Conservative treatment of partial gastrocnemius muscle avulsions in dogs using therapeutic ultrasound
A force plate study

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Keywords
Gastrocnemius muscle avulsion, therapeutic ultrasound, dog, ultrasonographic imaging, ground reaction forces

Summary
Objectives: In this report two cases of partial gastrocnemius muscle avulsion treated with pulsed therapeutic ultrasound are described. Methods: The outcome in these two dogs was evaluated using ultrasonographic imaging and the measurement of ground reaction forces with a force plate. Results: Both dogs showed an amelioration of the clinical signs within one month after commencement of the ultrasound therapy. The follow-up time for these cases was one year and six months respectively. Both of the dogs were free of lameness and had returned to their normal amount of exercise. Palpation of the fabella associated with the muscle injury did not produce any signs of pain. Ultrasonographic imaging did not detect any signs of haemorrhage or oedema, although scarring of muscle fibres was present. The force-plate analyses revealed an improvement. Clinical significance: These results suggest that therapeutic ultrasound could be a beneficial treatment modality for this kind of muscle injury.

Introduction
While Achilles tendon lesions are common injuries in dogs (1–3), injuries to the gastrocnemius muscle per se are less frequent (4). These injuries can occur at the origin of the lateral or medial heads of the gastrocnemius muscle, in the muscle belly, at the musculotendinous junction and in the region of the tendon insertion to the calcaneus (5, 6). While injury to the middle and distal regions of the muscle appears most frequently, injury to the proximal region of the gastrocnemius muscle is uncommon (5). Avulsion of the medial (5, 7) and lateral (6, 8, 9) heads of the gastrocnemius muscle, as well as, bilateral avulsion of the origins of the gastrocnemius muscle (4), have been described in single case reports. These injuries were often due to trauma (7, 8) and usually characterised by an acute onset of lameness and pain on palpation of the muscle origin and corresponding fabella. Diagnosis of gastrocnemius muscle injuries relies upon careful clinical examination, stressed radiographs and ultrasonographic examination. In cases with partial rupture of the gastrocnemius muscle, care should be taken not to mistake the clinical findings with a partial cranial cruciate ligament rupture (10).

Review of the literature on avulsion of the medial or lateral head of the gastrocnemius muscle revealed that various treatment modalities have been employed. Surgical fixation of the avulsed fabella or muscle fascia, combined with fixation of the hock joint in extension to neutralise forces on the gastrocnemius muscle, have resulted in acceptable outcomes (1, Table 1). However, these treatments were associated with complications such as wire breakage, leading to additional surgery (4, 9). One case was treated conservatively with non-steroidal anti-inflammatory drugs, physical therapy, and restriction of activity to a short leash (5).

In our report, the use of therapeutic ultrasound for the treatment of gastrocnemius muscle avulsion is described. Therapeutic ultrasound is a form of acoustic energy that is frequently used in physical therapy due to its purported effects of deep heating and pain relief (11). It has been proposed that there are two different main effects responsible for the beneficial effects of therapeutic ultrasound; thermal and non-thermal effects (11, 12).

The thermal effects are most evident with the use of continuous therapeutic ultrasound, and lead to an increased extensibility of collagen, which is very useful for stretching exercises (13) and for the reduction of muscle spasms (14). Non-thermal effects include a quicker entry into the proliferative phase during inflammation (15, 16) and a stimulation of tendon cell proliferation (17–19).
Although therapeutic ultrasound is a commonly used treatment modality in small animal physiotherapy, there is a lack of scientific reports describing the success of this modality for muscle injuries in dogs. One study failed to demonstrate any positive effects of ultrasound therapy on the healing of surgically severed Achilles tendons in dogs (20). The use of therapeutic ultrasound as a treatment modality for muscle injuries in humans is also described (21), but its effectiveness is controversial. For example, the use of non-thermal ultrasound and exercise did not significantly alter biomarkers of skeletal muscle regeneration in rats with injured gastrocnemius muscles (22). However findings of another study suggested that therapeutic pulsed ultrasound seemed to protect injured skeletal muscle tissue from oxidative injury (23).

The purpose of our report is to describe the use of therapeutic ultrasound to treat partial rupture of the proximal portion of the gastrocnemius muscle in dogs, with the outcome being evaluated by force-plate analysis and ultrasonography.

**Case histories**

Two cases of injuries to the proximal region of the gastrocnemius muscle are described. Both dogs were referred to the Clinic for Small Animal Surgery and Ophthalmology at the University of Veterinary Medicine in Vienna Austria with the tentative diagnosis of partial cranial cruciate ligament rupture.

**Case 1**

A nine-year-old, male Malinois (Belgium Shepherd) of 34 kg body weight was presented with the complaint of an acute exacerbation of a chronic lameness. There was a history of intermittent lameness on the right hindlimb of approximately three years duration. The dog had been treated with anti-inflammatory medications without any significant improvement of the clinical signs. The orthopaedic examination revealed second to third degree lameness (24), and the dog was only partially weight bearing on the affected limb in a standing position. Distinct atrophy of the hamstring muscles was present. Extension of the stifle joint and palpation of the right lateral fabella elicited signs of moderate pain. The right popliteal lymph node was slightly larger than the left. Cytology from arthrocentesis was within normal limits.

Radiographic examination of the right stifle showed a 7 mm wide bone fragment directly proximal to the lateral fabella (Fig. 1). A radiolucent area was seen in the proximal margin of the lateral fabella. Distal femoral bone showed blurred margins in this area. An avulsion fracture of the lateral fabella was diagnosed. Ultrasonography of this area revealed a normal joint space and a normal lateral meniscus. The lateral fabella was fractured; the fragment was visible as a hyperechoic structure with distal shadowing (Fig. 2).

The origin of the gastrocnemius muscle is described by force-plate analysis and ultrasonography.
muscle appeared hypoechoic to anechoic. The muscle fibres appeared heterogeneous. The dog was treated with carprofen® at a dose rate of 2 mg/kg daily for five days.

**Case 2**

A two-year-old male white German Shepherd dog of 30 kg body weight was presented with a history of sudden onset of third degree lameness on the right hindlimb of four days duration. There was no history of trauma that may have caused the lameness. The orthopaedic evaluation of the right femorotibial joint revealed signs of moderate pain on joint extension and severe pain on palpation of the mediomedial femur, especially when applying pressure on the medial fabella.

Radiographic examination of the stifle joint did not show any abnormality. Ultrasonography was performed and showed a normal stifle joint and menisci. The medial fabella was well demarcated. Distal to the medial fabella, the gastrocnemius muscle was hypoechoic. Muscle fibres were hyperechoic with hypoechoic areas; representing oedema, haematoma and partial muscle rupture (Fig. 4). The initial treatment administered was carprofen at a dose rate of 4 mg/kg once daily for two days with a dose reduction for the following five days to 2 mg/kg once daily.

**Force plate evaluation**

Evaluation of lameness in both animals was made by measurement of ground reaction forces (25–29) using a custom-built treadmill with four integrated force plates that were specifically developed for animalsb (25, 30–32). This allowed for the simultaneous measurement of both fore and hindlimbs which is of great advantage because it limits influencing factors, such as trial repetitions and deviations in velocity during the repetitions when using single force plates (25, 33). After acclimatization to the treadmill, the dogs were allowed to walk at a comfortable speed (dog 1: 1.22 m/s, dog 2: 1.22 m/s).

Follow-up measurements were performed at exactly the same speed as the first measurement. This fact is of great importance because velocity is an important influencing factor on the results of the measurements of ground reaction forces (33, 34). The vertically acting forces of peak vertical force (PFz) and vertical impulse (IFz) were recorded. The PFz describes the maximal force generated directly at the stance phase onset; the IFz is an integral of the time / force curve and reveals important information on the entire stance phase. Five valid trials were chosen for calculation of PFz and IFz. The mean of the five trials was calculated for each parameter and expressed in percent of body mass (% BM) (34). To describe the symmetry between the limb pairs, we calculated symmetry indices (SI), expressed as a percentage for PFz (SIPFz%) and IFz (SIIFz%) using a modification of a previously described formula (35) as follows:

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**Fig. 3** Sonogram of the right lateral fabella, longitudinal scan of case 1, two months after first examination. The region around the lateral fabella and bone fragment is more hypoechoic (arrows).

**Fig. 4** Sonogram of the region of the right medial fabella, longitudinal scan of case 2. There is an anechoic area (arrow) surrounding the medial head of the gastrocnemius muscle (GM).

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a Rimadyl® – Pfizer, Vienna, Austria
b Developed at the Ludwig-Maximilians-Universität München, U. Matis and at the Sporthochschule Köln, Germany, G. P Brüggemann.
where: $S$ = mean of a gait measurement from the limb with the smaller value (left or right) between the two limbs; $L$ = mean of the same gait measurement from the limb with the larger value.

Using this formula, an animal with perfect gait symmetry would have a $S_I$ of 0%, although deviation of $S_I$ of up to 4% for PFz and 6% for IFz for the hind leg in sound dogs are considered normal (35).

Measurements were taken immediately before the first treatment and at the end of the treatment period at five weeks in case 1 and four weeks in case 2. A third measurement was made at final follow-up at five months in case 1 and two months in case 2, from the time the treatment was started.

### Physical therapy

For the treatment of both dogs, therapeutic ultrasound was used according to the recommendations in the literature (36, 37). The dogs were not bandaged, but were kept on short leash walks for 6 to 8 weeks.

### Case 1

Thirteen treatment sessions using pulsed therapeutic ultrasound (1 MHz, pulse ratio 1:4) were performed. Each treatment session lasted 10 minutes. During the first two weeks therapeutic ultrasound was performed three times per week, after this period two times per week. Intensity of the therapeutic ultrasound was generally 1.0 W/cm². During the first two sessions, however, intensity was reduced to 0.7 W/cm² after five minutes because of signs of discomfort.

### Case 2

Twelve therapies using pulsed therapeutic ultrasound (1 MHz, pulse ratio 1:4) were performed three times per week. Each treatment session lasted 10 minutes. Intensity of the therapeutic ultrasound was generally 0.8 W/cm².

### Follow-up examination

During the five week treatment period, the dog showed continuous improvement. No visible lameness was detected at this time and extension of the stifle joint as well as palpation of the right lateral fabella revealed normal findings. The positive effect of the treatment could also be demonstrated by measurement of ground reaction forces (Table 2). The $S_I$ before treatment was started had deviations of 16% for PFz and 19% for IFz. After the treatment, the SIPFz (1%) was in the normal range, and the SIIFz (8%) had improved. At the final follow-up, both indices were within normal ranges.

### Table 1 Literature review and treatment modalities.

<table>
<thead>
<tr>
<th>Author</th>
<th>Main clinical sign</th>
<th>Head of the gastrocnemius muscle involved</th>
<th>Onset</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge and Owen</td>
<td>Plantigrade stance</td>
<td>lateral</td>
<td>acute</td>
<td>Monofilament nylon, external fixation.</td>
</tr>
<tr>
<td>(2005)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Robinson</td>
<td>Plantigrade stance</td>
<td>medial + lateral</td>
<td>chronic</td>
<td>Cerclage wire and splint bandage for an unknown duration of time.</td>
</tr>
<tr>
<td>(1999)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muir and Dueland</td>
<td>4th degree lameness</td>
<td>medial</td>
<td>chronic</td>
<td>Physiotherapy with swimming for three months, leash walks for three weeks.</td>
</tr>
<tr>
<td>(1994)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Prior</td>
<td>Lameness</td>
<td>lateral</td>
<td>chronic</td>
<td>Spiked washer and 3.5 cortical screw splint bandage for 10 days, lead walk for six weeks.</td>
</tr>
<tr>
<td>(1994)</td>
<td>(unknown degree)</td>
<td></td>
<td></td>
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</tbody>
</table>

### Table 2 Force-plate data of two dogs with partial gastrocnemius avulsion treated by therapeutic ultrasound.

<table>
<thead>
<tr>
<th></th>
<th>Before treatment</th>
<th>SI%</th>
<th>After treatment</th>
<th>SI%</th>
<th>Follow up</th>
<th>SI%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LH</td>
<td>RH</td>
<td>LH</td>
<td>RH</td>
<td>LH</td>
<td>RH</td>
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<tr>
<td>Case 1</td>
<td></td>
<td></td>
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<tr>
<td>PFz (% BM)</td>
<td>46.17</td>
<td>38.94</td>
<td>16%</td>
<td>40.01</td>
<td>40.36</td>
<td>1%</td>
</tr>
<tr>
<td>IFz (% BMs)</td>
<td>20.81</td>
<td>16.76</td>
<td>19%</td>
<td>18.57</td>
<td>17.01</td>
<td>8%</td>
</tr>
<tr>
<td>Case 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFz (% BM)</td>
<td>44.66</td>
<td>36.76</td>
<td>18%</td>
<td>43.49</td>
<td>42.93</td>
<td>1%</td>
</tr>
<tr>
<td>IFz (% BMs)</td>
<td>21.27</td>
<td>16.33</td>
<td>23%</td>
<td>22.34</td>
<td>23.45</td>
<td>5%</td>
</tr>
</tbody>
</table>

SI% = symmetry index (in percent); LH = left hindlimb; RH = right hindlimb; PFz = peak vertical force; IFz = vertical impulse; %BM = percent of body mass

$S_I% = \frac{S}{L} \times 100$

where: $S$ = mean of a gait measurement from the limb with the smaller value (left or right) between the two limbs; $L$ = mean of the same gait measurement from the limb with the larger value.

Using this formula, an animal with perfect gait symmetry would have a $S_I$ of 0%, although deviation of $S_I$ of up to 4% for PFz and 6% for IFz for the hind leg in sound dogs are considered normal (35).

Measurements were taken immediately before the first treatment and at the end of the treatment period at five weeks in case 1 and four weeks in case 2. A third measurement was made at final follow-up at five months in case 1 and two months in case 2, from the time the treatment was started.
Case 2

During the four week treatment period the dog showed continuous improvement of the clinical signs with decreased lameness and pain on palpation of the medial distal femur. The ground reaction force analysis is shown in Fig. 5; Table 2; the changes in SI over time followed a pattern similar to the other dog. Ultrasonographic evaluation at the time of the last therapy revealed some mineralization of the medial meniscus. The medial fabella was normal. The muscle was only slightly hypoechogenic with miniscule hyperechoic structures. Oedema of the gastrocnemius muscle was visibly reduced (Fig. 5). A sonographic recheck two months later showed similar findings. At this time, the clinical examination did not reveal any visible signs of lameness, swelling of the stifle joint, or pain during palpation of the lateral and medial fabella. Also, the owners reported that the dog had improved and had no problems with jumping into the car.

Discussion

To the authors’ knowledge, this report is the first to describe the use of therapeutic ultrasound as a treatment modality for partial avulsion of the origin of the gastrocnemius muscle in dogs. Both of the dogs were referred to our clinic with a tentative diagnosis of partial cranial cruciate ligament rupture. Indeed the clinical findings were suggestive for this injury, because the stifle joint was painful on extension and when trying to elicit a cranial drawer movement. However in these cases the pain was probably due to pressure on the origin of the gastrocnemius muscle. Furthermore, the joints were not swollen and there was not any instability with the tibial compression test performed while the dog was under general anaesthesia. Neither dog had a plantigrade stance, and other authors had stated that avulsion of the medial head of the gastrocnemius muscle is not associated with plantigrade stance (38).

Diagnostic ultrasonography is routinely used in humans to evaluate lesions of the gastrocnemius muscle. Ruptures of the medial head of the gastrocnemius muscle, also referred to as tennis leg, are frequently diagnosed in middle-aged people (39, 40). The ultrasonographic features of “tennis leg” of anechoic and hypoechogenic areas characteristic for oedema and haemorrhaging, as well as heterogeneous muscle fibres which identify ruptures, are identical to the lesions found in our cases.

For the treatment of the dogs described in this paper, pulsed therapeutic ultrasound was chosen. In pulsed ultrasound, the non-thermal mechanisms, which are mainly responsible for regeneration, predominate. An intensity range of 0.7 to 1 W/s² was chosen to gain an intensity range of 0.5–2.0 W/cm², which is reported to have the potential to induce various biophysical effects within tissues (41). Unfortunately there is still a lack of detailed data regarding the ideal intensity range of therapeutic ultrasound for the treatment of tendon or muscle injuries. Further studies are needed to determine the optimal intensity and treatment frequency of therapeutic ultrasound for these injuries. Also, comparisons with other treatments such as motion exercises, massage and external cooptation are needed.

With regards to the growing field of small animal physiotherapy, an objective evaluation of this kind of treatment is necessary. In our study, the outcomes were evaluated by diagnostic ultrasonography and force-plate analysis. To compare the cases described in this paper with those that have been described previously in the literature is problematic for various reasons.

Firstly, our two cases had only partial ruptures without any displacement of the fabella on stressed radiographs. All of the previously published cases had complete ruptures of the medial or lateral origin of the gastrocnemius tendon, or bilateral rupture (4, 5, 8, 9). Secondly, two dogs had a plantigrade stance (4, 9). Therefore the severity of injury in these previously reported cases seemed to be greater than in our two cases; the recovery times of these other cases ranged from six weeks to four months (4, 5, 7, 8).

Perhaps, it is not surprising that our patients, which were treated by ultrasound therapy, were associated with an amelioration of the clinical signs, and improvement in ultrasound and force-plates indices within one month after having started treatment. Even though these results of treatment of muscle injury with therapeutic ultrasound are encouraging future studies investigating larger groups of dogs and controls would be required to substantiate our findings, but because of the rareness of this kind of injury a controlled randomised study would be difficult to perform.

References

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