Acute Compartment Syndrome of the Forearm Following Autologous Blood Reinfusion: A Case Report

Matthew Noyes · Michael J. Coffey · Dennis M. Brown ·
Homayoun Mesghali

Received: 19 August 2009 / Accepted: 9 October 2009 / Published online: 29 October 2009
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Abstract Compartment syndrome is a condition with multiple reported etiologies, and permanent disability may ensue if not treated in a timely fashion. We report the first case, to our knowledge, of acute forearm compartment syndrome caused by intravenous autologous blood reinfusion. The patient underwent forearm fasciotomy, and hematoma was encountered deep to the superficial volar fascia, presumably extravasated from the reinfusion catheter. With the rise in the number of knee and hip arthroplasties, surgeons need a heightened awareness of the possible complications and morbidity associated with a presumed increase in autologous blood reinfusion.

Keywords Autologous blood reinfusion ·
Compartment syndrome of the forearm

Introduction

Compartment syndrome may cause devastating morbidity if not diagnosed and treated in a timely fashion. First referenced by Volkmann in 1881 [32], the diagnosis has become an interchangeable term describing the final sequelae of neuromuscular necrosis. While compartment syndrome may be a chronic condition, common acute

causes include fractures [6, 15, 17], crush injuries [1], burns [4], and limb ischemia from vascular injury [22] or external compression [30]. Unusual etiologies such as snake [23] or spider bite [7], intravenous fluid extravasation [8, 9], and anticoagulation [10] have also been reported. Regardless of its origin, the resulting increased interstitial pressure can cause an insult to normal tissue homeostasis and can lead to tissue necrosis if left untreated.

We report the case of a patient with compartment syndrome of the forearm following autologous blood reinfusion after primary total knee arthroplasty. This represents, to our knowledge, the first case of compartment syndrome of the forearm caused by a blood reinfusion catheter. The patient was informed that information concerning this case would be submitted for publication, and the patient provided consent.

Case Report

A 56-year-old African American woman presented to our clinic with an extensive history of left knee pain. Her past medical history was significant for essential hypertension, esophageal reflux disease, and diverticulitis. Clinical and radiographic examination revealed severe tri-compartmental osteoarthritis of the knee. Conservative therapy provided minimal relief of her symptoms, and she then underwent total knee arthroplasty. The estimated intraoperative blood loss was 100 mL, total tourniquet time was 65 min, and there were no intraoperative complications. A SureTrans Auto-transfusion System (Davol Inc., Cranston, RI, USA) with a size 14 French drain was placed prior to closure, exiting the knee laterally.

Approximately 9 h following surgery, the resident was called to see the patient regarding a painful and firm right

M. Noyes · M. J. Coffey (✉) · D. M. Brown · H. Mesghali
Department of Orthopaedic Surgery,
Wright State University Boonshoft School of Medicine,
30 E. Apple St, Suite 2200,
Dayton, OH 45409, USA
e-mail: michael.coffey@wright.edu

D. M. Brown · H. Mesghali
Good Samaritan Hospital/Montgomery Orthopaedic Surgeons,
Dayton, OH, USA

forearm. At that time, the patient had received approximately 200 mL of transfused blood from the reinfusion system through an 18 gauge intravenous catheter placed preoperatively at the right wrist flexion crease, 1.5 cm ulnar to the radial artery. The patient stated that she fell asleep when the transfusion started and awoke 1 h later with severe, intense right forearm pain. She reported numbness and tingling throughout her entire right hand and forearm, and was visibly upset and distraught with pain. The patient stated that she had a burning sensation when the intravenous catheter was initially placed and flushed with saline. She notified the nursing staff at that time; however, the issue apparently was neither addressed nor documented.

When palpated, both the volar and dorsal aspects of the forearm were extremely firm. The radial pulse was not palpable, but was identified with Doppler ultrasound. She was unable to determine static two-point discrimination of 1 cm in the radial, median, and ulnar nerve distributions of her hand. She exhibited increased pain with passive wrist flexion and extension, and with finger flexion and extension. Her grip strength could not be assessed secondary to pain; however, she was noted to have 2/5 strength in her intrinsic hand muscles, 2/5 strength in wrist extension, and 1/5 strength in wrist flexion.

Hemoglobin level drawn in the post-anesthesia care unit was 11.5 mg/dL and platelet count was 285,000. Her blood pressure was consistently 140/90 mm Hg and she was treated with her anti-hypertensive medications postoperatively. She was slightly tachycardic, but urine output was 50 mL/h, demonstrating adequate postoperative hydration. There was confirmation that the patient had not received any postoperative anticoagulation medication.

The patient's right forearm was elevated and warm compresses were placed in an attempt to relieve swelling and pain. The forearm was thoroughly inspected to ensure that the warm compresses were not restrictive and that the forearm was not receiving some type of external compression.

Forty-five minutes later, the patient was re-examined and stated that the severity of her pain was increasing and her hand and forearm were "completely numb." She continued to be tearful and appeared to be in intractable pain. The radial pulse was palpable at that time, however the forearm remained very firm with swollen soft tissues. There was no interval change in her sensory or motor exam.

The forearm compartments were measured using sterile technique with the Stryker Intracompartmental Pressure Monitor System (Stryker Orthopaedics, Kalamazoo, MI, USA). Initial and repeat measurements found the volar compartment to be 74 and 72 mmHg and the dorsal compartment to be 62 and 55 mmHg. Her blood pressure at that time was 142/92 mmHg. Based on the patient's clinical presentation, exam findings, and intracompartmental pressure readings, the diagnosis of compartment

syndrome of the forearm was made and the patient was taken to the operating room for right forearm fasciotomy.

Fasciotomy was performed within 4 h of the patient's onset of symptoms. Approximately 15–20 mL of hematoma was evacuated upon release of the superficial volar fascia, which was suspicious for extravasation of reinfusion blood. The flexor carpi ulnaris and flexor digitorum superficialis muscle bellies were noted to have a dusky appearance. The lactertus fibrosis and transverse carpal ligament were not released. The deep volar fascia was noted to be tight and was released, and the dorsal compartment was released through a small window in the interosseous membrane. The flexor digitorum profundus muscle belly did not appear dusky. The fasciotomy wounds were approximated using the rubber band and staple technique. The patient reported a drastic decrease in pain during the immediate postoperative period. Examination in the post-anesthesia care unit revealed no pain with passive range of motion of the wrist or fingers. Her grip strength was graded 4/5 and wrist flexion and extension were graded 5/5. She did have paresthesias of the volar and ulnar aspect of the thumb. The radial pulse was graded 2+ and capillary refill was less than 2 s on all nail beds of the right hand. She had a negative Froment's sign.

On postoperative day 1, the patient began physical therapy for her left knee. She continued to have numbness and tingling along the volar and ulnar aspects of the right thumb. She had no residual strength deficits by postoperative day 2. She was taken back to the operating room on postoperative day 4 for irrigation and debridement of the right forearm with delayed primary closure. The muscle bellies of the flexor carpi ulnaris and flexor digitorum superficialis did not appear as dusky compared to the previous procedure. The superficial fascia was not closed; however, the subcutaneous tissue and skin were closed with absorbable sutures. A volar splint was placed to protect the wound. The patient was discharged from the hospital on postoperative day 5.

The patient was seen 3 weeks following discharge from the hospital. The volar forearm wound had fully healed at that time without erythema or drainage. However, the patient continued to have residual paresthesia on the volar/ulnar aspect of the right thumb at that time.

Discussion

Early diagnosis of compartment syndrome of any etiology is imperative because it can cause irrevocable damage if left untreated. The forearm is the most common site of compartment syndrome in the upper extremity [14]. Pain is the most consistent symptom; however, pain with passive extension of the wrist and fingers has been reported to be the most sensitive indicator of compartment syndrome [24, 27]. The finding of a palpable radial pulse is equivocal in

the diagnosis [12]. Muscles have functional impairment after 2 to 4 h of ischemia whereas nerve tissue has been shown to have abnormal function after 30 min [25]. A study by Matsen et al. showed that when fasciotomy is delayed 12 h or more, only 8% have normal function compared to 68% who have a fasciotomy within 12 h [18].

With regard to the etiology of compartment syndrome in the case described here, our hypothesis is that there was malfunction or misplacement of the intravenous catheter with extravasation of blood from the autologous reinfusion apparatus into the forearm soft tissue. As mentioned previously, the patient reported pain with initial flushing of the intravenous catheter after placement. The catheter could have been placed through the vein and into the superficial fascial compartment. It is noteworthy that only a small amount of hematoma (15–20 mL) was identified after release of the superficial fascia in our patient. We found no previous studies that described forearm compartment syndrome from such a small amount of extravasated fluid.

Intravenous catheter infiltration is a common cause of forearm pain that rarely leads to compartment syndrome because of the extra-compartmental position of the veins. Kagel et al. reported only one forearm compartment syndrome out of 67 intravenous catheter complications over a 3-year period [14]. However, there are reports of upper extremity compartment syndrome due to extravasation of mannitol [8, 9] and intravenous regional anesthesia [3]. Symptoms such as those experienced by our patient can usually be relieved by simple elevation of the arm and warm compresses. This case also highlights the importance of performing a thorough physical examination and measuring intracompartmental pressures in scenarios where compartment syndrome is suspected.

The placement of the intravenous catheter at the wrist flexion crease is also of particular concern in this case. It is possible that the radial artery could have been damaged during placement, but we did not encounter active intraoperative bleeding from the radial aspect of the forearm. Nevertheless, we are now reluctant to allow nurses at our institution to place intravenous catheters in this location.

Autologous reinfusion following arthroplasty is controversial with regard to its effect on postoperative hemoglobin levels and the need for blood transfusion in the perioperative period [2, 5, 11, 13, 16, 19, 20, 26, 29, 34, 35]. Nevertheless, autologous reinfusion seems to be safe, as we were unable to find any mention of complications and/or adverse reactions directly related to the reinfusion of autologous blood into a peripheral intravenous line. As mentioned previously, we believe the complication in this case to be the first reported case of compartment syndrome of the forearm caused by a blood reinfusion catheter.

Hypotension is presumed to predispose to compartment syndrome, whereas hypertension is believed to protect from

tissue ischemia [33]. Nonetheless, cases have been reported describing hypertension as a predisposing factor to compartment syndrome [21]. Capillaries have been shown to occlude at 12 mmHg of external pressure [28]. Therefore, essential hypertension may be more damaging than protective in the clinical setting. Although our patient had elevated compartment pressures based on her diastolic blood pressure, we do not rely on absolute compartment pressures of 30 mmHg [31] at our institution, rather clinical suspicion remains an integral factor in our decision making.

This case underscores the significance of possible intravenous catheter complications not only during blood reinfusion, but during any type of infusion. This case also specifically delineates the issue that small amounts of extravasated fluid coupled with systemic hypertension can potentially lead to compartment syndrome. As the number of knee and hip arthroplasties continue to rise, surgeons need a heightened awareness of the possible complications and morbidity associated with a presumed increase in blood reinfusion.

References

1. Aerts P, De Boeck HD, Casteleyn PP, et al. Deep volar compartment syndrome of the forearm following minor crush injury. *J Pediatr Orthop*. 1989;9:69–71.
2. Amin A, Watson A, Mangwani J, et al. A prospective randomised controlled trial of autologous retransfusion in total knee replacement. *J Bone Joint Surg [Br]*. 2008;90-B:451–4.
3. Ananthanarayan C, Castro C, McKee N, et al. Compartment syndrome following regional anesthesia. *Can J Anaesth*. 2000;47:1094–8.
4. Brown RL, Greenhalgh DG, Kagan RJ, et al. The adequacy of limb escharotomies-fasciotomies after referral to a major burn center. *J Trauma*. 1994;37:916–20.
5. Carless P, Moxey A, O'Connell D, et al. Autologous transfusion techniques: a systematic review of their efficacy. *Transfus Med*. 2004;14:123–44.
6. Chloros GD, Papadonikolakis A, Ginn S, et al. Pronator quadratus space and compartment syndrome after low-energy fracture of the distal radius: a case report. *J Surg Orthop Adv*. 2008;17:102–6.
7. Cohen J, Bush S. Case report: compartment syndrome after a suspected black widow spider bite. *Ann Emerg Med*. 2005;45: 414–6.
8. Edwards JJ, Samuels D, Fu ES. Forearm compartment syndrome from intravenous mannitol extravasation during general anesthesia. *Anesth Analg*. 2003;96:245–6.
9. Erickson BA, Yap RL, Pazona JF, et al. Mannitol extravasation during partial nephrectomy leading to forearm compartment syndrome. *Int Braz J Urol*. 2007;33:68–71.
10. Ghasseimi A, Salman M, Tiwari A. Compartment syndrome of forearm following brachial artery puncture and subsequent anticoagulation. *J Interv Cardiol*. 2002;15:435.
11. Gordon AC, Pulido P, Copp SN, et al. The use of reinfusion drains after total knee arthroplasty in patients treated with low molecular weight heparin for thromboembolic prophylaxis. *HSS J*. 2005;1:19–24.
12. Hamlin C. Compartment syndrome in the upper extremity. *Emerg Med Clin North Am*. 1985;3:283–91.
13. Huet C, Salmi LR, Fergusson D, et al. A meta-analysis of the effectiveness of cell salvage to minimize perioperative allogeneic

- blood transfusion in cardiac and orthopedic surgery. *Anesth Analg.* 1999;89:861–9.
14. Kagel EM, Rayan GM. Intravenous catheter complications in the hand and forearm. *J Trauma.* 2004;56:123–7.
 15. Kupersmith LM, Weinfeld SB. Acute volar and dorsal compartment syndrome after distal radius fracture: a case report. *J Orthop Trauma.* 2003;17:382–6.
 16. Martin A, von Strempel A. Transfusion of autologous blood from reinfusion systems in total knee arthroplasty. *Int Orthop.* 2006;30:541–4.
 17. Maru M, Varma S, Gill P. Acute compartment syndrome in the forearm following closed reduction and K-wiring of wrist fracture. *Injury.* 2005;36:1257–9.
 18. Matsen FA, Winquist RA, Krugmire RB. Diagnosis and management of compartmental syndromes. *J Bone Joint Surg.* 1980;62:286–91.
 19. Munoz M, Ariza D, Garceran MJ, et al. Benefits of postoperative shed blood reinfusion in patients undergoing unilateral total knee replacement. *Arch Orthop Trauma Surg.* 2005;125:385–9.
 20. Munoz M, Ariza D, Florez A, et al. Reinfusion drains reduce postoperative transfusion requirements after primary total knee replacement surgery. *Transfus Med.* 2008;18:269–71.
 21. Namboothiri S. Compartment syndrome and systemic hypertension. *J Bone Joint Surg.* 2005;87B:1420–2.
 22. Perry MO, Thal ER, Shires GT. Management of arterial injuries. *Ann Surg.* 1971;173:403–8.
 23. Roberts RS, Csencsitz TA, Heard CW Jr. Upper extremity compartment syndromes following pit viper envenomation. *Clin Orthop Relat res.* 1985;193:184–8.
 24. Rorabeck CH, Macnab L. Anterior tibial compartment syndrome complicating fractures of the shaft of the tibia. *J Bone Joint Surg.* 1976;58A:549–50.
 25. Sheridan GW, Matsen FA. Fasciotomy in the treatment of the acute compartment syndrome. *J Bone Joint Surg.* 1976;58:112–5.
 26. Steinberg EL, Ben-Galim P, Yaniv Y, et al. Comparative analysis of the benefits of autotransfusion of blood by a shed blood collector after total knee replacement. *Arch Orthop Trauma Surg.* 2004;124:114–8.
 27. Thonse R, Ashford RU, Williams TI, et al. Differences in attitudes to analgesia in post-operative limb surgery put patients at risk of compartment syndrome. *Injury.* 2004;35:290–5.
 28. Tornetta P III, Templeman D. Compartment syndrome associated with tibial fracture. *Instr Course Lect.* 1997;46:303–8.
 29. Tripkovic B, Bukovic D, Sakic K, et al. Quality of the blood sampled from surgical drainage after total hip arthroplasty. *Coll Antropol.* 2008;32:153–60.
 30. Vidal P, Sykes PJ, O'Shaughnessy M, et al. Compartment syndrome after use of an automated arterial pressure monitoring device. *Br J Anaesth.* 1993;71:902–4.
 31. Vollmar B, Westermann S, Menger MD. Microvascular response to compartment syndrome-like external pressure elevation: an in vivo fluorescence microscopic study in hamstring striated muscle. *J Trauma.* 1999;46:91–6.
 32. Von Volkmann R. Die ischämischen Kontrakturen. *Zentralbl Chir.* 1881;8:801.
 33. Whitesides TE Jr, Heckman MM. Acute compartment syndrome: update on diagnosis and treatment. *J Am Acad Orthop Surg.* 1996;4:209–18.
 34. Wood GC, Kapoor A, Javed A. Autologous drains in arthroplasty: a randomized control trial. *J Arthroplasty.* 2008;23:808–13.
 35. Zacharopoulos A, Apostolopoulos A, Kyriakidis A. The effectiveness of reinfusion after total knee replacement. A prospective randomised controlled study. *Int Orthop.* 2007;31:303–8.