Compartment syndrome is a relatively common disorder whereby pressure in one or more muscle compartments increases during exercise, causing progressively increasing pain, and ultimately requiring cessation of activity. Subsequent rest leads to recovery, enabling the activity to be resumed, but the same symptoms ensue as soon as the same activity duration is reached again. The commonest muscles involved are those around the shin and calf, but it can occur in other muscle groups, including those of the forearm, foot and hand.

How does this occur?

All muscles or muscle groups in the body are enclosed in fascia, which is a relatively strong and relatively non-elastic membrane. During exercise, muscles require an increase in blood supply, in order to deliver extra oxygen and glycogen to meet the increased demand imposed by that exercise. As the blood vessels expand, the relative volume of the muscle and blood vessels within the fascial sheath, increases. Because the fascial sheath is relatively non-elastic, it only allows a certain amount of stretch. Hence, at a certain point, the pressure within the compartment starts to rise. As this happens, the veins, which are the low pressure vessels carrying the blood out of the compartment and back to the heart and lungs, start to become squashed, thus preventing proper drainage of waste products from the muscles. Hence, there is a buildup of lactic acid within the muscles and this causes local pain and further swelling.

If exercise is persisted with, the swelling, and hence the pressure, continues to increase to the extent that the veins are nearly completely blocked. If this happens, then the pressure within the muscle units gradually increases, and this may ultimately reach the pressure of the incoming arteries (which would normally bring fresh oxygen and nutrients to the muscles). Hence, in the worst case scenario, the pressure within the fascial sheath and the muscles, may almost reach that of the systemic blood pressure. This means that the pressure within the muscles may be elevated from a normal level of about 10 - 15 mm Hg or less (depending on the muscle group involved), to as high as 70 or 80 mm Hg.

What are the symptoms?

The symptoms are those of lactic acid accumulation, that is, increasing ache and pain in the affected muscle groups. This is exactly the same as what happens when exercise is done without training: that is, when you are unfit. The muscles become increasingly sore because of the lactic acid accumulation, they become increasingly tight because of the swelling, and they may ache for some days thereafter. In general, the higher the pressures and the more severe the compartment syndrome, the longer it takes for full recovery to ensue. This is because the lactic acid has to be washed out of the muscle and the muscle has to fully recover, losing all of its swelling and pain.

In some cases, as the pressure increases, the nerves in the area can also come under pressure. Hence, in some people,
the ache and pain can be associated with some numbness which, again, is transient and fully recovers with time.

The commonest area to be involved is the anterior shin. In this particular case, which is otherwise known as anterior compartment syndrome, the muscles that elevate the foot and toes are involved. This means that, as the symptoms progress, it becomes harder and harder to elevate the foot without pain. Hence, even simple activities such as tapping one’s foot to a tune, become difficult.

How long do symptoms last?

These symptoms can begin with just mild exercise in some instances but, in a anterior compartment syndrome, it may be worse in exercises that involve elevating the foot a lot. Hence, paradoxically, it may come on more easily with walking than with running. In every case however, there is a certain distance, or a certain amount of exercise, after which symptoms will begin. Depending on the severity of the condition, this may vary from walking a few hundred metres to running a few kilometres. For a given individual however, the amount and type of exercise required to bring this on is consistent and reproducible. Hence, following adequate rest and muscle recovery, repetition of the inducing exercise, for the same duration, will produce an identical symptom complex.

Recovery times are similarly consistent, and may vary from a few minutes to several days. In each instance however, recovery should be complete, and all the symptoms should abate. Only when the cause is traumatic, such as a direct blow causing bleeding into the muscle, or a fracture causing the same, does the pressure get high enough, and last long enough, to cause permanent muscle damage, something that constitutes a medical emergency.

Are there contributing factors?

When the condition is mild, it may occur because there are altered mechanics in what is an otherwise normal leg. Hence, it becomes important to look at foot and ankle mechanics, including correction of excessive foot pronation and tight Achilles tendons. These are things that your physiotherapist and your sports medicine physician can sort out relatively easily: and the treatment may just involve stretching, orthotics or a change in running shoe. If necessary, video assessment of running technique may be helpful and the above mentioned practitioners can usually do that, or arrange that, for you.
What is the differential diagnosis?

1) Shin splints

Shin splints are, in essence, a mild version of compartment syndrome. The symptoms are the same but to a lesser degree, and it is likely that conservative treatment, as described above, will cause resolution of the problem.

2) Periostitis

Periostitis is another variation in the spectrum of disorders that includes shin splints and compartment syndrome. The difference here is that the pressures may not be all that high, however, even with modest elevation, they cause a tightening of the fascial sheath around the compartment and this, in turn, causes a deformation of the compartment leading to increased tension on the periostium (the soft tissue sleeve around the bone) to which the fascia is attached. This tension causes the periostium to be pulled away from the bone and may cause some mild bleeding or bruising between it and the bone. This can be quite painful because the periostium is well supplied with nerve endings and is quite sensitive. Indeed, it can take a week or more to settle down and, typically, is felt along the edge of the bone, with tenderness being more on the bone than over the muscles.

3) Tibial stress fracture

Stress fractures can occur anywhere along this bone but, of particular concern, is the fracture that occurs in the mid to upper third of the tibia on its anterior surface (the front of the bone). This fracture, usually seen in runners, is caused by the muscles (which are all behind the bone) pulling on the bone like a bowstring on a bow. This, in association with the impact of heel strike, causes the bone to bow slightly. Ultimately, like metal fatigue, the bone develops a crack, starting at the anterior cortex (front edge), and progressing transversely across the tibia towards the back. Unlike most stress fractures, this is caused, not by the bone being compressed, but rather by it being pulled apart (tension). This, associated by the fact that the fracture occurs in very thick hard bone, may lead this fracture to progress to non-union. As a consequence of this, surgery may be required to get the bone to unite. This surgery usually involves the use of a tibial nail which, when inserted into the canal of the bone, splints the bone, thereby opposing the defamiation forces of walking, allowing healing to ensue.

4) Claudication

Claudication is a condition in which the compartment pressures may be normal but the blood supply to that compartment is inadequate. The symptoms are the same but, in this case, the cause is a poor blood supply, usually due to narrowing and hardening of the arteries. This is rare outside smokers but, if severe, can ultimately lead to death of the muscles and gangrene, for which the treatment may be amputation.

5) Aberrant vascular anatomy

Rarely, pain can come from poor blood supply, not because of vascular disease (atherosclerosis), but because of vessel pathology caused by a variation in vessel anatomy. The commonest of these is where the popliteal artery, the vessel supplying of all the blood to the lower leg, takes an abnormal course through the gastrocnemius muscle, rather than just passing straight down the centre of the back of the leg. This tortuosity can lead to damage to the inner lining of the vessel (the intima), which in turn can lead to a narrowing of the artery at the point where it is most kinked. This then leads to claudication pain in that muscle, coming on with increasing use.

Unlike compartment syndrome, or claudication from a pathologically narrow blood vessel, this problem seems to be a bit more varied in terms of when and how it comes on. If suspected, investigation by doppler, and / or angiography, is required. If confirmed review by a vascular surgeon is indicated.

How is the diagnosis made?

The most important component, like most conditions, is the history provided by you the patient. This, in association with tenderness, either over the muscle group or along the bone, can lead one to be highly suspicious of this syndrome. The definitive test however, is to measure the pressure in the muscle groups affected, and to do this both at rest (that is before exercise), and after exercise, when symptoms have set in. Having said that, if the pressures are abnormally high at rest, then further testing after exercise is generally not required.

In order to differentiate between shin splints, periostitis, and compartment syndrome, a bone scan is sometimes required. This will also show up a stress fracture of the tibia, however, when a stress fracture is considered likely, both by its position and by its marked focal tenderness, a plain x-ray may be all that is needed. If that is not definitive, then an MRI scan may be required.

What is the treatment?

The treatment is to prevent the muscle pressures getting high enough to interfere with the blood supply of the muscles. Where this is mild, and this includes shin splints and periostitis, appropriate conservative care (orthotics, therapy etc.) may be all that is required. Where the pressures...
are high, or where conservative treatment has not helped, then the definitive treatment is fasciotomy. This involves a release of the fascial sheath of the compartment concerned, so that the muscle can swell without a significant increase in pressure occurring. To achieve this, one or more splits are made in the fascia, along the length of the muscle. While these splits need to extend to almost the full length of the muscle, they can usually be performed through small skin incisions. For instance, in the anterior compartment, just a 2 cm skin incision is usually needed. The resulting splits then allow the muscle to swell more (bulging slightly through the splits) because it is no longer totally constrained within the compartment. That increased swelling however comes with lower, more normal, pressures: and hence is pain free.

Posterior compartment syndrome, which involves the calf muscles (often including the very deep muscles of the calf) is, fortunately, less common than anterior compartment syndrome. Because it involves the deeper muscles of the calf however, full decompression requires a bigger incision, and requires a slightly longer recovery time, than is required for decompression of the anterior compartment. In addition, releasing the posterior compartment along the whole length of the tibia through a limited skin incision, means that some of the surgery is done without direct visualisation. While this is also true for the anterior compartment, in releasing the posterior compartment fascia, there is some risk of cutting one or more of the various veins that cross that area. This is a risk that is very low in anterior compartment surgery due to the paucity of veins in that area, but moderate in posterior compartment surgery due to the local venous anatomy there. Because of this, if significant bleeding is encountered, the initial incision may have to be lengthened, in order to deal with the bleeding. Hence, while an incision for posterior compartment decompression may start out at 5 to 6 cm, it may end up being substantially longer in order to identify the area where bleeding is occurring, and to fix it.

Whereas anterior compartment surgery can be done as a day case, posterior compartment surgery usually requires one night in hospital and, because of the increased risk of bleeding, a drain usually used. In both instances however, it is important to elevate the legs for a week to try and minimise bleeding and swelling, which are the problems that most delay recovery. If the swelling can be minimised, then by six weeks some exercise can be recommenced, and by three months most people have resumed moderate if not full exercise.

When first exercising after surgery, the tightness and aching of the muscles may at first seem to be similar to how it was preoperatively, however, following surgery, this tightness and aching will most likely settle without having to cease exercise, and indeed, most people find that they can push through this to the extent that the ache improves by going past the point at which it would previously have prevented continuation. This therefore, is quite different to the preoperative situation, and is something that settles with time to the extent that most people can ultimately do normal exercise without any symptoms.

Note that the definitive treatment of shin splints and periostitis is identical to that for compartment syndrome. Dividing the fascia near the bone reduces the pull of the fascia on the bone and hence relieves the symptoms.

What can be done to help recovery?

1) maintain leg elevation, preferably to waist height, at least for the first week

2) moving the foot up and down at the ankle (dorsi-flexion and plantar-flexion) on an hourly basis beginning immediately
following surgery. This helps squeeze the swelling out of the muscles and it helps with the blood supply to the muscles. It should be performed several times, repeating the same every hour, until the foot can easily be pulled up to its maximum degree. Thereafter, gentle stretching of the muscles concerned is helpful.

3) maintaining some pressure on the leg for the first week by keeping the bandages firm. The bandages do not need to be tight, and if they are too tight they will actually restrict the blood supply to the area: and hence will not help the swelling.

4) the judicious use of ice in the first few days will help minimise bleeding and bruising, which is the main cause of swelling and delayed recovery. Anti-inflammatories should not be used in the first week because these increase the amount of bleeding and bruising. Therefore, they can be used.

5) after the first week, when the risk of bleeding has subsided, heat packs may be preferable to ice. These not only give good symptomatic relief but also increase the local blood supply: and hence increase local healing.

6) by the sixth week, exercise should be cautiously started. This should then be gradually increased, with the aim of reaching full training by 3 to 4 months. Whilst it is important not to exercise too hard in the first few weeks, it is also important to realise that, by that stage, no damage can be done. Hence, if vigorous exercises are undertaken prematurely (albeit after the first six weeks) then any pain or swelling should be temporary. Even if the muscles become very tender, they will fully recover. Further exercise can then usually be carried out on the following day, with progression of intensity and duration thereafter.

How successful is surgery?

In the anterior compartment, one can normally expect full resolution of all symptoms. It is rare that there is any residual problem and, if there is, it is often because the split in the fascia is not quite long enough or does not encompass the area of the worst problem. If treatment has been successful, then recurrence is unlikely.

Posterior compartment surgery, whilst still good, is not quite so successful. The surgery is a little bit more complicated, there is more of a tendency to post-operative bleeding, the fascial split can heal a little bit too tightly, and resolution of symptoms may be incomplete. Similarly, the chance of recurrence is higher than for other compartments, albeit that the success rate still exceeds 90%.

What if I do not want to have surgery?

Compartment syndrome frequently begins in the teenage years and, whilst we know what happens in this condition, we don't actually know the underlying cause. What we do know however, is that once it has started, it will not resolve by itself. Hence, the only alternative to surgery is activity modification. It does not seem to matter how long a break from exercise one takes, resumption of activity will bring back the symptoms. Thus, if modification of activity, with a change of type and amount of exercise is unacceptable, then a surgical resolution may be the only way to restore normal lifestyle. Fortunately the surgery is relatively minor (albeit a bit bigger in the case of posterior compartment syndrome than in anterior) and, by and large, highly successful.

If I have had one compartment decompressed will the others be affected?

If one compartment has been successfully decompressed, this may allow for a significant increase in intensity and duration of exercise. If one other compartment was marginal and only minimally symptomatic originally, then it may now start to give problems because of that increased exercise quotient. Hence, what was a minimally symptomatic compartment may subsequently require treatment. For the most part however, this is uncommon.

Can I have more than one compartment decompressed at the same time?

Yes, and this is frequently done when symptoms and pressure studies dictate it. The success is unchanged but, particularly where the posterior compartment is released in addition to the anterior and to the lateral, there can be some interference to the lymphatic drainage of the lower leg. This tends to be temporary but, for some months, some mild ankle swelling may ensue. This should not be a reason to decompress each compartment separately however.

Complications

Bleeding is the commonest problem that is encountered. Rarely is it a problem initially but, when it leads to increased bruising, then there will be increased scarring. This in turn can lead to tightness in the area, and therefore, incomplete symptom relief. The usual course however is a delayed recovery with the scar gradually softening with time and ultimately the leg symptoms resolving. That is, the outcome is as expected, but it takes a longer time to occur.

Incomplete relief of symptoms may occur for several reasons, the most common of which is due to excessive bleeding and scarring as discussed above. It can also occur where the splits in the fascia close up and heal tighter than expected. This is unlikely to occur in the anterior compartment when
foot exercises cause the muscle to bulge through the split, thereby keeping it open. In the posterior compartment however, this mechanics are somewhat different and it is harder to keep the splits open to that extent. In addition, in the posterior compartment, it is harder to achieve splits along the whole length of the tibia. For these reasons, this is the compartment where incomplete relief may be seen. Despite this, it is still uncommon to have sufficient symptoms to require further surgery.

**Recurrence** is very uncommon. If it does occur, it is usually in the posterior compartment and, sometimes, is related to injury which causes bruising and scarring in the fascia. It can usually be treated by revision of the surgery and, if the pressures are high pre-operatively, then a good result can be expected. Occasionally, recurrent pain is not associated with high pressures. In this instance, revision surgery is likely to be less successful, and other causes of the pain need to be looked for. Claudication, whereby the blood supply to the muscles is reduced, needs to be excluded.

**Infection** is usually a superficial problem related entirely to the skin wound. This procedure undermines the skin where the splits are to be made and hence, it does interfere with the blood supply of the skin in an area where it is not all that good in the first place. Hence, superficial infections are not all that uncommon, usually resulting in skin and wound redness. Because of this, everyone is given pre-operative antibiotics for this surgery and if any redness does develop further antibiotics will be given. Provided that treatment is given early, this will fully resolve and won’t interfere with the long term result.

Permanent numbness is rare and usually relates to damage to the superficial nerve that penetrates the fascia just above the ankle on the lateral side. It is more likely to occur if incisions are placed over that area and the nerve is not identified, hence, if the incisions are placed elsewhere, this is less likely.

**D.V.T.’s (deep venous thromboses)** are clots in the deep veins of the leg, usually the calf. They are uncommon in this type of surgery but can occur. They probably occur at the time of surgery or early thereafter, and then get slowly bigger over several days. Because of this, they may not be felt in the first few days. If noticeable, it is usually as an ache in the calf at the back of the leg. If this is thought to be occurring, then a duplex (doppler ultrasound) scan can be used to detect it, and appropriate treatment organised. Because bleeding is an issue with this surgery, and because this problem is uncommon with it, prophylactic anti-coagulation (thinning of the blood) is only used in high risk cases.

**P.E.** The concern of having clots in the vein is always that they may spread to the lungs (pulmonary embolism or P.E.). This is a rare event but does represent a major and serious complication of this and other lower limb surgery. In the majority of cases, like DVT’s themselves, it is treatable by thinning of the blood. This prevents new clot from forming and allows the body to slowly dissolve the clot that is present. It usually presents as chest pain which is worse on breathing in or coughing. It may also present as intermittent shortening of breath or a feeling of general unwellness. If considered to be a possibility, the definitive diagnosis is made by CT Angiography where contrast is put into a vein and the chest is CT scanned to reveal all the vessels in the lung. If any of these are blocked they can be seen and then treatment can begin.

Of note is the fact that, whilst peri-operative anti-coagulation can decrease the incidence of D.V.T.s, the incidence of pulmonary embolism is unchanged by this. Only full anti-coagulation will change the incidence of PE, and hence, this treatment would only be considered in very high risk cases (such as prior embolic events).

**Summary**

Compartment syndrome is a not uncommon problem, which affects athletes and non-athletes alike. It manifests as pain in one or more of the muscle compartments of the body, but most commonly involves those of the lower leg where it is in the spectrum of shin split type disorders. It is confirmed by pressure testing and, if the pressures are suggestive of the problem, then the definitive treatment is by release of the involved compartments. This then allows the muscles in that compartment to expand more freely such that, the swelling of the muscles that naturally occurs with exercise, can now happen without the increase in pressure that would otherwise have occurred. Hence, the activity related pain that was previously experienced, should be gone.

This is a problem that, once begun, does not resolve with time or rest. The surgery is relatively straightforward and mostly minor, the complication rate is low and the success rate is very high.

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