Compartment Syndrome of the Forearm and Hand After Brachial Artery Cannulation

Terese T. Horlocker, MD*, and Allen T. Bishop, MD†

Departments of *Anesthesiology and †Orthopedics, Mayo Clinic and Mayo Foundation, Rochester, Minnesota

Brachial artery cannulation is rarely associated with serious complications. Nevertheless, the brachial artery is often occluded after percutaneous cannulation, although recanalization may occur (1–3). Ischemia distal to the site of arterial puncture may be caused by intimal dissection, thrombus formation with or without embolization, arterial transection, or hematoma. The presence of an indwelling arterial catheter may also partially obstruct distal blood flow and decrease local tissue perfusion, resulting in compartment syndrome. We report the case of a patient with multiple traumatic injuries in which brachial artery cannulation was associated with compartment syndrome of the forearm and hand. Removal of the arterial catheter resulted in immediate decrease in compartment pressures, eliminating the need for fasciotomy.

Case Report

A 16-yr-old, 68-kg female was transferred to our institution for treatment after a motor vehicle accident. On initial evaluation, she was noted to have sustained a closed head injury with diffuse mild cerebral edema, facial fractures, thoracic and abdominal blunt trauma, and fractures of the pelvis, left humerus and ulna, left midshaft femur, and left upper tibia and fibula. There were no fractures of the right upper or lower extremities. Her previous medical history was unremarkable.

Endotracheal intubation was performed in the emergency room and, after placement of left subclavian and right internal jugular central venous catheters, the patient was brought to the operating room. Anesthesia was induced with scopolamine and fentanyl intravenously (IV). After unsuccessful attempts at placement of a right radial arterial catheter, a 20-gauge 2-inch Sureflo® arterial cannula (Terumo Medical Corporation, Elkton, MD) was inserted, after several needle passes, into the right brachial artery. A guidewire was not used. A 16-gauge catheter was also inserted IV in the right hand. The patient initially underwent repair of hepatic lacerations, splenectomy, and closure of diaphragmatic defect. The intraoperative course was complicated by massive blood loss requiring extensive fluid and blood resuscitation. Throughout this portion of the surgical procedure, the arterial blood pressure range was 90–120/35–70 mm Hg. Central venous pressures ranged from 7 to 12 mm Hg. Phenylephrine 200 μg was administered IV for mild hypotension of 90/35 mm Hg immediately after anesthetic induction. No other vasopressors were administered throughout the remainder of the operative course. Serial analysis of arterial blood gases consistently revealed adequate oxygenation, although a metabolic acidosis (bicarbonate 14 mEq/L, pHa 7.19) was present for the initial 2 h of operative time. Hemoglobin ranged from 7.5 to 9.6 g/dL.

Seven hours after anesthetic induction, upon completion of the intraabdominal and thoracic procedures, the surgical drapes were removed, and the patient was positioned for open reduction and internal fixation of her left lower extremity fractures, as well as irrigation and debridement of her left upper extremity injuries. The hemodynamic status was stable; arterial blood pressure was 100–130 mm Hg systolic and 60–85 mm Hg diastolic. At this time it was noted that there was significant swelling of the patient's right forearm, hand, and digits. The right upper extremity also appeared pale and cool. Distal radial and ulnar pulses were intermittently palpable. However, a pulse oximeter probe positioned on the right hand successfully detected a waveform, and reported an arterial saturation of 100%, which was consistent with a Pao_2 of 433 mm Hg. Pressures of all three forearm compartments, as measured by the wick catheter technique, were elevated to 30 mm Hg (normal 9–13 mm Hg). (The wick catheter consists of a fluid-filled tube sealed with a filament bundle. This effectively prevents tissue blockage of the orifice and permits transmission of compartmental interstitial fluid pressure to the catheter and attached transducer.) Although there was no evidence of infiltration, the right-hand IV cannula was removed. Three liters of lactated Ringer's solution had been infused through this 16-gauge catheter throughout the intraabdominal and thoracic surgical procedures. However, because arterial blood gas tensions and direct blood pressure measurement were considered essential in this patient, and no other site was available, the arterial catheter was not immediately discontinued.

Over the next hour, percutaneous cannulation of the left femoral and dorsalis pedis arteries was unsuccessfully attempted. Forearm compartment pressures had further increased to 40 mm Hg, and the arterial catheter was removed. Right forearm fasciotomy (requiring removal of the right arm blood pressure cuff) was considered. However, noninvasive automatic blood pressure cuff measurements from the right lower extremity were unreliable. Therefore, it was elected to place a blood pressure cuff on the right upper arm

Accepted for publication July 10, 1995.

Address correspondence and reprint requests to Terese T. Horlocker, MD, Department of Anesthesiology, Mayo Clinic, Rochester, MN 55905.

0003-2999/95/$5.00

and continue to monitor blood pressure from that site. Forearm compartment pressures were closely followed while a cutdown arteriotomy was performed on the right dorsalis pedis artery. During this time, right forearm compartment pressures acutely and progressively decreased, so that upon completion of the arteriotomy, the forearm compartment pressures were 18 to 20 mm Hg. Pressures measured in the thenar and hypothenar compartments were only slightly higher. Doppler examination revealed normal flow signals in brachial, radial, and ulnar arteries. Since both the forearm swelling and compartment pressures had significantly decreased, and the hand appeared to have adequate arterial flow, it was decided to observe the limb closely rather than proceed with fasciotomy. The remaining operative course proceeded uneventfully. Subsequent measurements demonstrated further reductions in compartment pressures. The total amount of fluids infused intraoperatively included 29 units of packed red blood cells, 16 units of fresh frozen plasma, 12 units of platelets, 3 L of albumin, and 15 L of lactated Ringer's solution.

Postoperatively, there was no pain or tenderness to palpation of the patient's right upper extremity and neurovascular integrity was preserved. The right dorsalis pedis arterial catheter was removed 72 h after placement. The patient continued to require ventilatory support, and a right radial arterial cannula was inserted. Upon discontinuation of the radial arterial line 4 days later, the right brachial artery was once again cannulated. The brachial catheter remained indwelling for 3 days before it was electively removed. Despite these subsequent right upper extremity arterial cannulations, there were no further episodes of increased compartment pressures or vascular ischemia during the remainder of her hospitalization.

Discussion

Serious ischemic complications rarely occur after arterial cannulation. The most frequently reported major complication from arterial puncture is thrombosis at the site of entry with distal ischemia. Factors significantly increasing the risk of ischemic complications include female gender; a patient history of hypertension, arteritis, or vascular disease; catheter size and composition; duration of cannulation; and the use of vasopressors (4–8). While the relative safety of radial arterial puncture and cannulation has been well documented in studies by Slogoff et al. (4) and Mandel and Dauchot (5), cannulation of the brachial artery is usually considered more hazardous. The lack of collateral circulation about the elbow may predispose to forearm and hand ischemic complications. Mortensen (6) reported complications in 14 (42%) of 34 patients who underwent brachial arteriography, including 3 patients (9%) with major complications requiring surgical treatment. In addition, brachial cutdown arteriotomy was also associated with a more frequent complication rate compared to external iliac and subclavian arteriotomy. Björk et al. (1) described a significant risk of angiographic and Doppler abnormalities of the brachial artery (14 of 25 patients [56%]) with short-term use of brachial arterial catheters. Barnes et al. (3) reported abnormal Doppler signals and/or absent distal pulses in 3 of 54 patients with brachial arterial catheters. However, there was no evidence of significant ischemia to the forearm or hand reported in either study.

The presence of an indwelling arterial catheter may sufficiently disrupt blood flow to the distal extremity to result in muscle and nerve ischemia in combination with increased tissue pressure, or compartment syndrome. In addition to arterial injury, the most common causes of compartment syndrome are fracture, soft tissue injury, and burns (9). Factors further increasing tissue pressure (local hemorrhage, infusion infiltration, tight casts or dressings) or decreasing local arterial pressure (hypotension, elevation of the limb above the heart, vasopressors) will worsen the ischemia. The diagnosis of compartment syndrome is a clinical one, based on evidence of tissue ischemia (pain, pallor, diminished or paresthetic sensation, motor weakness), in addition to compartment swelling and tightness on examination. Diagnosis is difficult in an unconscious or anesthetized patient. However, objective measurements will demonstrate elevated compartment pressures. The presence of distal pulses does not exclude the diagnosis, regardless of the etiology (10). Prolonged increases in compartment pressures result in muscle and nerve death. Since outcome depends on the severity and duration of the ischemia, the ischemic period must be minimized and perfusion restored within 6–8 h after the initial injury, usually by fasciotomy (10,11). While individual patient tolerance to compartment tamponade and ischemia can be expected to vary, an adverse outcome can result in significant loss of function, so decompressive fasciotomy is recommended for compartment pressures of 30–45 mm Hg (9,12) or 20 mm Hg below diastolic blood pressure (13). In the forearm, the anterior compartment, posterior compartment, and mobile wad compartment (containing the brachioradialis and radial wrist extensors) are interconnected, unlike the fascial compartments of the leg. Thus, fasciotomies of all three compartments may be unnecessary to relieve compartment syndrome in the forearm.

In this case, there were multiple factors adversely affecting local tissue blood flow and perfusion, predisposing the patient to compartment syndrome of the forearm. The patient had no history of vascular disease and underwent placement of a brachial arterial cannula in an arm without obvious bony or soft tissue injuries. Upon arrival to the operating room, the patient was hypovolemic, anemic, and acidotic and there were no palpable radial or ulnar pulses. Multiple attempts at placement of a radial arterial cannula may have resulted in continued hemorrhage into the wrist and forearm. Mild hypotension after induction of anesthesia necessitated administration of phenylephrine. Massive and sustained blood loss from the patient's

multiple injuries demanded aggressive colloid and crystalloid resuscitation, resulting in a generalized migration of fluid into the third space, including the arm with the brachial arterial catheter. A diffuse coagulopathy was also present intraoperatively, and may have contributed to increased bleeding into the extremity from soft tissue injuries. In addition, a large-gauge IV catheter had been placed in the same arm and was used throughout the first 7 h of surgery. Therefore, compartment pressures were increased by interstitial leakage, IV infusion, and coagulopathy, while tissue oxygen delivery was decreased by hypovolemia, hypotension, anemia, vasopressors, and the presence of a brachial arterial cannula. However, while the cause of the compartment syndrome was multifactorial, compartment pressures continued to increase, despite restoration of a normal intravascular volume and removal of the IV catheter. It was only after discontinuing the brachial arterial cannula that compartment pressures acutely decreased below the threshold for surgical intervention by fasciotomy. The multifactorial etiology of compartment syndrome is also illustrated by the fact that, several days later, the radial artery and subsequently the brachial artery were cannulated uneventfully in this patient.

In summary, we present a case of compartment syndrome after brachial arterial cannulation, a previously unreported complication. Earlier investigations have suggested that cannulation of the brachial artery may result in an increased incidence of ischemic complications compared to cannulation of other arterial sites (6). This case demonstrates the importance of frequent assessment of an extremity with an indwelling arterial catheter. Signs of distal ischemia such as pain, pallor, swelling, and diminution of pulses or Doppler signals warrant prompt removal of the catheter. The patient should be closely observed for restoration of limb perfusion. Patients with severe arterial compromise and prolonged ischemic periods may require surgical intervention (10).

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