Clinical Reports

Compartment syndrome following intravenous regional anesthesia

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Purpose: To present two cases of upper extremity compartment syndrome following intravenous regional anesthesia.

Clinical features: *Case 1:* A 57-yr-old man presented for surgical release of a left-hand Dupuytren's contracture. The procedure was performed under *iv* regional anesthesia with 360 mg lidocaine and sedation with 150 μ g fentanyl and 1.5 mg midazolam. Tourniquet time was 107 min at a pressure of 260 mmHg using three different tourniquet sites. Within minutes of tourniquet release, increased forearm muscle tension, hand anesthesia, pallor, and limited motor function developed. Serum CK and myoglobin levels rose. Myoglobinuria was present. Several fasciotomies and aggressive fluid therapy were performed. Patient made almost full recovery.

Case 2: A 73-yr-old woman with controlled hypertension had Dupuytren fasciotomy of her right hand under *iv* regional anesthesia with 200 mg lidocaine and sedation using 75 μ g fentanyl and 1.5 mg midazolam. Tourniquet time was 64 min at a pressure of 250 mmHg using three different tourniquet sites. The patient complained of pain at the *iv* site during injection of local anesthetic, third tourniquet inflation and after deflation of tourniquet. Thirty minutes after arrival in PACU, her fingers were bluish. She complained of pain and swelling of the forearm. Under general anesthesia, fasciotomy was performed. Myoglobin and CPK levels rose. CPK MB was high but troponin was negative. Three days later she developed pulmonary embolism. She was heparinized and subsequently discharged home. She recovered completely.

Conclusion: Compartment syndrome may have a rapid and severe onset. Etiology of our cases is still not established. We postulate that increased tissue pressure may be the cause. The anesthesiologists must be aware of compartment syndrome during regional anesthesia.

Objectif : Présenter deux cas de syndrome compartimental du membre supérieur apparu après une anesthésie intraveineuse régionale.

Éléments cliniques : *Cas 1 :* Un homme de 57 ans devait subir une intervention pour éliminer des contractures de Dupuytren à la main gauche. L'anesthésie *iv* régionale comportait 360 mg de lidocaïne et la sédation, 150 μ g de fentanyl et 1,5 mg de midazolam. Le garrot, maintenu pendant 107 min à 260 mmHg, a été placé à trois endroits différents. Quelques minutes après le relâchement du garrot, on a noté une augmentation de la tension musculaire à l'avant-bras, l'anesthésie de la main, de la pâleur et une limitation de la fonction motrice. On a enregistré des niveaux sériques élevés de CK et de myoglobine et la présence de myoglobinurie. On a réalisé quelques fasciotomies et administré beaucoup de liquides. La récupération a été pratiquement complète.

Cas 2 : Une femme de 73 ans dont, l'hypertension était contrôlée, a subi une fasciotomie de Dupuytren à la main droite sous anesthésie *iv* régionale avec 200 mg de lidocaïne, 75 μ g de fentanyl et 1,5 mg de midazolam. Le garrot, maintenu pendant 64 min à 250 mmHg, a été placé à trois endroits différents. La malade s'est plainte de douleur au point d'injection *iv* pendant l'administration de l'anesthésique local, lors du gonflement du troisième garrot et après le relâchement du garrot. Trente minutes après son arrivée à la salle de réveil, ses doigts étaient bleuâtres. Elle présentait de la douleur et de l'enflure à l'avant-bras. Une fasciotomie a été réalisée sous anesthésie générale. Les niveaux de myoglobine et de CPK se sont élevés, mais la troponine était négative. Trois jours plus tard, la patiente a présenté une embolie pulmonaire. Elle a été héparinisée et a pu quitter l'hôpital. Elle a connu une complète récupération.

Conclusion : Le syndrome compartimental peut être sévère et survenir rapidement. L'étiologie de nos cas est toujours inconnue, mais nous pensons à une augmentation de la pression tissulaire. Il faut savoir que le syndrome compartimental peut se développer pendant l'anesthésie régionale.

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COMPARTMENT syndrome arises when the circulation and function of tissues within a closed space are compromised by increased pressure within that space.¹ This initiates a cascade of events, beginning with vascular endothelial and tissue injury. The free radicals and inflammatory mediators produced contribute to further injury. Necrosis and loss of function may result. Additionally, there may be systemic sequelae (e.g. acute renal failure). Early diagnosis and treatment are important. Fasciotomy may be required to decrease tissue pressure and re-establish perfusion. Treatment is also directed towards other possible sequelae including myoglobinemia with aggressive fluid therapy and alkalization of urine. We report two cases of compartment syndrome of a rapid onset following intravenous regional anesthesia.

Case presentation

A robust 57-yr-old 87 kg man presented for surgical release of a left Dupuytren's contracture. He was not taking any medications and had no known drug allergies. Preoperative blood count was within normal limits.

Monitoring included pulse oximetry, NIBP and ECG. Oxygen was delivered via nasal prongs at a rate of 3 L·min⁻¹. An intravenous catheter was placed in the right forearm for fluid therapy. Preparation of the left arm consisted of cannulating a vein on the dorsum of the hand and subsequent exsanguination by elevation. A double tourniquet was placed over the upper arm and inflated to a pressure of 260 mmHg. Preservative free lidocaine, 360 mg, diluted with normal saline was injected. Another sterile single tourniquet was used on the forearm by the surgeon. After 40 min, the forearm tourniquet was inflated to 260 mmHg and the upper arm tourniquet was released. Total tourniquet time was 107 min, using three tourniquets in a sequential fashion from proximal double on the arm to single on forearm. The regional anesthetic was supplemented with 150 µg fentanyl in 50 µg doses and 1.5 mg midazolam given at the start of the case.

The intraoperative course and surgical procedure were uneventful. Good hemostasis was present throughout the procedure. On inflation of the forearm tourniquet, the patient complained of forearm pain. When the tourniquet was released at 107 min, an unusual painful hardness of the forearm musculature was noted. The patient was transferred to the PACU where he developed hand anesthesia, pallor of the fingers, limitation of wrist extension, marked metacarpophalangeal extension and interphalangeal flexion. It was evident that an acute compartment syndrome had developed.

The patient was returned to the OR within 20 min of arrival in the PACU and general anesthesia was induced with thiopental, rocuronium and fentanyl. After tracheal intubation, anesthesia was maintained with nitrous oxide 50% in oxygen and isoflurane 0.5%. A tourniquet was not used. Emergency release of the volar aspect of the forearm, carpal tunnel, small area of the extensor aspect, *in situ* and distal aspect of the biceps was performed. The volar forearm muscles expanded on release and the colour improved by the end of the procedure. Good radial and ulnar pulses were noted. There was no evidence of thrombosis in the forearm. All the veins appeared to be patent and of normal calibre. Heparin, 1000u *in situ*, was administered intraoperatively and the patient received prophylactic heparin 1000 u·hr⁻¹ until the Doppler test was negative. The duration of the second procedure was two hours.

Intraoperatively, blood samples taken in the recovery room revealed a plasma CK of 924 u·L⁻¹ and a plasma myoglobin of > 3967 µg·L. Urine sent between the first and second operation was positive for myoglobin. Myoglobin was evident for eight hours. After the second operation, the nephrology service was consulted and therapy consisted of hydration and urine alkalization. The plasma CK peaked at 52,200 u·L⁻¹ on the first day and declined rapidly reaching 7,800 u·L⁻¹ on day 2 post-op and 1,300 u·L⁻¹ on day 6 post-op. Plasma myoglobin concentration continued to decrease. Urine was negative for myoglobin on post-op day 1 and remained negative. Blood screen taken on day 1 showed only the drugs that had been given.

Extension of the proximal release was required on post-op day 1 and wound debridement with skin grafting on post-op day 5. The patient continued to improve and was discharged home on day 11 post-op. He did not develop renal failure or other systemic sequelae. Two months after discharge the patient underwent partial excision of skin graft. Biopsy of dermis and muscle demonstrated fibrosis, foreign body giant cell changes and chronic inflammation. Nerve conduction and EMG studies performed two months later were normal. Biopsy of the left quadriceps and left forearm was obtained five months after the initial surgery to rule out muscle pathology: histochemical assays demonstrated normal muscle. Electron microscope studies were consistent with normal muscle. The patient continued to recover and six months later underwent CABG without incident.

Case 2

A 73-yr-old 75 kg woman was scheduled for Dupuytren's fasciectomy of the right hand. She had no

allergies. She had three previous general anesthetics with no problems. System review showed a history of controlled hypertension and hypercholesterolemia. Medications consisted of 5 mg amlodipine OD, 10 mg simvastatin OD, 20 mg omeprazole OD, 0.05 mg eltroxin OD, and 325 mg losec ECASA and LOSEC.

Intraoperative monitoring included pulse oximetry, NIBP and ECG. Oxygen was given via nasal prongs at 4 L·min⁻¹. An intravenous catheter was inserted in the left hand. A double tourniquet was applied on the right arm. A 22 gauge angiocath was inserted in the right hand and an Esmarch bandage was wrapped around right upper extremity to drain the limb. A double tourniquet on the right arm and a single tourniquet on the forearm were applied. The tourniquet was inflated to 250 mmHg. Ten ml of preservative free lidocaine 2% diluted with 30 ml normal saline were injected intravenously. She complained of pain on injection. Fentanyl was given in doses of 50 µg and 25 µg. Midazolam, 1 mg, and 0.5 mg, was also given *iv*. A third tourniquet was applied on the forearm. When the third tourniquet was inflated and the upper arm tourniquet deflated after 32 min, the patient complained of severe pain in the arm. Additional fentanyl, 50 µg and midazolam, 0.5 mg, were given. The procedure was done with no further problems. The duration of inflation of the proximal arm tourniquet was 32 min, distal tourniquet was 12 min and the third forearm tourniquet was 20 min. In the PACU, her fingers were bluish and cool but she was able to localize light touch. Forty-five minutes later, the forearm was swollen to the elbow, the muscles felt firm and she complained of pain with wrist extension. She was brought back to the OR for forearm fasciotomy. She had general anesthesia with rapid sequence induction and tracheal intubation. Benadryl was given because the surgeon was concerned of an allergic reaction. Arterial blood analysis and electrolytes were normal. Blood drug screen was positive for the fentanyl and benzodiazepine. Hemoglobin was 105 g·L⁻¹, similar to preoperative value, creatinine was normal and serum myoglobin was 1,885 µg·L⁻¹ and CPK was 696 u·L⁻¹. The urine was negative for myoglobin. She was transferred to the ICU for observation. Ten hours after surgery, the CPK was 2,020 u·L⁻¹ and the myoglobin was 1,073 µg·L⁻¹. CKMB was 172.4 u·L⁻¹ and troponin was negative. The ECG remained unchanged. Benadryl 25 mg *po* every eight hours for 48 hr and and solu-cortef 50 mg for two doses were continued in the ICU. She remained hemodynamically stable. Three days postoperatively she developed hemoptysis, tenderness on the right calf muscle and had a positive V/Q scan for pulmonary embolism. She

was heparinized and two days later she developed a hematoma on the right forearm which was incised. Her condition improved and she was subsequently discharged on the 9th post-op day.

Discussion

Compartment syndrome has been reported following various forms of vascular access. These include attempts at obtaining access in the presence of a coagulopathy² and arterial catheter removal.³ Increased tissue pressure with accidental interstitial infusions of packed red cells⁴ or normal saline⁵ as well as hypertonic saline⁶ have also been described. Vascular disruption or catheter malplacement can occur during *iv* cannulation which may lead to impaired perfusion distal to the injury and increased tissue pressure by the extravasated blood or fluid.¹ In these cases, the precipitating event was clinically evident at the time of instrumentation or shortly thereafter, although the development of compartment syndrome may not have occurred until much later.

In both of our cases vascular access was obtained without difficulty. There was no evidence of traumatic insertion during cannula placement. Surgical exploration during the emergency fasciotomy did not reveal gross vascular injury or thrombosis at the *iv* site or compromise of the interosseal muscles. The possibility of accidental cannula placement into an aberrant artery with subsequent injection of lidocaine exists. However, a study involving intra-arterial injection of lidocaine reported no sequelae.⁷ The interesting feature in both of these cases was pain on injection of local anesthetic whether due to increased pressure in tissues, or vascular rupture although, at exploration, in both cases the vessels were intact. Lidocaine is frequently administered interstitially without adverse sequelae.

Several injected agents may cause compartment syndrome. Intravenous administration of blood products³ hypertonic saline⁶ and diazepam⁸ have led to or been postulated as a cause of compartment syndrome. Intra arterial injection of phenobarbital³ has also led to compartment syndrome. The mechanisms include direct vessel injury leading to thrombosis or vasospasm, or increased osmotic activity leading to intravascular volume expansion.

In these cases the substances administered to the surgical limb included isotonic saline and lidocaine. Both solutions were clearly identified and noted to be well before their expiry dates and were preservative free. There is a possibility the patient had an idiosyncratic reaction to an agent or patient had the risk factors for development of this complication such as vascular integrity. Our patients had local anesthetic

exposures many times previously with no reported reactions. The possibility of malignant hyperthermia in association with massive muscle damage⁹ is very unlikely as all systemic parameters were normal.

Inflation pressure and duration have been implicated as tourniquet related factors of compartment syndrome. One reported case used a pressure of 520 mmHg¹⁰ and another used a continuous tourniquet time of 4.5 hr.¹¹ These were well above our tourniquet parameters. A forearm tourniquet was used to make the patient comfortable and spare prolonged tourniquet time on the upper arms.

Other related problems include increases in tissue pressures which may result from increased fluid content secondary to the volume of material injected or as a consequence of post-tourniquet hyperemia and swelling. These issues were addressed in a recent prospective study of healthy volunteers undergoing a simulated IVRA of the lower limb with tourniquet application and *iv* saline administration.¹²⁻¹³ There was no difference in tissue pressure before or after tourniquet inflation. Injected volumes up to 130 ml of saline did not result in tissue pressure changes. Finally, there were no tissue pressure changes as a function of time up to 30 min after tourniquet deflation, reflecting hyperemia and swelling.

Myoglobinuria develops when the serum myoglobin levels exceeds the renal threshold of 15,000 µg·L⁻¹ with normal serum levels being 75 to 85 µg·L. The renal threshold will be reached when at least 100 g of muscle releases myoglobin.¹⁴⁻¹⁶

We feel that all the drug vials and diluents must be kept aside after each case so that we can check if any problems arise. We wanted to rule out any muscle disorders and that was the reason for muscle biopsy. Our second patient had been taking simvastatin for hypercholesterolemia and rare cases of myoglobinuria occur but its association with surgery with this treatment is not reported.

In summary, *iv* regional anesthesia is usually a simple and safe technique for limb procedures. However, compartment syndrome may occur.^{6,17-19} In our first case the compartment syndrome had a rapid and severe onset. The second case was less severe. The exact etiology remains obscure but we believe that it may be related to increased tissue pressure or possible allergy to local anesthetics or other additive drugs (which is unlikely as both had local anesthetics for dental extractions). If a patient complains of pain on *iv* injection, the injection should be stopped or made very slowly to minimize the increase in pressure particularly if a very small size angiocath is employed. The anesthesiologist must be aware of the potential for compartment syndrome during intravenous regional anesthesia when a tourniquet is employed.

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