Arthrogenic Muscle Inhibition Following Knee Injury or Surgery: Pathophysiology, Classification, and Treatment

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Background: Arthrogenic muscle inhibition (AMI), a process in which quadriceps activation failure is caused by neural inhibition, is common following knee injury or surgery. No classifications exist to describe the variable presentations of AMI following knee injury.

Indications: AMI can result in significant morbidity following knee injury, and it is essential to recognize and treat. It is crucial to identify patients at higher risk of postoperative complications as surgery should be delayed for specific rehabilitation programs. Understanding the pathophysiology of AMI is vital as this can guide therapeutic interventions.

Technique Description: AMI following knee injury can present in a variety of ways including inhibition of the vastus medialis obliquus (VMO) muscle, extension deficits due to hamstring contracture, as well as chronic extension deficits. They also respond differently to conventional treatment modalities and often require longer and specific rehabilitation programs. Therefore, we propose a classification to define these different presentations.

Results: Grade 0 is a normal VMO contraction. Grade 1a is when VMO contraction is inhibited but activation failure is reversible with simple exercises while Grade 1b requires longer and specific rehabilitation programs. Grade 2a is when VMO contraction is inhibited with an associated extension deficit due to hamstring contracture, but activation failure and loss of range of motion is reversible with simple exercises. However, Grade 2b is refractory to simple exercises, and longer and specific rehabilitation programs are required. Grade 3 is a chronic extension deficit that is irreducible without extensive posterior arthrolysis.

Conclusion: In conclusion, AMI is a process in which quadriceps activation failure is caused by neural inhibition and is common following knee injury or surgery. Not taking AMI into account preoperatively can result in a very high risk of stiffness postoperatively. We propose a classification for AMI following knee injury or surgery, which describes different presentations and can be used to guide management.

Keywords: knee injury; ACL; quadriceps; hamstring; neuromuscular; rehabilitation

VIDEO TRANSCRIPT

Arthrogenic muscle inhibition (AMI) is common following knee injury or surgery. The aim of this video is to propose a classification to define the different presentations of AMI following knee injury or surgery which can also guide management.

Author disclosures are displayed here and available online.

AMI is a neurological process resulting in complex clinical impairment. Knee injury results in disrupted sensory feedback to the higher brain centers, triggering somatosensory and motor cortex dysfunction. Ultimately, this leads to a cortical reflex causing quadriceps activation failure and a subsequent spinal reflex resulting in a hamstring contracture.

Not taking AMI into account preoperatively can result in a very high risk of stiffness postoperatively. This is particularly prevalent following acute knee surgery such as tibial spine avulsion fixation, patellar dislocations, or anterior cruciate ligament (ACL) repair. It is essential to eliminate motor inhibition before considering any surgery to avoid these complications.

AMI following knee injury can present in a variety of ways. Often the knee looks normal, but there is inhibition of the vastus medialis obliquus (VMO) muscle. On other

Video Journal of Sports Medicine (VJSM®), 2(3), 26350254221086295
DOI: 10.1177/26350254221086295

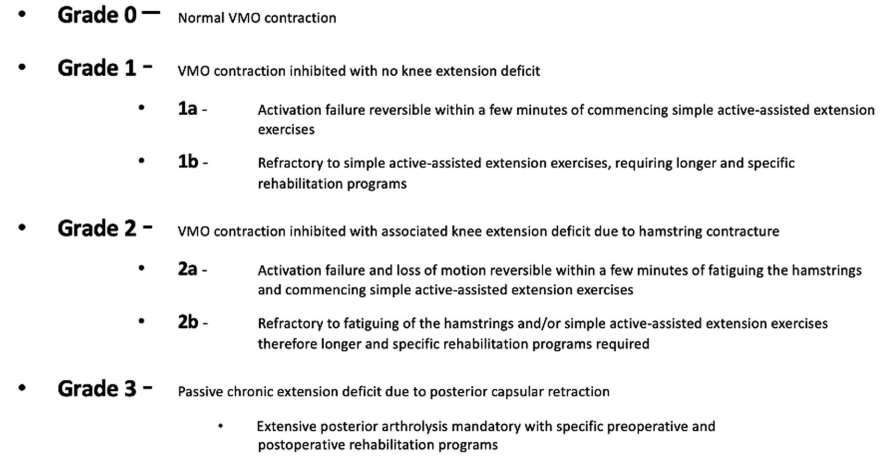

Figure 1. Classification of arthrogenic muscle inhibition following knee injury or surgery. VMO, vastus medialis obliquus.

occasions, there is a large effusion or hemarthrosis that may need aspirated.

Patients may present with an extension deficit which is due to a hamstring contracture and quadriceps inactivation rather than a mechanical block as clearly demonstrated in these images.

Treatment involves re-education of the quadriceps and hamstring muscles. This can be simple exercises that can be performed in the clinic, although some patients may require further management with specific rehabilitation programs focusing on elimination of AMI. This often requires manual exercises, biofeedback, and ultimately neuromotor reprogramming exercises.

Therefore, we propose a classification to define these variable presentations and to guide therapeutic interventions (Figure 1). Grade 0 is a normal VMO contraction. Grade 1a is when VMO contraction is inhibited but activation failure is reversible with simple exercises while Grade 1b requires longer and specific rehabilitation programs. Grade 2a is when VMO contraction is inhibited with an associated extension deficit due to hamstring contracture but activation failure and loss of range of motion is reversible with simple exercises. However, Grade 2b is refractory to simple exercises and longer and specific rehabilitation programs are required. Grade 3 is a chronic extension deficit that is irreducible without extensive posterior arthrolysis.

This patient demonstrates a normal VMO contraction with the heel clearly rising from the examination couch.

This patient is only a few days following his right knee injury with an obvious effusion, but he still demonstrates a normal contraction of the VMO in comparison with the contralateral side.

This young female patient sustained an acute left ACL rupture and has Grade 1a AMI. She has a normal VMO contraction of the contralateral knee, but it is clear that the VMO is inhibited on the injured leg. A small pillow is placed under the knee to allow 30° flexion and relax the hamstrings. The patient is then asked to perform heel lifts which can be facilitated, resulting in passive contractions. The patient is then asked to contract the muscle without lifting the heel, and this can be checked by ensuring the patella migrates proximally. If the patient only contracts the rectus femoris, the patella will not move proximally.

The thickness of the pillow is then gradually reduced, ensuring the patient still has good contractions on each reduction. Allowing the patient to palpate the proximal aspect of the patella and feel the proximal migration of the patella on each VMO contraction gives a proprioceptive and visual feedback of quadriceps activation. Satisfactory VMO contractions are now demonstrated in comparison with the contralateral side, showing a vast improvement from her initial efforts. Therefore, this is Grade 1a AMI as initial VMO contraction inhibition has responded to these simple exercises. It is also important to assess VMO contraction in the more difficult seated and standing positions. It is vital to ensure the patient understands how to perform the exercises and is aware to perform them frequently.

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Submitted January 3, 2022; accepted February 8, 2022.
One or more of the authors has declared the following potential conflict of interest or source of funding: B.S.-C. received support from Arthrex. M.T. received support from Arthrex. E.C. received support from Arthrex. J.-M.F. received support from Arthrex; and received consulting fees from Arthrex and Newclip Technics. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

In comparison, this young female patient sustained an acute right ACL rupture but has Grade 1b AMI. Her VMO is undoubtedly inhibited in comparison with the contralateral side. Normal VMO contraction is evident on the left leg with her heel rising from the examination couch but she is unable to do this on the right leg and, as is often typical with AMI, she is only able to contract the rectus femoris. Similar to the previous case, active-assisted extension exercises are performed. Isometric quadricep contractions are then performed with palpation of the proximal patella to ensure correct contractions are being performed. The patient palpates the proximal patella to provide proprioceptive feedback. However, it is evident that she is unable to perform good contractions of the VMO in extension and is contracting tibialis anterior to compensate. We can see that the patient can perform good contractions of the VMO when the pillow is positioned to provide flexion. However, once the pillow is removed, she is unable to maintain these contractions. This is also clearly demonstrated when viewed from the side, with the heel remaining on the examination couch. This is Grade 1b AMI.

This patient sustained a right patellar dislocation and also has Grade 1b AMI. The VMO contraction is inhibited in comparison with the contralateral side. It is also evident that she is contracting the rectus femoris and tibialis anterior instead of her VMO. Patellar dislocations typically have Grade 1b AMI and require further treatment to re-educate the quadriceps prior to considering any form of surgery.

This is another patient with Grade 1b AMI. The VMO inhibition is demonstrated on the right leg. Again, when viewed from the side, he is unable to raise the heel from the examination couch. His VMO inhibition was refractory to simple exercises and required several weeks of specific rehabilitation focusing on VMO contractions using manual exercises and biofeedback. As demonstrated, this responded well, and a vast improvement can be seen when he returned to the clinic following re-education of the quadriceps.

This young male patient sustained an acute left ACL rupture. His VMO is evidently inhibited in comparison with the contralateral side, and he has an associated extension deficit. In the prone position, examination reveals normal tone on the right leg and an obvious contracture of the hamstrings on the injured side. The patient is then asked to repetitively contract the hamstrings against resistance then fully relax the hamstrings. This is repeated until the hamstrings are fully fatigued and the contracture resolves. This is Grade 2a AMI.

In comparison, this is another young male patient who sustained a right ACL rupture playing soccer and has Grade 2b AMI. He has an obvious extension deficit with VMO inhibition. In the prone position, examination reveals normal tone on the left leg and an obvious contracture of the hamstrings on the injured side. As previous, the hamstrings are fully fatigued until the contracture resolves. It is important to gently support the foot on its way down to the examination table and not to push against the leg to gain extension as it will be painful.

Once full passive extension of the knee is recovered, it is important to reactivate the VMO, otherwise a recurrent extension deficit will likely occur. In this patient, VMO contraction was still inhibited; therefore, aspiration of his hemarthrosis was performed. However, the VMO was still inhibited in comparison with the contralateral side. This is Grade 2b AMI and requires further treatment modalities prior to any surgical intervention or a poor outcome is inevitable.

This patient had a chronic extension deficit of her right knee after complications following her initial ACL reconstruction and partial medial meniscectomy. She had undergone a manipulation under anesthetic and arthroscopic arthrolysis in the first 12 months following her initial surgery. She then presented 18 months postoperatively with complete inhibition of her quadriceps with no hamstring contracture. Her gait was impaired, and she had difficulty going up and down stairs. She underwent specific rehabilitation, focusing on wakening up her quadriceps with biofeedback and activation of her VMO. Arthroscopic posterior arthrolysis was performed thereafter, and she then underwent further specific rehabilitation. Six months postoperatively her extension deficit was resolved, she walked with a normal gait and had no difficulties with stairs. This is Grade 3 AMI with a successful result following surgery.

In conclusion, AMI is a process in which quadriceps activation failure is caused by neural inhibition and is common following knee injury or surgery. Not taking AMI into account preoperatively can result in a very high risk of stiffness postoperatively. Further studies are required to define the incidence and to identify risk factors for AMI. We propose a classification for AMI following knee injury or surgery, which describes different presentations and can be used to guide management.

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