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Conservative treatment of an acute compartment syndrome of the thigh

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Abstract Compartment syndromes of the thigh after blunt trauma without any fracture are rare. Most surgeons recommend operative treatment. There are different rules for compartment syndromes of the thigh in young athletes after blunt trauma compared to compartment syndromes at other locations [(1) the large volume of the quadriceps muscle, (2) its relatively elastic fascia, (3) the direct proximal contact to the hip muscles which allows extravasation of fluid out of the compartment)]. We present a case of conservative treatment of elevated intra-compartmental pressure (ICP) of the anterior thigh after blunt trauma and the follow-up until return to sport. Conservative treatment of a compartment syndrome of the thigh after blunt trauma in a young patient without fracture or vascular damage was successful without short-term sequelae. Recovery of muscle strength is delayed but return to sport is possible. Depending on the severity the diagnosis and follow-up with ICP measurements and MRI is necessary. There is a very good chance for excellent outcome without any risk of surgery. However, a long healing time is possible.

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Introduction

Compartment syndrome is an orthopaedic emergency. Due to rising intra-compartmental pressures (ICP) the viability of the compartment is jeopardised. This was first described by Volkmann [26]. Normal intramuscular pressure is 0–8 mmHg. Symptoms, like pain and paraesthesia usually occur between 20 and 30 mmHg [18]. Irreversible changes occur at an ICP of more than 30 mmHg with a duration more than 6 h [9].

Most studies use the delta pressure (e.g. difference between mean arterial pressure and the ICP) as a basis for clinical decisions. Fasciotomy is suggested in cases of delta pressure below 40 mmHg [17]. There are a number of different theories regarding the decision to operate on an acute compartment syndrome [1, 11, 13, 14]. However, the pressure at which time fasciotomy has to be performed is still unknown [24]. We suspect that a considerable number of fasciotomies are performed, because some surgeons believe that dealing with the complications of a fasciotomy is the minor problem than taking the responsibility of the morbidity in cases of missed compartment syndromes.

Compartment syndromes of the thigh after blunt trauma without any fracture are rare. There is only a single case described in the literature [2, 4, 6–8, 10, 12, 16, 19, 21–23, 25, 28]. Most surgeons recommend operative treatment [2, 4, 6, 8, 12, 16, 19, 20, 22, 23, 25]. However, the literature describes few cases of compartment syndrome of the thigh treated without fasciotomy [7, 10, 21].

We present a case of conservative treatment of elevated ICP of the anterior thigh after blunt trauma and the follow-up until return to sport. This case documents a series of ICP measurements, MR examinations, serum and urine examinations and force control of the affected extremity by Cybex 6000 Testing and Rehabilitation System (CYBEX Division of LUMEX, Inc., Ronkonkoma, NY, USA). The patient was followed for a period of 6 months until he fully returned to sport.

Case presentation

A 16-year-old male sustained a high-energy blow to the right anterior thigh from an opposing player during a second league soccer match. Immediately after the trauma, he felt pain but was able to walk home from the soccer field unassisted. During the following night, pain and swelling increased. The patient presented to our institution 24 h after the injury.

On physical exam, there was severe swelling of the thigh (3 cm circumference difference; Table 1), no open wounds, and no superficial haematoma. We found mild effusion of the knee joint and a normal neurovascular status. The patient was unable to perform a straight leg rise. The examiner was able to fully extend the knee passively. The knee could not be flexed beyond 30°. Plain radiographs showed no fracture. MRI (1.5 T System, Avanto®, Siemens Medical solutions, Erlangen, Germany) and ultrasound (Elegra®, Siemens Medical solutions, Erlangen, Germany) were acquired immediately after the physical examination. In the ultrasound, a circumscribed mass (Fig. 1) within the swollen vastus intermedius muscle was seen. In the MR examination, the fluid-sensitive STIR sequence showed a circumscribed intramuscular mass ($3.5 \times 6.4 \times 9.4\ cm^3$ in size) within the vastus intermedius muscle (Fig. 2a, b). The slight hyperintensity within this mass in the T1-weighted image (Fig. 2c) proves the haemorrhagic content within the mass. Besides this circumscribed intramuscular haematoma, there was diffuse swelling and fluid collection within the vastus intermedius muscle and fluid collection along the fascia of this muscle.

The tissue pressure measurements were performed with an intra-arterial blood pressure monitoring device

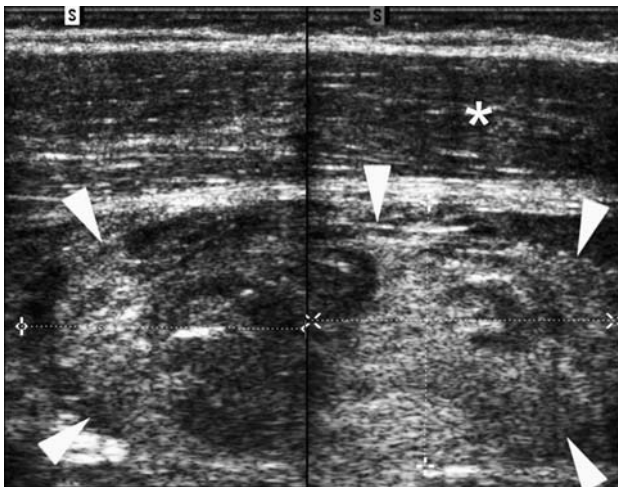

Fig. 1 Sonography 24 h after the trauma. Sonography (7.5 MHz transducer) 24 h after the trauma reveals circumscribed haematoma (*arrowheads*) within the vastus intermedius muscle. Normal appearance of the rectus femoris muscle (*asterisk*)

Table 1 Monitoring of intracompartmental pressure and the thigh circumference in dependence to time after trauma, right leg

Time after trauma	ICP–RF (mmHg)	ICP–VI (mmHg)	Circumference 7.5 (cm)	Circumference 15 (cm)	Range of motion extension /flexion
24 h (hospital admission)	80	100	43	48	0°/20°/30°
26 h		80	43	48	(rest, no active
30 h		75	42.5	47.5	or passive
32 h		63	42.5	47.5	motion)
35 h		60	42	47	
42 h		48	42	47	
50 h (transfer from ICU to general ward)	50	40	42	46.5	0°/20°/40°
5 days (hospital discharge)			41	46	0°/20°/80°
10 days	22	33	41	45	0°/15°/40°
14 days	–	–	–	–	0°/10°/50°
30 days			39	41.5	0°/20°/90°
50 days			39	44	0°/0°/140°
6 Months			39	44	0°/0°/140°

ICP intra-compartment pressure, *RF* rectus femoris muscle, *IV* vastus intermedius muscle

Circumference 7.5 = circumference of thigh measured 7.5 cm superior to superior patellar pole, Circumference 15 = circumference of thigh measured 15 cm superior to superior patellar pole

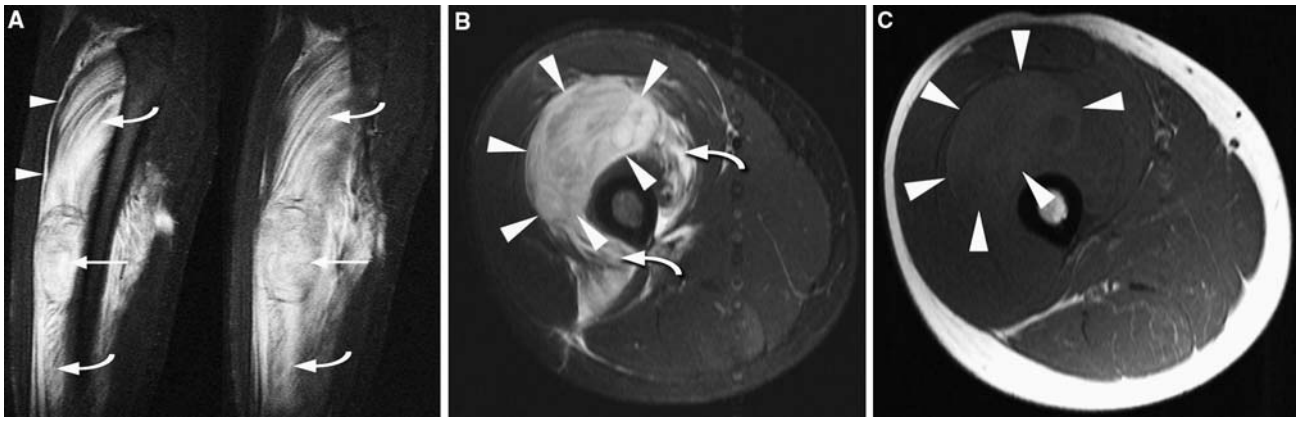

Fig. 2 MR imaging 24 h after the trauma. **a** Sagittal fluid sensitive STIR sequence 24 h after the trauma shows localized haematoma (*arrow*) and diffuse edeme (*curved arrows*) within the enlarged vastus intermedius muscle. There is a layer of fluid (*arrowheads*) along the fascia of the vastus intermedius muscle visible. **b** Axial STIR image at the level of the circumscribed haematoma (*arrowheads*) shows distinct enlargement of the vastus intermedius muscle. Additional diffuse edema within the muscle (*curved arrows*). **c** T1-weighted axial image at the same level as **b** identifies slightly hyperintens signal within the circumscribed fluid collection (*arrowheads*), which allows defining the fluid as haematoma

(Marquette Hellige [GE] Gmbh Medizintechnik, Freiburg, Germany) in our intensive care unit (ICU) using an 0.9×55 mm^2, (20G $\times$ 2, 3/16 in.) needle in a standardised fashion as described from Whitesides and co-workers [27]. The advantage of this system is its reliability of calibration. Anterior compartment superficial pressures of the rectus femoris (superficial) and vastus intermedius (deep) muscles were 80 and 100 mmHg, respectively (Table 1). In the first series of measurements, the values for the medial (20 mmHg) and dorsal (37 mmHg) compartment of the thigh were also elevated without any symptoms in these areas. We did not further follow the medial and dorsal compartment.

At this point, we discussed the potential risks and benefits of the different treatment modality extensively with the patient and his family. Conservative treatment according to Robinson et al. [21] was recommended by the treating physician and senior author (JR). We also discussed the possibility of fasciotomy. The patient and his parents refused surgical intervention and agreed to conservative treatment. The patient did agree to serial monitoring of compartment pressures. During the first 48 h he was treated in the ICU for optimal control and if necessary fast intervention.

The patient was kept in bed for the first 48 h having his leg straight. No active or passive motion and no massage were allowed. Local cooling was obtained. This treatment is recommend by the study of Jackson [10], who published his great experience in treating quadriceps contusions of different severity at West Point cadets. To prevent deep venous thrombosis, a prophylactic daily subcutaneous administration of enoxaparin sodium (Clexane© 20) was performed for a total of 4 weeks. Additionally, Bromelain (Traumanase® forte; A Nattermann and Cie. GmbH, Koeln, Germany) to reduce swelling and 2 g Paracetamol/day as pain medication was given. Without any manipulation of the leg, there was only a moderate pain level, which was manageable easily. After 48 h we started physical therapy focussed on keeping and increasing the amount of passive and active range of motion. A continuous passive motion (CPM) machine was used. Frequency and range of motion in the treatment cycles was increased during the following days. At this time the patient was able to perform a straight leg rise with an active extension lag of 20°. The active extension lag and the limited flexion was our main concern at the beginning. Physical therapy was performed below pain level and not forced because of the concern of re-injury due to muscle strain [10].

Fifty hours after injury, pressure in the anterior compartment decreased linearly to 40 mmHg. The measurement was stopped at that time. During the whole measurement period, mean arterial pressure remained over 100 mmHg. Urine myoglobin was always normal (< 6 µg/l) and creatinine phoshokinase was elevated initially after the trauma (388 U/I) and normalized after 4 days (157 U/l). The patient was discharged from hospital after 5 days. At that time he had an active range of motion of – 20° extension and 80° flexion. Passively full extension of the knee could be reached.

After discharge, additional MRI and clinical examination were performed 10 days, 8 weeks and 6 months after injury. Ten days after injury pressure measurement in the deep anterior compartment was repeated

(30 mmHg). At that time, MR imaging showed distinct decrease of the diffuse swelling and edema within the vastus intermedius muscle and decrease of the fluid collection along the vastus intermedius fascia (Fig 3a). The circumscribed haematoma within the muscle (Fig. 3a, b) was unchanged in size ($3.5 \times 6.1 \times 10.0\ cm^3$). Contrast enhanced images were acquired at this time and demonstrated peripheral contrast enhancement of the haematoma (Fig. 3c).

Eight weeks after trauma, the size of the circumscribed haematoma (Fig. 4) decreased significantly ($2.5 \times 0.9 \times 5.4\ cm^3$). Six months after the injury, only slight residual edema within the vastus intermedius muscle could be seen in the STIR sequence (Fig. 5). Compared to the contralateral side, the vastus intermedius muscle on the left was slightly atrophic (Fig. 5a, b).

Due to the known high risk of developing Myositis Ossificans after muscle trauma, a series of plain X-ray was performed at every follow-up. No signs of ossification where detected in a period of 6 months.

We monitored quadriceps strength using the Cybex® system after 8 weeks and 6 month. The measurements were performed in a standardized way. Eight weeks after trauma, a rightsided extension force deficit of 39% compering to the contralateral leg was measured. After 6 months there was still a rightsided extension force deficit of 32%. Regardless of this persisting deficit, maximum torque improved from 84 N m after 8 weeks to 105 N m after 6 months.

The patient ambulated with two crutches for 4 weeks. After 8 weeks he reached an active range of motion (full extension/flexion) of 140°. After 14 weeks the patient started jogging slowly and began active training after 5 months. One month later he attended his first soccer game.

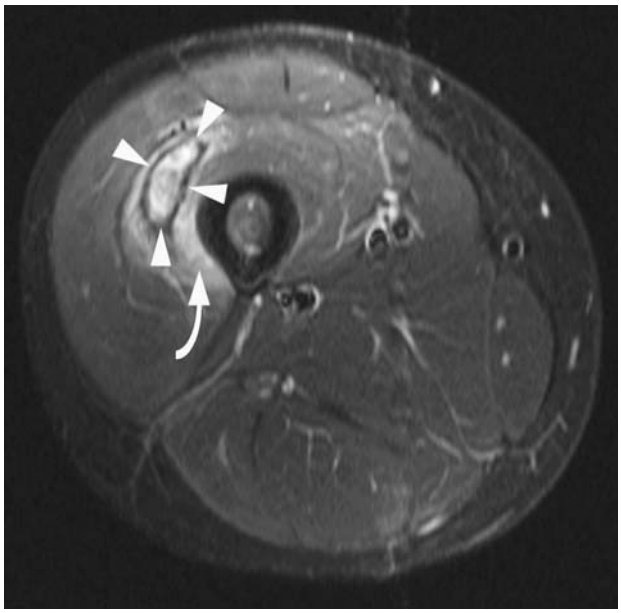

Fig. 4 MR examination eight weeks after the trauma. Axial STIR sequence eight weeks after the trauma reveals distinct decrease of the haematoma size which shows a T2-hypointense rim (*arrowheads*) and some residual diffuse muscle edema (*curved arrow*)

Discussion

To our knowledge, this is the first case of a conservatively treated compartment syndrome documented with plain radiographs, MR imaging, compartment

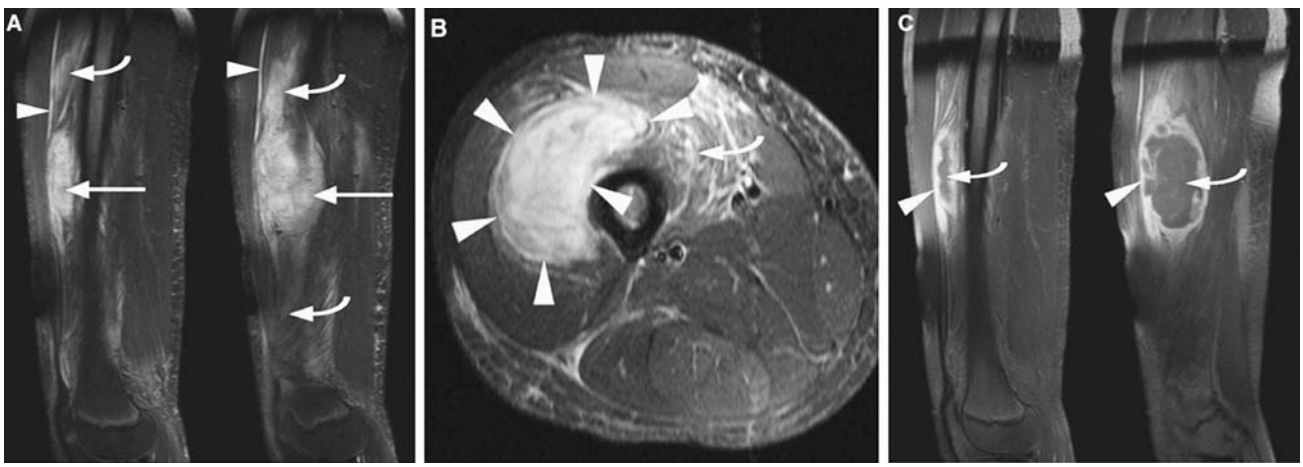

Fig. 3 MR imaging 10 days after the trauma. **a** Two contiguous sagittal STIR images 10 days after trauma show only minor decrease of the localized haematoma (*arrows*) but distinct decrease of the diffuse intramuscular edema within the vastus intermedius muscle. Some fluid is still visible along the fascia (*arrowheads*). **b** Axial STIR image at the level of the circumscribed haematoma (*arrowheads*) with some residual intramuscular edema (*curved arrow*). **c** Two contiguous contrast enhanced sagittal T1-weighted fat suppressed images show peripheral contrast enhancement (*arrowheads*) of the haematoma (*curved arrows*)

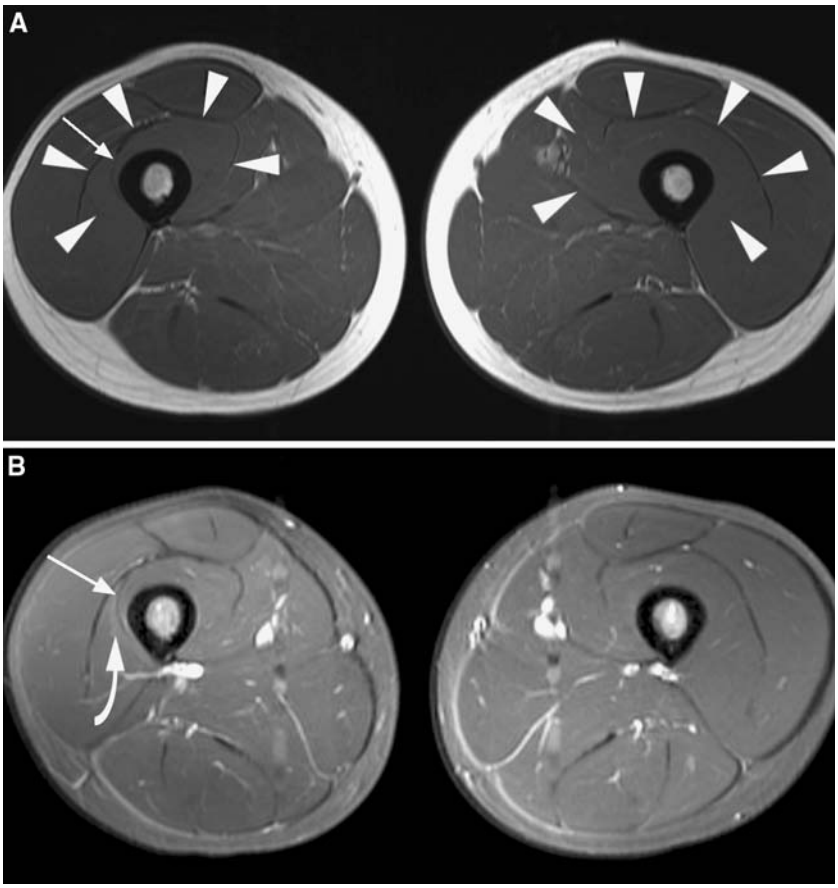

Fig. 5 MR examination 6 months after the trauma. **a** Axial T1-weighted image of both thighs for comparison of the vastus intermedius muscles (*arrowheads*) shows some atrophy of the rightsided muscle and a scar within the right vastus intermedius muscle (*arrow*). **b** Axial STIR images show minor residual edema (*curved arrow*) and scar (*arrow*) within the vastus intermedius muscle of the right thigh

pressure monitoring and force measurements over a period of 6 months.

The clinical situation 24 h after injury was serious. Our physical examination suggested the need of surgical intervention. Our decision was based on the experiences of Robinson et al. [21] who described a high rate of postoperative complications. The initial follow-up until 4 weeks after trauma was not very promising. Pain was always a minor problem in this case. But we and the patient were concerned about the limited range of motion and the weakness of the affected muscle.The trauma history of thigh compartment syndrome without fracture caused by direct contusion in a ball game is typical and was reported many times: 5 of 6 cases [21]; 1 case [2], 1 case [6], 2 cases [22], 18 of 18 cases [10], 6 of 8 cases [23], 3 of 3 cases [7]. Other causes are high-energy injuries most often related to femur fracture or severe vascular damage. The delay in the onset of severe symptoms seems to be characteristic. In our case, the symptoms such as pain, swelling, and loss in range of motion had its maximum 24 h after injury. Diaz et al. [7] reported three basketball player, which continued the game after contusion before symptoms increased in the following 12–24 h. Rooser et al. [23] reported that all his sports trauma patients continued their game before seeing a doctor. Mulder et al. [19] described increasing symptoms 40 h after the trauma in one case. Such time delay can also be found in several other investigations [2, 6, 15, 16, 22].

Four weeks after trauma, the clinical situation was still questionable but already four weeks later, our patient showed a dramatic improvement in function. Robinson et al. [21] reported that all his six patients returned to previous sports activities after 3–8 weeks. Jackson and Feagin [10] reported recovery time of 88–180 days after severe injuries with no permanent disability.

There are no comparative studies about operative versus non-operative treatment of thigh compartment syndromes in athletes. Reports of both treatment options show promising results. In all reported cases of conservative treatment, all patients made a full functional recovery. The only reported complication is the development of myositis ossificans described by Jackson and Feagin (13 out of 18 patients [10]) which never lead to a permanent disability in their study group and surgery was not necessary in these cases.

Obviously, there are different rules for compartment syndromes of the thigh in young athletes after blunt trauma compared to compartment syndromes at other

locations. Robinson et al. [21] proposed three reasons for this phenomenon: (1) the large volume of the quadriceps muscle; (2) its relatively elastic fascia; (3) the direct proximal contact to the hip muscles, which allows extravasation of fluid out of the compartment. In contrast to our description of the possibility of conservative treatment after blunt trauma, we recommend surgical intervention of compartment syndromes after fractures, vascular injuries, old patients or in case of multi-trauma patients.

According to the severity of injury, we propose following management strategies in case of compartment syndrome of the anterior compartment of the thigh.

In cases of mild contusion: Monitoring of clinical and neurovascular status, measurement of thigh circumference and conventional radiographs are recommended. If no other pathology is discovered, 2–3 days of bed rest, local cooling, analgesics, Bromelain, age and weight adapted anti thrombotic prophylactics for the time of limited weight bearing, physical therapy with pain free mobilisation, CPM, weight bearing depending on pain, and prohibition of massage and contact sports for 6 weeks are recommended. One has to be aware of delayed onset of severe symptoms (12–48 h after injury).

In cases of severe contusion: Monitoring of clinical and neurovascular status as well as acquisition of conventional radiographs and MR imaging are recommended. ICPs should be measured initially and every 6 h. If the ICP decreases, no further measurement is necessary. In case of ICP persistence > 80 mmHg the frequency of measurements has to be increased. Thigh circumference should also be measured during the first 48 h and before discharge. We recommend bed rest, intensive pain management, and neurovascular monitoring. At our institution patients are initially treated in the ICU having a restriction to food in case of necessity of an emergency fasciotomy. Management should also include the abandonment of physical therapy and massage for the first 2–3 days. Bed rest, analgetics, Bromelain, anti thrombotic prophylactics and local cooling are necessary. Depending on the symptoms, one can start with pain free mobilization as recommend for light contusions. Conventional radiographically follow-up at 6 weeks and 3 months after trauma to exclude myositis ossificans is important. Patients receive clear instructions that a long time interval until improvement of muscle function is expected. There are no contact sports allowed within three months to avoid re-injury.

Ultrasound [3] and MR imaging [5] are both possible tools to identify either circumscribed fluid collections, such as haematoma, or diffuse bleeding within a muscle. In cases of large haematoma, clear measurement of its size is often not possible by ultrasound. Therefore, in the acute setting we prefer MR imaging for clear delineation of the borders of the process. Additional to circumscribed fluid collections, using fluid sensitive sequences, diffuse fluid within the muscles and fluid along the fascia can be seen clearly. Bleeding as well as their changes over time (follow-up examinations) can be identified by the use of T1- and T2-weighted sequences, which allow identification of haemoglobin breakdown products [5]. In the late stage, MR imaging is an objective method for delineation of muscle atrophy and fatty degeneration, as well as for identification of residual seroma.

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