Breakthrough Pain Despite Complete Sensory Block and Management of Suspected Compartment Syndrome

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Peripheral nerve blocks provide excellent pain relief and enhance the patients' recovery from trauma and surgeries. However, the application of peripheral nerve blocks, in patients at risk for acute compartment syndrome (ACS), has long been debated due to concern for delaying or masking the diagnosis of ACS. Nevertheless, there is still no clear evidence that the properly administered and monitored peripheral nerve blocks contribute to the delayed diagnosis of ACS. Rather, breakthrough pain in patients with a functioning continuous low-concentration peripheral nerve block can be a warning sign and facilitate early recognition of ACS. We describe a scenario of a patient, whom the breakthrough postoperative pain despite well-functioning continuous nerve block triggered the early management of suspected ACS. We also review relevant aspects of ACS pathophysiology and peripheral nerve blocks, as well as the discussion of the previous similar case reports. Finally, the suggested concept of management of peripheral nerve block in patients at risk for ACS is presented.

Keywords: *Acute compartment syndrome, Peripheral nerve blocks, Ischemic pain*

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Acute compartment syndrome (ACS), a condition that can lead to devastating postoperative complications, requires early diagnosis and prompt intervention to prevent permanent disability[1,2]. Peripheral nerve blocks have been implicated in masking and delaying the diagnosis of acute compartment syndrome[3-5]. However, there is still no clear evidence demonstrating that properly administered and monitored peripheral nerve blocks contribute to the delayed diagnosis of ACS. Rather, breakthrough pain in patients with functioning continuous low-concentration peripheral nerve block can be a warning sign of ACS and facilitate early diagnosis and treatment of such preventable damage[6-11]. We describe a scenario where breakthrough postoperative pain, despite well-functioning continuous nerve block, triggered the early management of suspected acute compartment syndrome and led to a good outcome.

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Material and Method

This case is presented with the written consent of the described patient. The authors searched for literature in MEDLINE database (May 2016) to examine similar clinical scenarios. The keywords included "peripheral nerve block", "regional anesthesia", and "acute compartment syndrome".

Case description

A 67 year-old female with a history of obesity (weight 102 kg, height 170 cm), diabetes, and chronic obstructive pulmonary disease presented with right distal humerus fracture resulting from mechanical fall. She underwent open reduction with internal fixation under general anesthesia and continuous retroclavicular brachial plexus block.

The ultrasound-guided retroclavicular block was performed without difficulties, under minimal sedation, in the preoperative holding area (SonoSite M Turbo US machine with linear 38 mm 10-12 MHz ultrasound probe, Fujifilm SonoSite, Bothell, WA). The 18G 100 mm Tuohy-tip needle (B Braun Medical Inc,

Bethlehem, PA) was inserted, and 30 mL of 0.5% ropivacaine was injected through the needle at the depth of 6 cm from skin. The 20G B Braun non-stimulating catheter (closed-tip, 3 side holes) was inserted and secured at 15 cm at the skin. The patient then was transferred to the operating room and had general anesthesia for the surgery.

The surgery was complicated and went on for 7 hours. Estimated blood loss was 500 mL, and 3,000 mL of crystalloid was given. Tourniquet time was 2 hours. At the end of the surgery, a posterior splint was applied.

In the post-anesthesia care unit, the anesthesiologist started peripheral nerve catheter infusion with 0.2% bupivacaine at 10 mL/hr. However, the patient started to report 9/10 of pain score in the right elbow. Another 10 mL of 0.2% bupivacaine were bolused through the perineural catheter. Forty minutes later, the patient still complained of severe pain; the catherter was pulled out to 10 cm at the skin, and 10 mL of 1.5% mepivacaine was given. Twenty minutes later, her pain score decreased to 5/10, but her physical examination showed ulnar sparing. The catheter was pulled further back to 9 cm at the skin, and the second dose of 10 mL of 1.5% mepivacaine was given. Patient finally felt more comfortable, and her pain score decreased to 0-2/10 before she was transferred to the ward.

Five hours after the surgery, she reported a return of severe "10/10" pain score. The postoperative pain service was notified and assessed the patient. The perineural catheter was still intact at 8.5 cm at the skin. Her right upper extremity still had adequate perfusion, grossly intact motor function, and decreased sensation a right upper extremity except the skin over the musculocutaneous nerve distribution. A bolus of 10 mL of 0.5% ropivacaine was administered. Twenty minutes later, the extremity sensation was reassessed; she had appropriately decreased sensation in all areas of brachial plexus territory and still had weak movement in her fingers. However, despite complete upper extremity sensory block, she reported persistent 10/10 pain without relief.

Given the unusual presentation of intractable out-of-proportion pain in the setting of complete sensory block, the anesthesiologists contacted the orthopedic team to discuss the possibility of ACS. They re-evaluated the patient and found increased distal forearm and hand swelling. The splint was partially opened and increased swelling at right elbow was noted. These measures resulted in limited but immediate relief, and the patient's pain decreased to more tolerable levels, rated as 7-8/10. The patient still had intact distal perfusion of right forearm, her forearm muscles were soft, and there was no pain on passive motion. As her pain improved after loosening the splint, the surgical team decided to keep the splint open and did not measure the compartment pressure invasively. Her right arm was gently elevated, and a cold pack was applied. Neurovascular checks, including distal perfusion, pain at rest and pain on passive motion were then performed hourly.

As the patient was still in pain and signs of ACS were being monitored, the multidisciplinary team considered the risks of keeping the continuous perineural infusion were less than the risks of stopping the infusion which could accelerate the pain and increase opioid consumption, which would impair her consciousness and impact the neurovascular monitoring. The brachial plexus infusion with 0.2% bupivacaine was continued at 10 mL/hr, supplemented by low-dose intravenous hydromorphone patient-controlled analgesia (0.2 mg bolus, 7 minutes lock out). This decision was collaboratively discussed and agreed upon by the senior orthopedic surgeon, the senior anesthesiologists in the teams, and the patient.

Subsequently, the pain level remained stable at 7/10. She did not complain of excruciating pain again, and did not require escalating doses of intravenous analgesics through the rest of the night after the surgery. No further signs or symptoms of ACS developed. On the first postoperative day, her pain scores and opioid requirements steadily decreased, her partial motor weakness resolved, and the perineural catheter accidentally slipped out in the afternoon. The remainder of the postoperative course was unremarkable, and the patient was discharged home on the second post-operative day. Her follow-up examination at 3 weeks

Fig. 1 Patient's right arm after operation (left), and post-operative x-ray of right elbow (right).

showed no sensory or motor deficits and other complications.

Discussion

Acute compartment syndrome is a devastating complication from elevated pressure in a confined fascial space, leading to neurovascular compromise and ultimately to tissue necrosis. Early diagnosis and prompt intervention are vital to prevent permanent disability. As pain out of proportion and pain on passive movement are considered as the early signs for diagnosis before irreversible tissue damage starts to occur, peripheral nerve blocks have been blamed in masking, confounding, and delaying the diagnosis of ACS and have been considered to be relatively contraindicated for at-risk patients[7,12]. We reviewed the literature on ACS and peripheral nerve blockade and found the best clinical evidence in case reports. Most reports described similar scenarios, breakthrough pain despite complete sensory block, with different conclusions and opinions over the time (Table 1).

In three case reports published before 2009, the authors suggested that peripheral nerve blocks resulted in delayed diagnosis of ACS; however, the conclusions that link the peripheral nerve block with ACS are questionable[3-5]. Hyder et al described a case of lower leg which ACS diagnosed 48 hours after tibial nail fixation for fractured tibial shaft and with a single shot 3-in-1 block[3]. However, Eyres et al commentted in a letter to the editor on the discrepancy in innervation between the reported nerve block and the affected compartment, as well as the block duration[13]. Noorpori et al described foot compartment syndrome in a patient who had ankle block and a revision forefoot arthroplasty[4]. The diagnosis was done during the first 12 hours after surgery, when the patient gradually developed severe pain[4]. Fasciotomies were performed, pain subsided, and there were no long-term complications. However, the authors concluded that the PNB led to delay in diagnosis of ACS, rather than that breakthrough pain actually helped them to recognize this complication and make the correct diagnosis. Uzel et al reported a thigh compartment syndrome 20 hours after intramedullar femoral nailing and single-shot femoral nerve block[5]. Even if the detection of ACS was triggered by excruciating pain and led to fasciotomy, the authors' interpretation of the PNB influencing on ACS diagnosis remains debatable.

Subsequent case reports after 2011, describing breakthrough pain despite complete sensory block in patients presenting with ACS, suggested that breakthrough pain was a warning sign for ACS[6-11]. (The regional anesthetic technique was mostly continuous peripheral nerve block with catheter, different from earlier reports which were single injection technique). The authors recommended using peripheral nerve blocks with caution and close monitoring. Some of the more recent articles even proposed that the use of peripheral nerve blocks in these patients may be appropriate with suggestion of specific guidelines and protocols in place[7-11]. Nevertheless, even though there is no definitive evidence that peripheral nerve blocks delay in the diagnosis of ACS, many anesthesiologists and surgeons are still very reluctant to use peripheral nerve block in patients who are at risk for ACS.

Avoiding peripheral nerve blocks doesn't eliminate the risk but may lead to an even more complicate clinical picture. Firstly, the sensitivity of pain as the diagnostic criterion for ACS itself is quite low, only 13 to 19%, with positive predictive value of 11 to 15% and all postoperative patients will have some degree of pain, while "pain out of proportion" is subjective and difficult to define[14]. Breakthough pain in the setting of functioning block can be considered as "pain out of proportion" and may turn out to be a strong indicator to the recognition of ACS. Secondly, without peripheral nerve block, patients may need higher doses of systemic opioids for pain control. Opioids are moderately effective for treatement of pain, including ischemic pain, and they decrease the level of consciousness and ability to monitor, report, and recognize early an impending compartment syndrome. Several case reports suggested that systemic narcotics masked ischemic pain in a dose-related fashion and resulted in delay in diagnosis of ACS[15-17]. Peripheral nerve blocks provide analgesia without sedation and may theoretically provide postoperative analgesia without masking ischemic pain.

Differential neural blockade and local anesthetics regimen for ACS

Compared to postsurgical pain, ischemic pain is more intense nociception, augmented by various inflammatory mediators such as bradykinin, adenosine, potassium and hydrogen ions, and tissue acidosis[6]. Unlike postsurgical pain, which is transmitted through both A-delta and C-fibers, models of ischemic pain from tourniquet application point more towards C-fibers pathway[18,19].

Local anesthetics blocks small myelinated

Table 1. detail of case reports on acute compartment syndrome (ACS) and peripheral nerve block (PNB)

Article	Surgery	Nerve block	Results
Compartment syndrome in tibial shaft fracture missed because of a local nerve block. Hyder[3], 1996	Intramedullary nailing of the tibial shaft	Femoral, obturator, lateral cutaneous nerve of thigh block, single shot (0.5% bupivacaine)	No pain, but altered sensation in foot and leg. Inability to extend the big toe. Anterior compartment pressure of leg was measured first at 48 hours the after operation, found to be 108 mmHg. Fasciotomy performed, anterior compartment muscles found dead. Patient walked with orthosis. Nerve block held responsible for the delayed diagnosis.
Acute compartment syndrome following revisonal arthroplasty of the forefoot: the dangers of ankle block. Noopuri[4], 2000	Revision arthroplasty of forefoot	Ankle block, single shot (0.25% bupivacaine 30 mL)	Severe foot pain, 12 hours after operation.Fasciotomy were performed, muscles appeared viable. No neurological deficit on follow up.
Thigh compartment syndrome after intramedullary femoral nailing: possible femoral neve block influence on diagnosis timing. Uzel[5], 2009	Intramedullary nailing of femoral shaft	Femoral nerve block, single shot (0.75% ropivacaine 20 mL)	Severe thigh pain, 20 hours after operation, intracompartment pressure was 54 mmHg.Immediate fasciotomy was performed, muscles appeared viable. No neurological deficit on follow up.
Did continous femoral and sciatic nerve block obscure the diagnosis or delay the treatment of acute lower leg compartment syndrome. Cometa[6], 2011	Distal femur and proximal tibia osteotomy	Sciatic nerve block, catheter (0.5% ropivacaine 30 mL bolus, followed by 0.2% ropivacaine 10 mL/hr)Femoral nerve block, catheter (0.5% ropivacaine 30 mL bolus, followed by 0.2% ropivacaine 5 mL/hr)	Servere leg pain despite infusing catherter and bolus, on POD2, Intracompartment pressure was 30 mmHg, measured about 2.5 hours later.Fasciotomy was performed, 4 hours after pain through the block. Operative inspection found some muscle group appeared dusky. Fasciotomy site closure was done 5 days later, some anterior and lateral muscle of leg was found to be nonviable and removed.
Compartment syndrome of the forearm in patient with an infraclavicular \catheter, Breakthrough pain as indicator. Aguirre[7], 2013	ORIF distal humerus	Infraclavicular brachial plexus block, catheter (0.5% ropivacaine 30 mL bolus, followed by 0.3% ropivacaine 6 mL/hr)	Severe pain in forarm, despite complete sensory and motor block, 14 hours after surgery. Intracompartment pressure was 40 mmHg.Immediate fasciotomy was performed with intraoperative finding consistent with ACS. Patient had full recovery, no sequalae.

ORIF = open reduction internal fixation; ED = emergency department; POD1 = post-operative day 1; POD2 = post-operative day 2; POD4 = post-operative day 4

Table 1. Cont.

Article	Surgery	Nerve block	Results
Compartment syndrome diagnosed in due time by breakthrough pain despite continous peripheral nerve block. Munk-Andersen[8], 2013	ORIF distal tibia and fibula	Sciatic nerve block, single shot twice, then catheter (2% lignocaine 10 mL bolus, followed by 0.2% ropivacaine 4mL/hr)	Severe pain in lower leg despite funcitoning catheter, on POD1. Immediate fasciotomy was performed with intraoperative finding consistent with ACS. Patient had full recovery, no sequalae.
Evolving compartment syndrome not masked by a continuous peripheral nerve block. Walker[9], 2012	Calcaneal lengthening	Sciatic nerve block, catheter (0.5% bupivacaine 15 mL bolus, followed by 0.2% ropivacaine 8mL/hr) Salphenous block, single shot (0.5% bupivacaine 5 mL)	Severe pain in left foot on POD1 evening and patient presented at ED on early POD2 morning. Patient had decreased foot sensation but no motor block. The pain was immediately relieved by splitting the cast. The infusion was continued with close follow up and catheter was removed on POD4. No sequalae.
Regional anesthesia does not consistently block ischemic pain. Kucera[10], 2014	Ankle ligament reconstruction	Sciatic nerve block, single shot (0.5% ropivacaine 30 mL) Femoral nerve block, single shot (0.75% ropivacaine 20 mL)	Severe pain in medial part of ankle despite complete sensory and motor block, 90 minutes after surgeryThe cast was removed and readjusted with subsequent complete resolution of pain. No sequalae.
Postsurgical compartment syndrome of the forearm diagnosed in a child receiving a continuous infra-clavicular peripheral nerve block. Sermeus[11], 2015	Resection of a forearm osteochondroma	Infra-clavicular block, catheter (0.125% levobupivacaine 7 mL bolus, then 3 mL/hr continuous infusion)	Patient complained of pain despite an effective infra-clavicular block, on POD1. Physical examination showed the fingers were swollen, decreased sensation and motor strength.The cast was removed, pain disappeared, motor function and sensation recovered. The open cast with loose circumferential bandage was re-applied again after the symptoms were improved. No sequalae.

ORIF = open reduction internal fixation; ED = emergency department; POD1 = post-operative day 1; POD2 = post-operative day 2; POD4 = post-operative day 4

fibers (A-delta fiber, nociceptive reception) before large myelinated fibers (A-alpha fiber, motor efferent) then finally nonmyelinated C-fibers[20,21]. This phenomenon, differential neural blockade, may provide a plausible explanation for patients who have complete sensory block or even complete motor block may still experience ischemic pain: a complete A-delta fibers blockade in the setting of incomplete C-fibers blockade (ischemic pain pathway).

Theoretically, if local anesthetics are titrated to the level in which surgical nociception is blocked before the motor blockade and dense sensory blockade, it should be possible to alleviate post-surgical pain without eliminating the ability to recognize ischemic pain. A continuous perineural infusion, starting at low-dose and titrated to provide adequate analgesia without motor block is the ideal and safe anesthetic technique. This technique would allow clinicians to ensure that the block is not too dense to interupt pain signals from C-fibers as well as to monitor the development of motor deficits as a sign of ACS.

The concentration and volume of local anesthetics for adequate analgesia while sparing motor function depends on the target nerve and the type of local anesthetics. A continuous brachial plexus block with low concentration ropivacaine (0.1 to 0.2%) has been shown to be effective analgesic with motor-sparing effect[22,23]. However, complete motor block has also been reported with infusion of 0.2% ropivacaine at high volume rate (12 mL/hr), and many publications supported that volume of the infusion impacts the motor function[24]. In order to avoid motor blockade, we suggest low concentration (0.1 to 0.2%) and low volume/rate (5 to 8 mL/hr) of ropivacaine infusion through brachial plexus catheter and titrate to the desired effect.

Low-dose bupivacaine can also be used to produce a differential block[20,25]. Compared to ropivacaine, bupivacaine has comparable analgesic effects and is less expensive[25]. We suggest to start bupivacaine at a concentration of 0.125 to 0.2% and at a lower rate (5 to 6 mL/hr), initially. If the patient shows any signs of inadequate analgesia at this rate, we suggest to give a bolus of 5 to 10 mL and increase the rate of the infusion by 2 mL/hr. When analgesia is adequate, but motor block starts to develop, titrating down to a lower concentration (0.0625% bupivacaine or 0.1% ropivacaine) is also possible.

Lessons from our case

Our patient presented with breakthrough pain in her right forearm despite motor and sensory block. Aguirre et al. reported a similar scenario of the pateint who had the ACS and underwent emergency fasciotomy[7]. Even if we couldn't prove that we prevented the ACS, we believe the breakthrough pain despite complete sensory block triggered management that was patient-safety orientated. Nevertheless, even if the patient did not suffer from any sequelae of ACS, there are some points about our management worth discussing .

Firstly, in order to test the function of the catheter, instead of 0.5% ropivacaine 10 mL, lower concentration of local anesthetics, such as 0.1 to 0.2% bupivicaine or ropivacaine[7] in 5 to 10 mL increments, could have been a more prudent choice, in order to avoid the dense sensory-motor block. Alternatively, fast-onset and short-acting local anesthetics, such as 1% lidocaine, would also be a good choice, especially when the clinician try to assess the function of the perineural catheter.

Secondly, the decision to continue the local anesthetic infusion was different from the previous reports. The decision, discussed with the surgical team and the patient, was based on carefully weighing the risks and benefits in the setting of vigilant patient monitoring. As discussed earlier, the patient was still in pain after the cast was released; discontinuation of regional analgesia could have escalated the pain, which would have been difficult to interpret as secondary to block resolution or to worsening muscle ischemia. However, instead of infusion rate at 10 mL/hr of 0.2% bupivacaine, we suggest lower concentration and lower rate of local anesthetics, to avoid dense motor and sensory block.

Thirdly, systemic opioids, especially IV-PCA, can also mask ischemic pain; rescue analgesics with IV-PCA in the patient at risk for ACS should be given carefully. Monitoring during the vigilant observation period should include not only the typical signs and symptoms of ACS but also awareness of escalating opioid need as a warning sign of ACS[12]. We are proposing a concept protocal to employ and closely monitor continuous peripheral nerve blocks in patients at risk for ACS to acute pain service and orthopedics (Table 2).

Finally, more evidence is still needed to demonstrate that continuous low-dose peripheral nerve block may not compromise, but even aid in early diagnosis of ACS. Our review focuses on PNB and ACS only, and our conclusion cannot be automatically applied to neuraxial blockade.

Table 2. Suggested concept monitoring and management protocol

Continuous peripheral nerve blocks in patients at risk for acute compartment syndrome (ACS)
1. Identify a patient at risk (increased risk with leg or forarm injury, age <35 years, male) and discuss with the trauma team and the patient about risks/benefits of PNB and monitoring for ACS
2. Perform and document a focused neurologic exam
3. Formulate a plan - choice of block location, technique and local anesthetic; Recommend low-concentration local anes thetics at low infusion rate (0.0625-0.125% bupivacaine or 0.1-0.2% ropivacaine, at 5-6 mL/hr) - If intraoperative nerve injury is feared and immediate post-procedure neurological examination is necessary, the nerve block may be performed postoperatively after the re-assessment - If postoperative block is considered challenging (due to tissue swelling, difficult positioning, cast), preoperative catheter placement and bolus with normal saline remains an option.
4. Time out/safety pause before the nerve block and surgery to confirm mutual understanding and communication
5. A formalized sign out to the postoperative pain service with a management/follow up plan
6. Considerations for the acute postoperative pain team for breakthrough pain: - Examine the patient and perform a thorough neurological exam, focusing on the distribution of pain and presence of sensory and motor deficits; critical to assess circulation - If the patient has an incomplete block, check the catheter and test with 5-10 mL of low concentration local anesthetic. Re-assess again, and if the patient still has pain with complete extremity numbness, alert the surgical team to re-evaluate the patient together.
7. Specific considerations for the orthopedic surgery team for breakthrough pain: - Consider breakthrough pain as emergency - Assess for ACS and decide if invasive compartment pressure or emergency fasciotomy are indicated - Consider non-invasive measures (remove external source of compression, mildly elevate the extremity) and reassess frequently, especially if pain is not improving after removal of the external compression
8. Pain management during high-risk monitoring period: Not enough data to affirm the optimal pain management during monitoring for ACS at this point. The clinical decision should be made on a case-by-case basis in the setting of monitoring and multidisciplinary team discussion at expert level (supervising teaching staff). Low-dose perineural infusion may be continued if the teams are aware of potential ACS and monitor for signs and symptoms of ACS. Closely monitor systemic analgesic use and consider escalating dosmLe of systemic analgesics as a warning sign of ACS.

Conclusion

Breakthrough pain in the setting of successful peripheral nerve blockade should be considered as a possible sign of impending compartment syndrome. Early detection, close interdisciplinary communication, discussion, and timely management are important in averting the devastating consequences of ACS.

What is already known on this topic?

Peripheral nerve blocks, in patients at risk for acute compartment syndrome (ACS), have long been debated due to concerns for delayed or masked the diagnosis of acute compartment syndrome

What this study adds?

Breakthrough pain in the setting of successful peripheral nerve blockade should be regarded as a possible sign of impending compartment syndrome. Early detection, close interdisciplinary communication, discussion, and timely management are important in averting the devastating consequences of acute compartment syndrome.

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Potential conflicts of interest

None.

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อาการปวดทั้งที่มีอาการชาจากการระงับความรู้สึกเส้นประสาทส่วนปลายและการรักษากรณีที่สงสัยภาวะความดันในช่องกล้ามเนื้อสูงขึ้นแบบเฉียบพลัน

นันตสรณ์ สิญจนบุณยะกุล, เอมิลี เนลสัน, มิทเชล แฮร์ริส, คาเมน วลาสสก็อฟ

การบริหารยาชาเฉพาะที่เพื่อระงับความรู้สึกที่เส้นประสาทส่วนปลายสามารถลดอาการปวดหลังผ่าตัดได้ดีและช่วยให้ผู้ป่วยฟื้นตัวจากการบาดเจ็บและการผ่าตัดดีขึ้น อย่างไรก็ตามการบริหารเฉพาะที่เพื่อระงับความรู้สึกที่เส้นประสาทส่วนปลายในผู้ป่วยที่มีความเสี่ยงต่อการเกิดภาวะความดันในช่องกล้ามเนื้อสูงแบบเฉียบพลันนั้นยังเป็นที่ถกเถียง เนื่องจากมีความกังวลว่าจะมีผลให้การวินิจฉัยล่าช้าหรือไม่สามารถวินิจฉัยภาวะนี้อย่างไรก็ดียังไม่มีหลักฐานประจักษ์ชัดว่าการบริหารยาชาและการเฝ้าระวังอย่างถูกต้องทำให้การวินิจฉัยภาวะนี้ล่าช้า นอกจากนี้การที่ผู้ป่วยมีอาการปวดเฉียบพลันขณะได้รับยาชาความเข้มข้นต่ำหยดอย่างต่อเนื่องเพื่อระงับความรู้สึกที่เส้นประสาทส่วนปลายและแขนหรือขายังชาอาจเป็นอาการเตือนและกระตุ้นให้วินิจฉัยภาวะนี้เร็วขึ้น ผู้นิพนธ์บรรยายกรณีศึกษาของผู้ป่วยที่มีอาการปวดเฉียบพลันหลังผ่าตัดและพบว่าผู้ป่วยได้รับการระงับความรู้สึกที่เส้นประสาทส่วนปลายยังคงทำงานดีแต่มีอาการปวดจึงทำให้สงสัยภาวะความดันในช่องกล้ามเนื้อสูงขึ้นแบบเฉียบพลันและรีบให้การรักษา ผู้นิพนธ์ได้รวบรวมข้อมูลของพยาธิสรีระวิทยาของการเกิดภาวะนี้กับการระงับความรู้สึกที่เส้นประสาทส่วนปลายรวมทั้งวิจารณ์กรณีศึกษาในอดีตที่คล้ายกัน สุดท้ายได้แนะนำหลักการในการดูแลผู้ป่วยที่ได้รับการระงับความรู้สึกที่เส้นประสาทส่วนปลายที่เสี่ยงต่อการเกิดภาวะความดันในช่องกล้ามเนื้อสูงขึ้นแบบเฉียบพลัน
