

INCIDENCE AND RISK FACTORS FOR ARTHROGENIC MUSCLE INHIBITION AFTER ACL RECONSTRUCTION

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SUMMARY

Background: Arthrogenic muscle inhibition (AMI) is a common clinical complication following anterior cruciate ligament (ACL) injury and reconstruction, characterized by quadriceps activation deficits and potential knee extension loss. While the pathophysiology involving spinal reflex dysfunction and supraspinal alterations is increasingly understood, the specific postoperative incidence and associated risk factors remain inadequately defined in current orthopedic literature.

Objective: This study aimed to determine the incidence of AMI during the first six weeks following ACL reconstruction and to identify clinical variables associated with its occurrence.

Key Points: A prospective analysis of 210 patients undergoing primary or revision ACL reconstruction was conducted. The incidence of AMI was 48.6% at three weeks postoperatively, decreasing to 24.3% at six weeks. Multivariate analysis identified three significant risk factors for AMI at the three-week interval: preoperative presence of AMI (OR 8.2), immediate postoperative pain scores exceeding 7/10 on a numerical rating scale (OR 4.6), and the absence of preoperative physiotherapy (OR 2.6). Most identified cases were classified as Grade A (clinically reversible). No significant correlations between the studied risk factors and AMI were observed at the six-week mark.

Conclusion: AMI affects nearly half of patients in the early recovery phase following ACL reconstruction. Identification of high-risk patients—specifically those with preoperative deficits, high acute pain levels, or lack of prehabilitation—is essential. Implementation of targeted neuromuscular exercises and early pain management may mitigate these deficits and prevent long-term sequelae such as quadriceps atrophy, gait abnormalities, and secondary joint degeneration.

KEYWORDS

Anterior Cruciate Ligament Reconstruction; Quadriceps Muscle; Muscle Inhibition; Postoperative Complications; Range of Motion, Articular

INTRODUCTION

AMI is a deficit in knee extension, which is sometimes associated fixed flexion as an antalgic response after trauma or surgery. [1] This central reflex mechanism can persist if it is not addressed quickly with a specific treatment [2],[3]. Recent developments in our understanding of the pathophysiology of this complication mean that we can improve our awareness of its mechanism. The disruptions have their origin in the central nervous system and manifest in different ways [4] (Figure 1) :

- Firstly, local factors such as inflammation, swelling, pain and the destruction of mechanoreceptors appear to lead to disrupted sensory feedback. This triggers a dysfunction of spinal reflex pathways, activating the flexor reflex (contracture of the hamstrings), Ib non-reciprocal inhibition pathways and the gamma loop. All of these factors contribute to reducing quadriceps contraction.
- Potential supraspinal influences have also been described, such as increased motor threshold in the M1 region of the cerebral cortex, and the activation or inhibition of certain cortical and subcortical areas. It seems that the purpose of all these reflex mechanisms, whether of the central or peripheral nervous system, is to protect the altered joint (Figure 2).

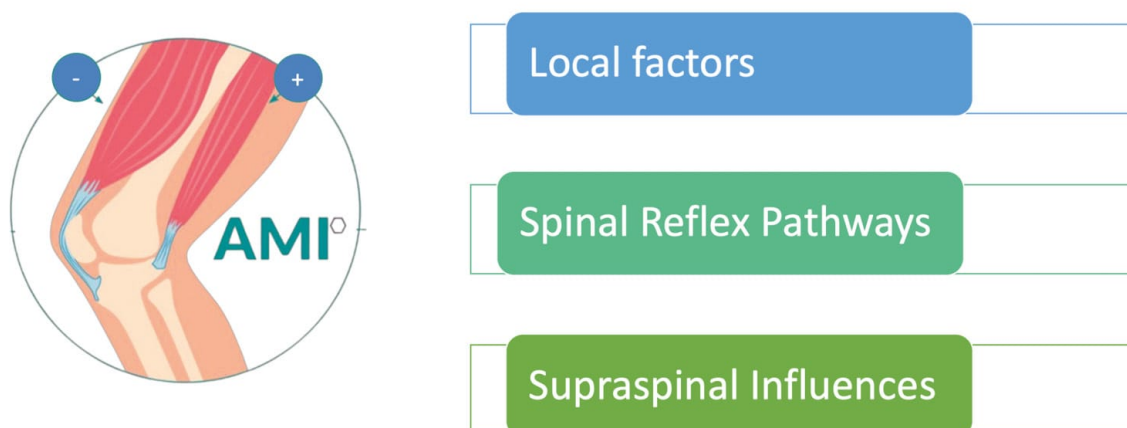


Figure 1 : Quadriceps arthrogenic muscle inhibition: neural mechanism and treatment perspective [4]

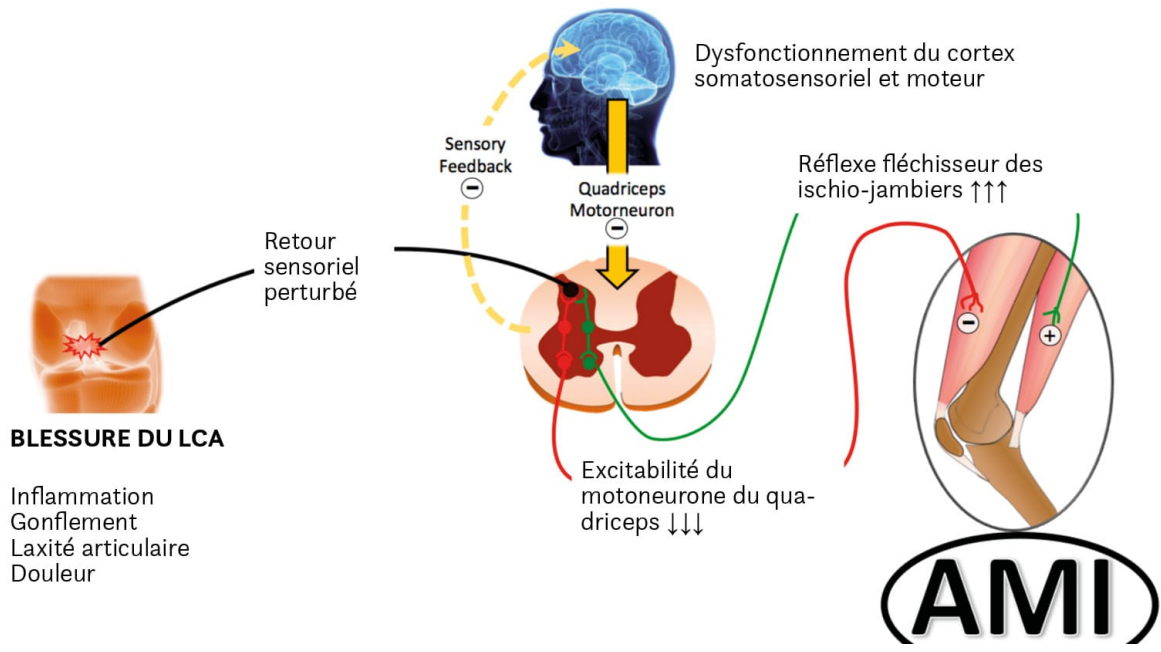


Figure 2 : Knee extension deficit in the early postoperative period predispose to cyclops syndrome after ACL reconstruction. A risk factor analysis in 3633 patients from the SANTI study group database. [12]

With new surgical techniques for ACL reconstruction emerging over the past 20 years, there has been a clear improvement in outcomes. In spite of this, complications of stiffness remain a significant and common source of post-operative morbidity [5]. In 2023, Sonnery-Cottet et al [6] proposed a clinical classification for AMI, reporting that 56% of patients were presenting with a clinical picture of AMI after ACL injury. The risk factors were also identified [7]. However, the incidence of AMI after ACL surgery is still, to date, unknown. This study aims to evaluate the incidence of AMI in the six weeks after anterior cruciate ligament surgery and to identify the associated risk factors. The hypothesis is that AMI is common after ACL reconstruction and that the factors that are identified as important pre-operatively remain so post-operatively.

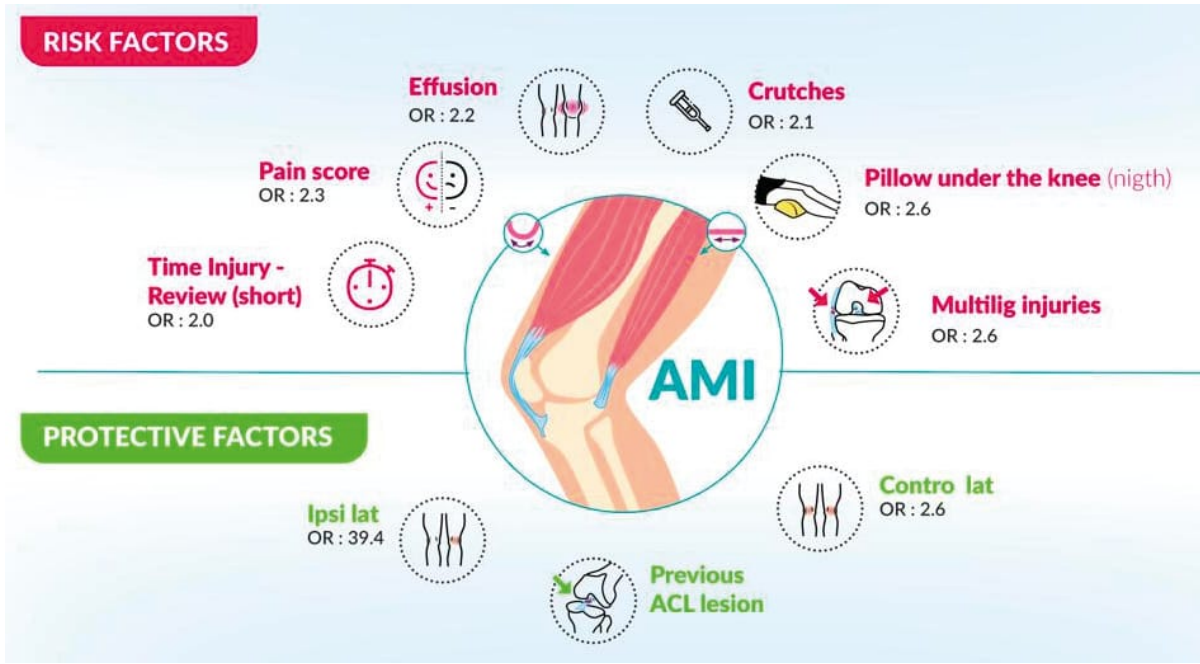


Figure 3 : Quadriceps arthrogenic muscle inhibition: neural mechanism and treatment perspective [4]

METHOD

This non-randomised, comparative, retrospective study was approved by the ethics committee. A consecutive series of patients who were undergoing either primary or revision ACL reconstruction surgery between January and October 2023 were invited to be included. The clinical examination and magnetic resonance imaging (MRI) confirmed ACL damage to either the native ACL or an ACL graft. Patients were excluded if they presented with a fracture of the ipsilateral or contralateral limb, had a multiligament knee injury or if they refused to participate in the study.

Patients were enrolled at the pre-operative consultation with the orthopaedic surgeons. They then had a follow-up sports medicine consultation 3 and 6 weeks after the ACL reconstruction surgery.

At each consultation: Co (pre-surgery), C3 (3 weeks post-surgery) and C6 (6 weeks post-surgery), patients completed a monitoring questionnaire from the surgeons/doctors. There were three different questionnaires, one for each consultation, accessed via three QR codes that had been generated specifically for our study (Q0 at Co, Q3 at C3 and Q6 at C6). At each consultation, the AMI grade was determined by the practitioner based on the following clinical classification [6] (Figure 4).

- **Grade 0** : contraction normale du VMO
- **Grade 1A** : la contraction du VMO est inhibée sans déficit d'extension mais l'échec de l'activation est réversible en quelques minutes après le début d'exercices simples d'extension assistée.
- **Grade 1B** : comme 1A mais réfractaire aux exercices simples d'extension active et nécessite des programmes de rééducation plus longs et spécifiques.
- **Grade 2A** : la contraction du VMO est inhibée avec un déficit d'extension associé dû à la contracture des ischio-jambiers, mais l'échec de l'activation et la perte d'amplitude du mouvement sont réversibles en quelques minutes après avoir fatigué les ischio-jambiers et commencé des exercices d'extension simples et actifs.
- **Grade 2B** : comme 2A, mais réfractaire à la fatigue des ischio-jambiers et/ou à des exercices simples d'extension assistée et des programmes de rééducation plus longs et spécifiques sont nécessaires.
- **Grade 3** : déficit d'extension chronique passif dû à une rétraction capsulaire postérieure.

Figure 4 : Clinical Classification of Arthrogenic Muscle Inhibition (AMI) Grades

RÉSULTATS

In total, 210 patients were prospectively recruited between January and October 2023. Of these, 38.6 % of patients presented signs of AMI (n=81) in the post-operative period. Three weeks post-operatively, a total of 48.6% of patients (n=102) presented with a clinical picture of AMI. Of these, 64.7% already had AMI prior to surgery ($p < 0.001$). The number of patients presenting with a clinical picture of AMI had fallen to 24.3% by 6 weeks post-surgery. Of these, 66.7% had presented with AMI prior to surgery ($p < 0.001$). The incidence and grades of AMI observed are shown in table 1. It was also noted that in the vast majority of cases AMI was reversible (grade A).

	AMI preop	AMI 3 weeks	AMI 6 weeks
Total (%)	38.6	48.6	24.3
Grade 1A n (%)	36 (44.4)	49 (48.0)	28 (54.9)
Grade 1B n (%)	17 (21.0)	12 (11.8)	8 (15.7)
Grade 2A n (%)	21 (25.9)	32 (31.4)	9 (17.6)
Grade 2B n (%)	7 (8.6)	9 (8.8)	6 (11.8)

Table 1 : Incidence and grade of AMI at pre-operation, (N=210)

The risk factors identified in a multivariate analysis were: pain that must exceed 7/10 on the numerical rating scale immediately after surgery, pre-operative AMI and no physiotherapy pre-operatively. The odds ratios are shown in figures 5 and 6.

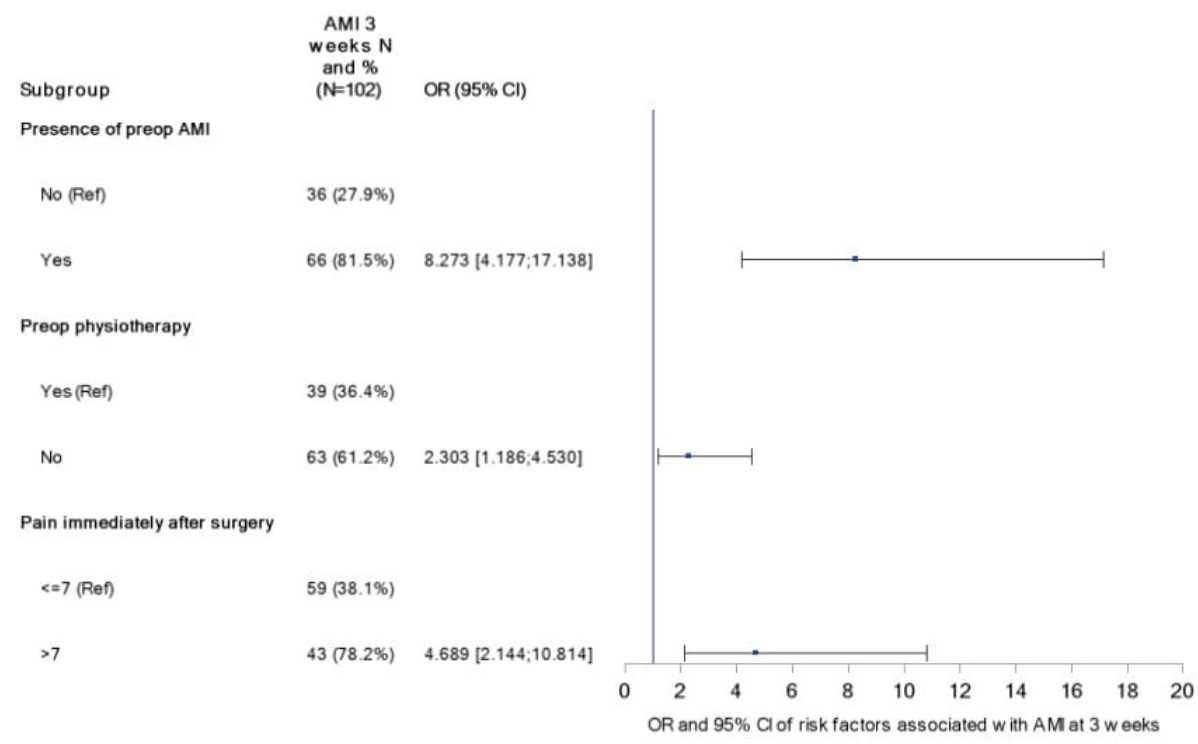


Figure 5 : Forest plot of risk factors associated with 3 weeks - All patients (N=198)

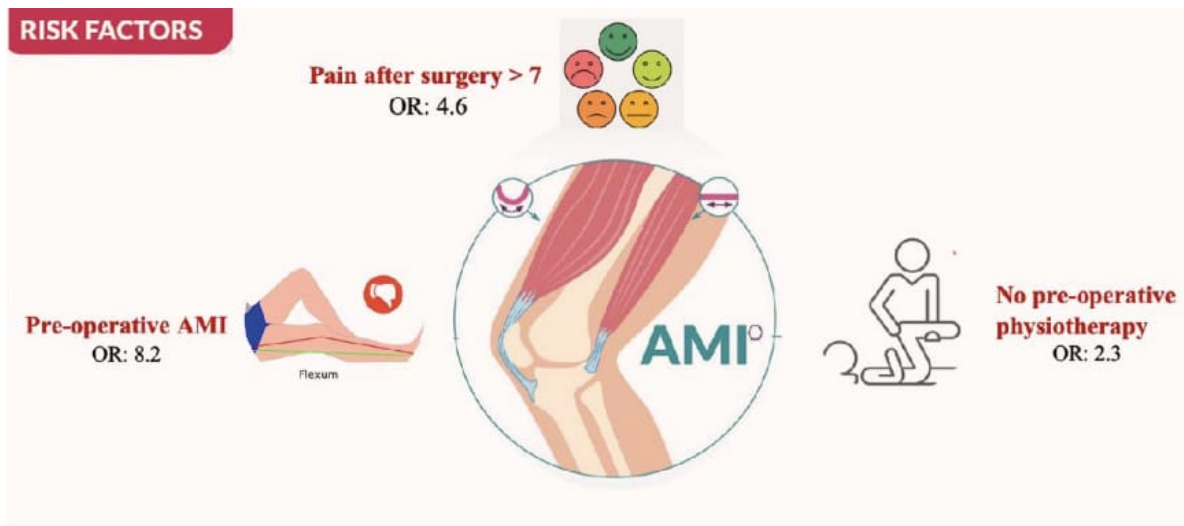


Figure 6 : Factors influencing the occurrence of arthroscopic muscle inhibition (AMI) after ACL reconstruction.

However, based on the same statistical regressions, none of the risk factors were found to be correlated with the presence of an AMI at 6 weeks.

DISCUSSION

Our study demonstrates that there is a high incidence of post-operative AMI after ACL surgery. More specifically, almost half (48.6%) of all patients presented with clinical signs of AMI at 3 weeks and 24.3% at 6 weeks post-operatively. Of these, 79.4% at week 3 and 72% at week 6 presented with types that are clinically reversible with specific exercises (grade 1A or 2A) [5]. The risk factors identified for AMI 3 weeks after the operation were

- Pre-operative AMI (risk multiplied by 8.2)
- Pain on immediate post-operative VAS rated higher than 7 (risk multiplied by 4.6)
- Absence of any pre-operative physiotherapy (risk multiplied by 2.6).

No risk factor was identified for the presence of an AMI 6 weeks after ligament repair.

For this study, we looked exclusively at motor deficits. Nevertheless, a number of studies, including the Piskin meta-analysis, refer to cognitive involvement after ACL rupture, whether treated surgically or not [8]. More specifically, there is evidence of deficits in reaction time, processing speed and visual and verbal memory in athletes with ACL injuries. In addition, athletes with an ACL injury were found to sacrifice their cognitive performances to maintain sufficient postural control or, in the reverse scenario, postural stability declines with additional cognitive load [9].

Our study shows that when AMI is identified it can be effectively managed with simple exercises, and that this approach can begin from the first pre-operative consultation. This is important information for practitioners, whether they are doctors specialising in sports medicine or rehabilitation, surgeons or physiotherapists. They need to be vigilant when checking for AMI from the very first consultation as these patients are at high risk of post-operative AMI. Moreover, the high prevalence of AMI post-operatively underscores the importance of raising awareness of this complication and using a universal classification.

Based on the results of this study, we can put forward a number of management proposals to avoid the onset of AMI post-operatively. In addition to screening at-risk patients, i.e. those who have pre-operative AMI, it is essential to give them advice and explain the pathophysiology to them, showing them the effective exercises, which gives them the tools to reduce this motor inhibition [3],[10],[11]. Physiotherapy prior to surgery is also important. Equally, immediate post-operative antalgic response must be controlled as far as possible through appropriate treatments. Use of a cryotherapy and compression cuff seems to be effective from the recovery room onwards, although our study was not able to prove this due to a lack of statistical power.

It is important to remember that untreated AMI can have significant repercussions. It can lead to pain, abnormal gait, quadriceps weakness and atrophy and impaired dynamic stability. In the longer term, it can result in stiffness, cyclops syndrome, chronic pain, proprioception deficits consequently impairing the motor pattern for walking, and even osteoarthritis in the long term, as demonstrated by Shelbourne et al [12],[13],[14],[15]. A recent study by Zunzarren found that 42% of patients had a persistent muscle deficit in the operated limb when compared to the contralateral limb [16]. This applies to the quadriceps but also the other lower limb muscles such as the gluteal muscles, hamstrings and so on.

There are few articles in the literature that point to the right physiotherapy management of AMI [10]. Simple exercises to wake up the quadriceps, such as very rapid contraction and open kinetic circuit resistance training, and fatiguing hamstring release exercises are simple and effective strategies, as long as they are repeated every day. Similarly, electrical nerve stimulation with biofeedback (widely used for neuromuscular retraining in gynaecological indications) seems to be promising, and consists of a central action with a visual signal, although it remains to be evaluated scientifically in this indication [17].

The main limitation of our study is that it only took place at a single site. Moreover, it was not exhaustive as it did not look at all the risk factors. The section of the questionnaire completed by the patient could be subject to recall bias. In addition, the incidence of grade 3 AMI was not studied because a longer follow-up duration would be required, which was beyond the scope of this study. Finally, there was no control group that was not offered a treatment to resolve AMI because, in our view, these exercises are invaluable to reduce morbidity and it would be unethical to include a no-treatment group.

CONCLUSION

AMI occurs in 48.6% of patients at 3 weeks and in 24.3% at 6 weeks after ACL reconstruction. When it occurs, it is clinically reversible in the majority of patients with the use of appropriate exercises and specific physiotherapy programmes. The risk factors identified for the presence of AMI at 3 weeks post-surgery are pre-operative AMI, an immediately post-operative pain score exceeding 7/10 and no pre-operative physiotherapy.

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