis was achieved by clinical and ultrasonographic examinations. Among the cases included in this study, ultrasonography was easily performed and well tolerated and facilitated clear identification of the injury, especially when images of the contralateral areas were used as a reference. However, ultrasonography is limited for examination of the entire SVT and SVC muscles. All injuries described in this study were defined as second degree (ie, partial muscle tears). A diagnosis of second-degree muscle injury is made when there is increased size, heterogeneous echogenicity, and focal anechoic areas involving < 100% of the cross-sectional area of an injured muscle at ultrasonographic examination. However, it was not possible to assess involvement of the most dorsal portion of the muscles located at the medial aspect of the scapula and tendinous/aponeurotic insertion; thus, a potential third-degree tear (complete destruction of the myotendinous junction) could not be excluded.

Rupture of the serratus ventralis muscle is described in the literature as a rare injury that develops only as a consequence of trauma and is characterized by proximal displacement of the scapula with poor prognosis. Trauma in the described cases was excluded because horses developed the muscle injuries during competition and training without any reported trauma by the riders. In addition, the results of this study demonstrated that horses with spontaneous SVT and SVC injuries were able to resume training and competition in a reasonable period of time. A favorable long-term prognosis in most cases has been reported after partial or complete tears of other equine muscles located in the proximal hind limbs, thigh, or croup or in the proximal forelimbs. A favorable outcome is not affected by the limb involved, whether single or multiple muscles are affected, or the age of the horse, and the recovery time is reported to be as long as 52 weeks in some cases. Recurrence of injury and persistent gait abnormality may occur.

A substantial number of muscle injuries in horses are reported to be the result of trauma; however, muscle tears as the consequence of sports activity are well described. Muscle tears in the athlete occur almost only during eccentric contraction, which is characterized by an active contraction while the muscle is elongated under load. It is a very efficient contributor to load absorption. The mechanism of eccentric contraction at the origin of muscle injuries during high-intensity activity for extended periods is well described in human athletes. Damage to the muscle fibers occurs when forces exceed muscle capacity. Moreover, the severity of muscle damage increases with the number of eccentric contractions during the activity. The role of eccentric contraction of the SVC and SVT muscles in horses is to prevent ventral displacement of the thorax during the first part of the stance phase, especially during the last sequence of the canter when the horse and rider body weights are supported by the forelimbs and then by the leading forelimb only.

To date, SVT and SVC injuries have only been described in endurance horses trained and competing in the Middle East, with lameness occurring after a long distance race or training. Repetitive loading cycles over an extended period at high intensity, such as endurance races in deep sand in the Middle East, might have played an important role in the development of these injuries in this particular population.
of horses, suggesting that the same peak loads over numerous consecutive strides cannot be reproduced in other disciplines.

Although uncommon, tears to the SVT and SVC muscles of endurance horses can result from training and competing in specific environments. Ultrasonography is key for definitive diagnosis of tears to the SVT and SVC muscles, and prognosis is good after appropriate rest and rehabilitation.

Acknowledgments
None reported.

Disclosures
Dr. Beccati is a member of the JAVMA Scientific Review Board, but was not involved in the editorial evaluation of or decision to accept this article for publication.

No AI-assisted technologies were used in the generation of this manuscript.

Funding
The authors have nothing to disclose.

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