Arterial trauma during central venous catheter insertion: Case series, review and proposed algorithm

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Background: Percutaneous catheterization is a frequently-used technique to gain access to the central venous circulation. Inadvertent arterial puncture is often without consequence, but can lead to devastating complications if it goes unrecognized and a large-bore dilator or catheter is inserted. The present study reviews our experience with these complications and the literature to determine the safest way to manage catheter-related cervicothoracic arterial injury (CRCAI).

Methods: We retrospectively identified all cases of iatrogenic carotid or subclavian injury following central venous catheterization at three large institutions in Montreal. We reviewed the French and English literature published from 1980 to 2006, in PubMed, and selected studies with the following criteria: arterial misplacement of a large-caliber cannula (≥7F), adult patients (>18 years old), description of the method for managing arterial trauma, reference population (denominator) to estimate the success rate of the therapeutic option chosen. A consensus panel of vascular surgeons, anesthetists and intensivists reviewed this information and proposed a treatment algorithm.

Results: Thirteen patients were treated for CRCAI in participating institutions. Five of them underwent immediate catheter removal and compression, and all had severe complications resulting in major stroke and death in one patient, with the other four undergoing further intervention for a false aneurysm or massive bleeding. The remaining eight patients were treated by immediate open repair (six) or through an endovascular approach (two) for subclavian artery trauma without complications. Five articles met all our inclusion criteria, for a total of 30 patients with iatrogenic arterial cannulation: 17 were treated by immediate catheter removal and direct external pressure; eight (47%) had major complications requiring further interventions; and two died. The remaining 13 patients submitted to immediate surgical exploration, catheter removal and artery repair under direct vision, without any complications (47% vs 0%, P = .004).

Conclusion: During central venous placement, prevention of arterial puncture and cannulation is essential to minimize serious sequelae. If arterial trauma with a large-caliber catheter occurs, prompt surgical or endovascular treatment seems to be the safest approach. The pull/pressure technique is associated with a significant risk of hematoma, airway obstruction, stroke, and false aneurysm. Endovascular treatment appears to be safe for the management of arterial injuries that are difficult to expose surgically, such as those below or behind the clavicle. After arterial repair, prompt neurological evaluation should be performed, even if it requires postponing elective intervention. Imaging is suggested to exclude arterial complications, especially if arterial trauma site was not examined and repaired. (J Vasc Surg 2008;48:918-25.)

The clinical insertion of a central venous catheter in the subclavian vein of battlefield-wounded patients was first described in 1952 by Aubaniac.1 Percutaneous central venous cannulation is now a useful and commonly-performed procedure across medical and surgical specialties. Approximately 7 million of such central lines are installed each year in the United States,2 the most common sites being the internal jugular, subclavian, and femoral veins. These catheters are an essential aid in the management of numerous patients, facilitating hemodynamic monitoring, intravenous drug therapy, parenteral nutrition, hemodialysis, and rapid volume resuscitation.

While several randomized studies have shown the superiority of ultrasound-guided internal jugular vein cannulation, venous puncture and catheterization are still frequently performed in a blind manner, employing visual and palpable surface landmarks, with a reported success rate between 75% and 99%.3 Despite training and experience, the installation of such catheters is not risk-free. Acute mechanical complications are usually associated with injury to contiguous structures4 such as the pleura, nerves, esophagus, or nearby arteries. Inadvertent arterial puncture with a small needle is usually benign, and occurs in 5% of cases (0% to 11%).4 Much more morbid complications from arterial misplacement of large-caliber cannula have an incidence of 0.1% to 0.8% (Fig 1).5 These complications include hematoma, which can potentially expand and obstruct the airway,6 hemothorax,7 pseudoaneurysm,8 arteriovenous fistula9 (Fig 2), and stroke.5,10-13 No definite guidelines are found in the literature to address accidental large-bore (≥7F) arterial cannulation in perioperative patients. These arterial traumas are managed either by removal and external compression, an endovascular intervention, or by surgical exploration and direct arterial repair.
Our hypothesis was that removal of large bore catheters followed by external compression is associated with higher complication rates than an endovascular or open surgical exploration and repair of the arterial defect. The aim of this article is to review our series of arterial traumas related to internal jugular or subclavian access, to compare our cases with previous experience, to assess the strategic options when such complications are recognized, and to propose an algorithm for the management of catheter-related cervico-thoracic arterial injuries (CRCAI).

METHODS

Case series. We retrospectively identified all cases of iatrogenic carotid or subclavian injury following central venous catheterization with a catheter or dilator of 7F or more. Vascular surgeons, anesthesiologists, and intensive care unit (ICU) staff from three university affiliated hospitals in Montreal were invited to submit cases. In our own hospital, the vascular service database and ICU research database were searched for appropriate surgical codes and diagnosis (iatrogenic arterial, carotid, subclavian, or catheter related trauma). The ICU database was searched to compute the number of central venous catheter days and central venous catheters as the denominator to estimate the risk of arterial injury. Local institutional review board approval was obtained for this study.

Review of the literature. To establish guidelines regarding the management of CRCAI, we reviewed English and French publications from 1980 to 2006 in the PubMed database: the keywords, central venous catheter, were combined with arterial cannulation, arterial injury, carotid pseudoaneurysm, arteriovenous fistula, and stroke. Articles were manually searched and selected if they discussed misplacement of a large-bore catheter (≥7F) in adult patients (>18 years old). For the initial analysis, we included only case series reporting the method used to manage the arterial trauma, allowing us to estimate the success rate of the therapeutic option chosen.

Development of an algorithm for CRCAI management. After review of the literature and our case series, a multidisciplinary consensus panel comprised of four vascular surgeons, an anesthesiologist, and an intensivist, was delegated to define the optimal therapeutic strategy to decrease the risk of complications when a large-bore catheter was inadvertently placed in an artery.

Statistical analysis. The data was analyzed with NCSS software (Kaysville, Utah). Complication rates among different strategies were compared by Fisher exact test. \( P < .05 \) was considered significant.

RESULTS

Cases identified at participating centers

We identified seven cases of CRCAI at our institution (CHUM), four of which occurred at Hôtel-Dieu pavilion (HD) and three at Notre-Dame pavilion (ND). Five cases were identified at the Montreal General Hospital. One case was identified at Hôpital Maisonneuve-Rosemont (HMR). To estimate the risk of such injury, we had access to the Hôtel-Dieu ICU database. Hôtel-Dieu is a 300-bed hospital, included in the Centre Hospitalier de l’Université de Montréal (CHUM), with a strong cardiac and vascular program but no trauma or solid organ transplant service. The period from January 2001 to December 2006 was reviewed. About 1000 central venous lines and 200 pulmonary artery catheters are inserted annually, which corresponds to a total of 7200 during the observation period. We identified four cases of arterial trauma by catheter during that period, yielding an estimated incidence of 1/1800 (95% confident interval [CI], 1/5000-1/714).

Five patients were treated by immediate catheter removal and compression. All of them had severe complica-
tions, resulting in major stroke and death in one case, and bleeding requiring surgical intervention in three cases. The remaining eight patients were treated by immediate open repair (six) or through an endovascular approach (two) for subclavian artery trauma without complications. Details of these 13 cases are described below.

**Case 1 (ND).** A 70-year-old man was scheduled for myocardial revascularization. The insertion of a pulmonary artery catheter in the operating room was part of the operative planning for the anesthesia team. Under standard monitoring with the patient under general anesthesia, the patient was prepped and placed in the Trendelenburg position for insertion of the pulmonary artery catheter via the right internal jugular vein. Vessel access was obtained using the Seldinger technique with the use of an 18-gauge needle. Flow out of the catheter appeared to be venous. An 8.5F introducer sheath was placed over the guidewire, and pulsatile flow was observed from the sideport. The sheath was immediately removed from the artery, which was compressed at the insertion site. No cervical hematoma was noted. On duplex examination by the anesthetist, the carotid artery was normal, without the presence of a flap or flow acceleration. The planned surgery proceeded with the patient receiving 150 UI/kg unfractionated heparin for off-pump coronary artery bypass grafting, which was reversed by protamine on a 1:1 basis. In the early postoperative period, the patient’s pupils were found to be unequal and the patient was unresponsive. Computed tomography (CT) revealed massive infarction of the right cerebral hemisphere. An angiogram showed a thrombosed right internal carotid artery with an incomplete circle of Willis. The patient died within 24 hours from massive cerebral edema and resulting brain death.

**Case 2 (HD).** An 80-year-old man was scheduled for left lower limb bypass. The insertion of a central line in the operating room was part of the operative planning from the anesthesia team. Under standard monitoring with the patient under general anesthesia, the patient was prepped and placed in the Trendelenburg position for insertion of a central line via the right subclavian vein. An 8F introducer sheath was inserted using the Seldinger technique. Pulsatile flow was noted through the sideport. The catheter was left in place and the surgical procedure allowed to continue and was completed. The patient was transported to the angiography suite for endovascular treatment of the suspected iatrogenic arterial trauma. The right subclavian artery was accessed through a transfemoral approach. Under fluoroscopic guidance and angiographic image acquisitions, the catheter was removed and there were no signs of active bleeding or false aneurysm were noted. No additional interventions or complications occurred.

**Case 3 (HD).** A 65-year-old man was admitted to the ICU after a right pneumonectomy was readmitted to the ICU with respiratory failure and hemodynamic instability. Cardiac echography demonstrated pulmonary hypertension. A large-bore 8F catheter was inadvertently inserted in the right common carotid artery despite ultrasound guidance. Arterial injury was immediately recognized prompting vascular surgery consultation. The patient underwent surgical exploration, the catheter removed under direct vision, and the artery repaired without complications. The patient made an uneventful recovery.

**Case 4 (HD).** A 70-year-old man presented to the emergency room with a painful abdominal aortic aneurysm and was scheduled for urgent repair. Under general anesthesia, the patient was prepped and placed in the Trendelenburg position for insertion of a central line via the right subclavian vein. An 8F introducer sheath was inserted using the Seldinger technique. Pulsatile flow was noted through the sideport. The catheter was left in place and the surgical procedure allowed to continue and was completed. The patient was transported to the angiography suite for endovascular treatment of the suspected iatrogenic arterial trauma. The right subclavian artery was accessed through a transfemoral approach. Under fluoroscopic guidance and angiographic image acquisitions, the catheter was removed and there were no signs of active bleeding or false aneurysm were noted. No additional interventions or complications occurred.

**Case 5 (HD).** A 65-year-old man in our burn unit underwent central line cannulation of the right subclavian artery with a triple lumen 7F catheter. The injury was recognized immediately, the catheter was left in place, and vascular surgery consultation sought. The patient was transported to the angiography suite. A guiding catheter was inserted in the subclavian artery by transfemoral approach. The central line was exchanged over a 7F introducer, which was then removed after which a collagen-based vascular closure device was deployed to ensure hemostasis. Angiographic image acquisition after deployment of the sealing device did not show active bleeding therefore no further endovascular treatment was needed. The patient made an uneventful recovery.

**Case 6 (ND).** A 63-year-old man in the ICU after a right pneumonectomy was admitted to the ICU with respiratory failure and hemodynamic instability. Cardiac echography demonstrated pulmonary hypertension. A large-bore 8F catheter was inadvertently inserted in the right common carotid artery despite ultrasound guidance. Arterial injury was immediately recognized prompting vascular surgery consultation. The patient underwent surgical exploration, the catheter removed under direct vision, and the artery repaired without complications.

**Case 7 (ND).** A 74-year-old man admitted to the ICU because of pulmonary emboli suspicion, requiring emergent intubation. With the aide of superficial landmarks, a large-bore 8F catheter was inadvertently inserted into the right common carotid artery. Patient was fully anticoagulated with heparin at that time. The patient underwent immediate surgical exploration and catheter removal under direct vision. The artery was repaired without related complications. Catheter was noted to cross the jugular vein before entering the common carotid artery.

**Case 8 (MGH).** A 74-year-old man was admitted to the coronary unit for an acute myocardial infarct. An attempt to place a left jugular dialysis catheter using the superficial landmarks was made by the anesthesiologist in the...
operating room. Return seemed venous but when catheter was inserted, arterial trauma was immediately recognized because of pulsatile bleeding and arterial pressure through the catheter. Vascular surgery consultation was sought. Physical examination revealed no hematoma, and the catheter insertion point at the skin was deemed to be in the left posterior cervical triangle. Cervical exploration revealed that the catheter was in the proximal subclavian artery. Catheter removal and arterial repair through a supraclavicular approach was performed with no related complications.

Case 9 (MGH). A 59-year-old woman presented at the emergency room in shock. A large bore catheter was inserted in the right subclavian region without difficulty but was not working properly. The next day, arterial pressures and waveforms were transduced through that catheter. The patient had no signs of hematoma or neurological deficit. The patient was brought to the operating room for catheter removal. The plan was to control the subclavian artery in the supraclavicular and infraclavicular positions. The entry point was hypothesized as being behind the mid portion of the clavicle. While exposing the supraclavicular portion, the catheter was found to enter the subclavian artery in close proximity to the innominate artery. Removal of the catheter and two pledgeted prolene u-stitches were used for arterial repair with no complications.

Case 10 (MGH). A 79-year-old woman presented at the emergency room with acute on chronic renal failure and a potassium of 7.5. Insertion of a dialysis catheter was attempted through the right jugular vein. Several punctures were made and the catheter was noted to be in an artery because of pulsatile return. After correction of her hyperkalemia, she was brought to the operating room. Physical examination did not reveal any hematoma, but the entry site at skin level was low. The catheter was found to have entered into the distal innominate artery. Control of the carotid, subclavian and innominate was obtained through a ministernotomy. The catheter was removed and the artery repaired with two pledgeted u-stitches. No complications occurred.

Case 11 (MGH). A 79-year-old man was admitted in the ICU following a cranial trauma. A 7F three-lumen catheter was inserted into his left subclavian and arterial return was noted immediately and confirmed by transducing arterial pressure measurements. Chest x-ray was normal except for the catheter placement in the arterial circulation. The catheter was removed and local pressure applied. The patient became hemodynamically unstable and required fluid resuscitation with saline and blood products. No hematoma was noted. A chest x-ray revealed the presence of a left hemothorax. The vascular surgeon on call performed an angiogram through a femoral approach, and no active bleeding was noted. Pressure and resuscitation was continued. Patient had no sequelae from this complication.

Case 12 (MGH). A 78-year-old man trauma patient was in the ICU breathing using moderate pressure support through a tracheostomy cannula. Left subclavian access was attempted but the 7F, 20 cm, three-lumen catheter was inserted in an artery. The injury was immediately recognized. The catheter was immediately removed and pressure applied at the insertion point. Over the next few hours the patient required volume resuscitation in the form of saline and blood products. A chest x-ray revealed a left pleural effusion. A chest tube was placed, and drained a small amount of blood. A thoracic surgery consult was sought and a second 32F left chest tube was placed by the thoracic surgeon. Again, little blood was drained but the pleural effusion did not resolve. A total left lung collapse with respiratory compromise was observed 24 hours after the central line attempt. The patient required six units of blood within the first 24 hours. He was brought to the operating room for left lung decortication. During the surgery, a 3 mm hole was found on the left lateral part of the descending thoracic aorta, 2 cm below the origin of the left subclavian artery. The arterial entry site was partially clotted but bled massively during the surgical approach and was directly repaired. During surgery the patient required vasoactive drugs, a rapid transfuser and four units of blood and four units of fresh frozen plasma. A perioperative transesophageal examination revealed no descending aortic thrombus or dissection. The patient had no other complications related to the arterial puncture or the thoracotomy.

Case 13 (HMR). A 67-year-old woman was admitted to the intensive care unit and an attempt was made to install a triple lumen catheter in the left internal jugular vein. Using dynamic ultrasound, the internal jugular vein and carotid artery were visualised; they were superposed in their more proximal part. Puncture with the localizing needle revealed a venous flow. The introducer sheath was placed over the guidewire and pulsatile flow was observed. The catheter was left in place and the vascular surgery team was consulted. They immediately transferred the patient to the operating room. Exploration revealed that the catheter had transected through the internal jugular vein and the carotid artery. Both vessels were repaired and a Doppler at the end of the intervention revealed good flow without thrombus and a fixed atheromatous plaque. The patient was woken up in the operating room to check her neurologic status, which was intact, and was then re-induced. The patient made an uneventful recovery and no neurologic deficit or hematoma was noted.

Management of CRCAI

Overall, five articles met all our inclusion criteria regarding the management of CRCAI, which allowed the identification of 30 patients. All had undergone jugular vein catheter placement either in the ICU (eight), the operating room (20), or on the ward (two). Seventeen of them were treated by immediate cannula removal, followed by application of direct pressure at the puncture site for 5 to 30 minutes. The remaining 13 patients were treated by surgical exploration of the artery, catheter removal under direct vision, and artery repair. In both groups, the dimensions of the catheters were similar, varying between 7 and 8.5F. Eight of the 30 patients experienced complications. These eight patients were all treated initially by the removal/pressure technique. The timing of complication recognition varied, occurring immediately after catheter
removal in four cases. Three patients had a rapidly enlarging hematoma leading to airway compromise requiring urgent difficult intubation. One patient died of a stroke recognized immediately after catheter removal and pressure for 15 minutes (stroke risk = 5.9% [1/17]). Other complications included pseudoaneurysm (three) and hemothorax (one). Four of these eight patients had to undergo urgent surgical intervention, and two died. None of the 13 patients treated by immediate surgery suffered complications before or after the intervention (complications: 47% (8/17) vs 0% (0/13), \( P = .004 \) (Fig 3); mortality: 12% (2/17) vs 0% (0/13), \( P = .49 \)).

Using the same inclusion criteria but in case reports, we found 27 patients with sufficient details of trauma: eight were at the level of the carotid \(^5,7,8,10,11,13\) and 19 at the level of the subclavian artery. \(^8,9,17-22\) Seven patients with carotid cannulation had complications following treatment by the pull/pressure method. These complications included five strokes resulting in two deaths, and two hematomas requiring emergent intubation. Three of these patients required surgery. One patient was treated initially by delayed surgical exploration, \(^13\) which resulted in a stroke due to an embolic event. The surgical procedure took place more than 72 hours after insertion of the large-caliber catheter. Nineteen patients with an inadvertent subclavian artery cannulation were reported: seven had complications after pull/pressure, and 12 were treated successfully without complications by the endovascular approach. The misplaced catheter was left in situ until treated successfully with a percutaneous closure device (eight cases) or hemostasis with balloon inflation (four cases) under local anesthesia. These procedures were uneventful, and none of the patients suffered any complications. The seven complications occurring after the pull/pressure approach were hemorrhage requiring emergent intubation in two cases and open surgery in all cases. We also found one patient with complication following treatment with the pull/pressure method for a vertebral artery trauma. \(^11\)

By pooling the data from published series and case reports, patients treated by the pull/pressure method for the carotid (15/24) and the subclavian (7/7) had significant complications. Patients treated by surgical exploration (1/14) or by the endovascular approach (0/12) had very few complications. The single complication in the surgical treatment group was an embolic stroke, possibly due to a delayed surgical intervention. \(^13\) In that case, the surgical procedure took place more than 72 hours after insertion of the large-caliber catheter. Four catheter-related deaths (12.5%, 4/32) were reported in the literature in patients treated by pull/pressure. The incidence of complications was highly different between pull/pressure vs the surgical or endovascular approach, with a relative risk of 17.86 favoring surgical or endovascular repair (\( P < .001 \)) and a number needed to treat of 1.5 (1.3-2.4).

**DISCUSSION**

Complications after catheter-related cervicothoracic arterial trauma can be devastating. Iatrogenic trauma to the carotid or subclavian arteries may provoke severe bleeding, arterial dissection, emboli, or thrombosis. Several case reports of complications, such as airway obstruction by cervical hematoma, shock from hemothorax, stroke from arterial thrombosis or cerebral emboli, pseudoaneurysm, or arteriovenous fistula, can be found. \(^23\)

In anesthetized patients, inadvertent arterial cannulation that is not promptly recognized and managed can lead to debilitating irreversible complications. Domino and colleagues \(^24\) observed that injuries related to central venous lines were a frequent cause of claims in North America. In addition, these injuries had a higher degree of severity and increased mortality compared with other claims in the American Society of Anesthesiologists Closed Claims database.

In a recent survey among vascular surgeons who were presented with a hypothetical case of a large (8.5F) catheter in a carotid artery, although 90% of respondent saw this complication one to five times per year, as many as two-thirds of them answered that they would simply pull the large-bore sheath and apply pressure in the anesthetized patient if cannulation was recognized promptly. \(^25\) Interestingly, when vascular surgeons were shown the results of the present study at the 2007 Canadian Society of Vascular Surgery meeting, most of them changed their management as seen in response to pre- and post-test questions (Appendix, online only). This underscores the need to disseminate the present information among professionals placing central venous lines as well as guidelines for the prevention and management of these arterial injuries.

**Injury prevention.** Traditionally, central venous lines were placed using superficial landmarks. Recently, the ultrasound guidance was proven efficient; nine prospective, randomized studies compared anatomical landmark versus ultrasound-guided internal jugular vein cannulation. \(^26-35\) In all these trials, initial success rates were higher in the ultrasound guidance group. Complications were also reported and inadvertent arterial puncture rates were significantly lower by ultrasound in seven out of nine studies. In
our center, we noted an increase use of ultrasound guidance for central line cannulation in the past 2 years, especially in the intensive care. As seen in two of our patients, carotid cannulation can occur despite ultrasound guidance. While the focus of the present case series is not injury prevention but treatment of arterial injury with a large bore catheter once they are recognized, it gave us the opportunity to further discuss the prevention issue in the operating room and the intensive care unit and increased the awareness of potential complication severity and proper training for central line placement.

Needle injury. Pulling a small 22-gauge or 25-gauge “exploring” needle from a carotid artery and applying external pressure to prevent hemorrhagic complications is a common management approach which seems inconsequential in most cases. This is probably often not reported in the medical record and underreported in the literature. Only a few cases of major complications related to needles in carotid arteries or the aorta have been reported. In these cases, carotid puncture with a 20-gauge or 21-gauge needle occurred under general anesthesia and was treated by external compression for 3 to 15 minutes. These patients had significant carotid atherosclerotic plaque and presented embolic stroke in the first 48 hours postoperation. Postponing elective operation and neurological follow-up for 24 hours could be justified for selected patients, especially those with atherosclerotic carotid disease, higher stubs needle gauge, more than one arterial puncture, or hematoma.

Large-bore catheter injury. Once recognized, the management of more serious cervicothoracic arterial injuries will depend on several factors, such as the injury setting, patient stability, catheter diameter and arterial injury, whether still in place, and neurological status of the patient. Early recognition of the arterial trauma and prompt management are required.

Two different approaches to unintended arterial cannulation during central venous catheterization have been taken: removal of the cannula, followed by the application of local pressure, and immediate surgical or endovascular management. The present data demonstrate that with catheter 7F and over, the pull/pressure technique could be associated with significantly higher morbidity than surgical or endovascular management, including stroke, suddenly expanding hematoma causing airway compression, false aneurysm, or death.

One must take care to recognize that the low internal jugular vein approach can injure not only the carotid artery but also the subclavian or innominate vessels and even the aorta. Subclavian approaches can also injure the aorta, common carotid, or innominate artery. Although the target veins run in parallel to the major arteries, a significant proportion of the arterial injuries were remote from the intended access vein, precluding effective external pressure to tamponade the bleeding from the arterial puncture.

Under no circumstances should prolonged arterial cannulation be tolerated. Several cases are described with thrombus found at the site of the arterial injury, especially after prolonged catheterization. Heparinization should be considered if immediate treatment is not possible.

Stroke following the pull/pressure technique has been described. Our results suggest an immediate stroke risk of 5.6% associated with the pull/pressure approach when treating large-bore carotid injuries. Even a normal carotid duplex in a sedated patient does not rule out a stroke. Therefore, we suggest prompt neurological evaluation before pursuing any elective intervention. Postponing elective surgery will ensure that the anesthetized patient is not having an unrecognized stroke. Kron and colleagues recommend postponing elective open-heart surgery after two patients suffered serious complications when surgery was performed immediately after removal of the misplaced large sheath.

More recently, endovascular techniques, with covered stent placement or percutaneous arterial closure device, have been reported in cervical arterial injuries. These options are ideal for arterial trauma sites below or behind the clavicle, such as the proximal carotid and subclavian artery. Arterial trauma below the sternoclavicular joint should not be repaired through a cervical approach. Clinical suspicion of these low injuries should prompt preoperative imaging to clarify the injury site and treatment plan.

Our review revealed that complications such as a false aneurysm or arteriovenous fistula can be recognized as late as 2 weeks after CRCAI treated by the pull/pressure technique. Such findings in imaging studies would be useful to plan further treatment. Therefore, it would be reasonable to obtain imaging in patients treated by the pull/pressure technique, even if they are asymptomatic. Finally, 24 hours serial clinical follow-up to exclude enlarging hematoma or neurological complications is suggested, even if imaging is normal.

Relevant experience can also be obtained from management of the puncture site in percutaneous endovascular interventions such as common femoral artery catheterization, keeping in mind that these are planned arterial catheterizations and are not accidental. Most coronary or peripheral procedures are performed with 5 or 6F catheter, smaller than current central venous catheter (7 to 8.5F). Major bleeding or hematoma after catheter removal and pressure in the groin occurs in 1.0% to 2.4% of patients, and the complication rate increases with larger catheters. Complications are more frequent when the puncture site is either too high or too low, precluding pressure against the femoral head. Such knowledge should be taken into account when treating CRCAI, as cervical hemorrhage or cerebral ischemic complications are far more serious and deadly. Adequate compression in the cervical area is not possible without jeopardizing cerebral perfusion. We found several cases of rapidly enlarging hematoma after the removal of a misplaced catheter, resulting in difficult emergent intubation. The high rate of false aneurysms after the pull/pressure management of large CRCAI is not surprising.

There are no definite guidelines about the management of accidental arterial cannulation during central venous catheterization. Based on our review, we recommend the guidelines enumerated in Fig 4.
Limitations. The present study has some limitations. First, obviously, we cannot assume that all cases of arterial injuries are reported. Some arterial injuries treated by pull/pressure that cause no complications may remain totally unreported and may not even be entered in the patient’s chart. In our institution, however, hospital policy does not allow central line to be placed on the ward. Following our search in anesthesia, ICU, and vascular surgery departments, we are confident that we have tracked most central line placements. Second, published papers merely represent a selection bias of case reports (publication selection), and series with spectacular or uncommon complications. On one hand, uncomplicated arterial injuries treated by pull/pressure or patients presenting a major complication after the pull/pressure method are not reported. On the other hand, innovative approaches such as stenting or arterial closure devices are more prone to be described in the literature. The reference population criteria that we used for initial study selection minimizes this bias by excluding case reports and providing estimates of the success rate of a chosen approach.

CONCLUSION

During central venous placement, prevention of arterial puncture and cannulation is essential to minimize serious sequelae. If arterial trauma with a large-caliber catheter occurs, prompt surgical or endovascular treatment seems to be the safest approach. The pull/pressure technique is associated with a significant risk of hematoma, airway obstruction, stroke, and false aneurysm, especially when the site of arterial trauma cannot be effectively compressed. Endovascular treatment appears to be safe for the management of arterial injuries that are difficult to expose surgically, such as those below or behind the clavicle. After arterial repair, prompt neurological evaluation should be performed, even if it requires postponing elective intervention. Imaging is suggested to exclude arterial complications, especially if arterial trauma site was not examined and repaired.

AUTHOR CONTRIBUTIONS

Conception and design: M-CG, SE, MD
Analysis and interpretation: M-CG, SE, DB
Data collection: M-CG, SE, DB, MC, NB, JFB, MD, LB
Writing the article: M-CG, SE, DB, MC
Critical revision of the article: M-CG, SE, DB, MC, NB, J-FB, LB
Final approval of the article: M-CG, SE, DB, MC, NB, J-FB, MD, LB
Statistical analysis: M-CG, SE, DB
Obtained funding: SE
Overall responsibility: SE
M-CG and SE contributed equally to this work.

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The authors present an interesting retrospective series on the management of iatrogenic carotid and subclavian artery trauma after attempted central venous catheterization at their institutions. This is an important and timely topic because we all strive to limit complications from the various interventions we are called on to perform. In brief, the authors compared results from the approach of pulling the catheter and using pressure, the pull-and-push technique, with the approach of using surgical or endovascular interventions to limit morbidity and mortality. Although the numbers of patients reported are relatively small, the data strongly suggest that the pull-and-push technique has a much higher morbidity than the surgical or endovascular approach.

What are the controversial points of this article? The first is that the incidence of this problem is very low; therefore, it is difficult to amass sufficient patients to establish statistically significant numbers. Despite this, the differences between the two groups are striking and cannot be ignored.

The second controversial point is that the use of the pull-and-push technique requires less time and resources than open surgical or endovascular techniques. Again, the major complications that were found by the authors more than justify the use of surgical and endovascular techniques. One has to be honest and decide if you were the patient, what approach would you prefer? Are you willing to risk a stroke or difficulty in stopping hemorrhage?

In summary, one should approach the percutaneous placement of needles or catheters into the central veins with the use of ultrasound guidance. Second, a physician who suspects inadvertent placement of the needle or catheter into the carotid or subclavian arteries should obtain immediate vascular surgical consultation to decide the next series of steps. The algorithm described by the authors is logical and simple and should help guide the reader in the care of these patients.

INVITED COMMENTARY
Stuart I. Myers, MD, Chattanooga, Tenn

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The authors present an interesting retrospective series on the management of iatrogenic carotid and subclavian artery trauma after attempted central venous catheterization at their institutions. This is an important and timely topic because we all strive to limit complications from the various interventions we are called on to perform. In brief, the authors compared results from the approach of pulling the catheter and using pressure, the pull-and-push technique, with the approach of using surgical or endovascular interventions to limit morbidity and mortality. Although the numbers of patients reported are relatively small, the data strongly suggest that the pull-and-push technique has a much higher morbidity than the surgical or endovascular approach.

What are the controversial points of this article? The first is that the incidence of this problem is very low; therefore, it is difficult to amass sufficient patients to establish statistically significant numbers. Despite this, the differences between the two groups are striking and cannot be ignored.

The second controversial point is that the use of the pull-and-push technique requires less time and resources than open surgical or endovascular techniques. Again, the major complications that were found by the authors more than justify the use of surgical and endovascular techniques. One has to be honest and decide if you were the patient, what approach would you prefer? Are you willing to risk a stroke or difficulty in stopping hemorrhage?

In summary, one should approach the percutaneous placement of needles or catheters into the central veins with the use of ultrasound guidance. Second, a physician who suspects inadvertent placement of the needle or catheter into the carotid or subclavian arteries should obtain immediate vascular surgical consultation to decide the next series of steps. The algorithm described by the authors is logical and simple and should help guide the reader in the care of these patients.