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 specialities. 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 structures[4] 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,[7,8] pseudoaneurysm,[8] arteriovenous fistula[9] (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.

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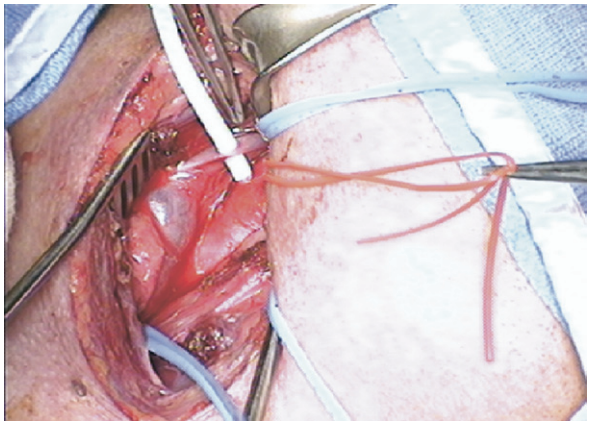

Fig 1. An 8.5F introducer crossing the right internal jugular vein and placed in the common carotid artery. Despite adequate initial venous puncture, carotid trauma can occur during cannulation.

Fig 2. Carotido-jugular arteriovenous fistula after arterial injury with an 8F introducer.

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 cervicothoracic 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 ($\geq$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. Vessel access was obtained using the Seldinger technic with the aid of an 18-gauge needle. Flow out of the catheter appeared to be venous. The 8F 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. The surgical procedure was performed as planned. Postoperatively, the patient presented with signs of cervical trauma as witnessed by the presence of a hematoma and a thrill over the right cervical region. Computed tomography (CT) and angiography (Fig 2) demonstrated a large, false aneurysm with an associated arteriovenous fistula. The patient underwent open surgery and made an uneventful recovery.

Case 3 (HD). A 65-year-old male with a tracheostomy underwent a failed attempted right jugular vein access in the ICU. An 8F sheath was placed over the guidewire, and pulsatile flow was monitored from the sideport. The catheter was immediately removed, but a hematoma with brisk bleeding was immediately noted despite compression. He was quickly transferred to the operating room. Exploration revealed that the catheter had injured both the jugular vein and the internal carotid artery. An intraluminal thrombus was found at the arterial trauma site. Repair of both vessels was uneventful and without further complications.

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 technic. 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 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.

Case 7 (ND). A 74-year-old man was 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 puncture 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,[4,6,14-16] 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

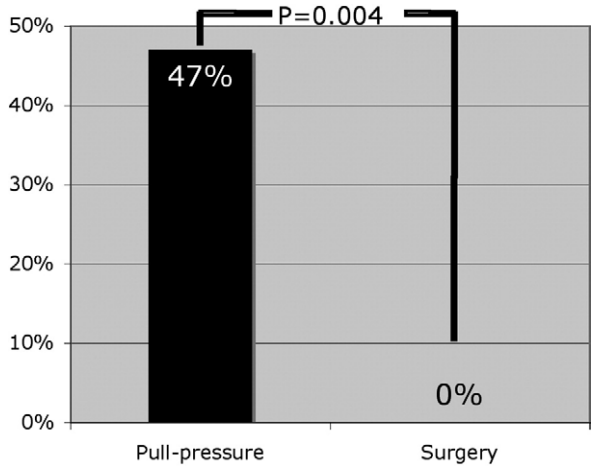

Fig 3. Complications related to differential management of catheter-related cervicothoracic artery injury.

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 artery (15/24) and the subclavian artery (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.[25-33] 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.[34-36] 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.[5,37,38] 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.[39] 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[16] 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.[4,7] 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.

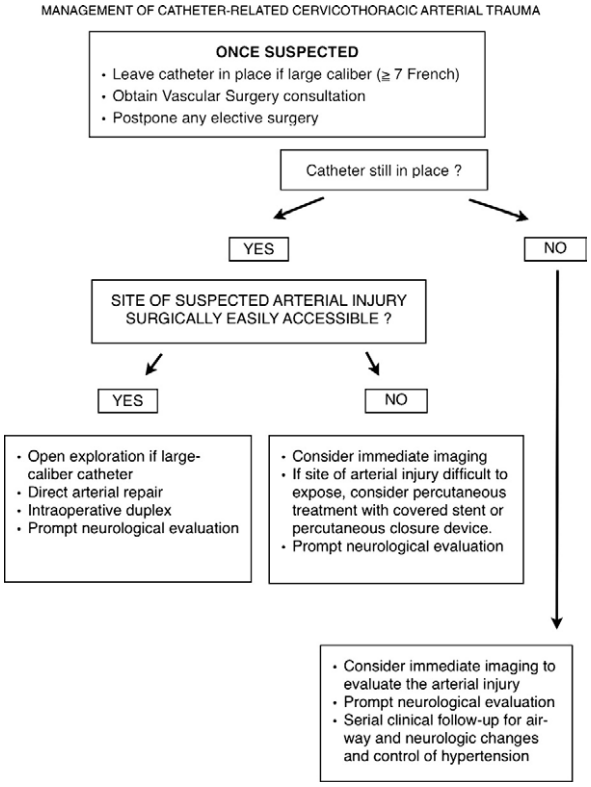

Fig 4. Proposed algorithm for cervical or thoracic arterial injury with a large-bore catheter.

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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INVITED COMMENTARY

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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?

The third controversial point is that the article does not dwell on the real issue, and that is prevention.

In my own practice, I use ultrasound guidance to place needles for central venous access, access of arteriovenous fistulas and grafts, and to perform diagnostic and interventional approaches to venous and arterial disease. Ultrasound-guided needle placement is quite easy, allows direct placement of the needle in the desired vessel, and requires very little training and experience. Logically, one would think that the use of ultrasound guidance would be particularly helpful to physicians who are not comfortable with percutaneous needle or catheter placement.

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.

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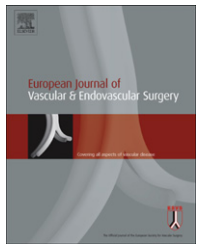

Management of Inadvertent Arterial Catheterisation Associated with Central Venous Access Procedures

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KEYWORDS
Carotid artery injuries;
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Endovascular repair

Abstract *Objective:* This study aims to describe the clinical management of inadvertent arterial catheterisation after attempted central venous catheterisation.
Methods: Patients referred for surgical or endovascular management for inadvertent arterial catheterisation during a 5-year period were identified from an endovascular database, providing prospective information on techniques and outcome. The corresponding patient records and radiographic reports were analysed retrospectively.
Results: Eleven inadvertent arterial (four common carotid, six subclavian and one femoral) catheterisations had been carried out in 10 patients. Risk factors were obesity ($n = 2$), short neck ($n = 1$) and emergency procedure ($n = 4$). All central venous access procedures but one had been made using external landmark techniques. The techniques used were stent-graft placement ($n = 6$), percutaneous suture device ($n = 2$), external compression after angiography ($n = 1$), balloon occlusion and open repair ($n = 1$) and open repair after failure of percutaneous suture device ($n = 1$). There were no procedure-related complications within a median follow-up period of 16 months.
Conclusions: Inadvertent arterial catheterisation during central venous cannulation is associated with obesity, emergency puncture and lack of ultrasonic guidance and should be suspected on retrograde/pulsatile catheter flow or local haematoma. If arterial catheterisation is recognised, the catheter should be left in place and the patient be referred for percutaneous/endovascular or surgical management.

The use of central venous catheters is widespread to provide venous access, nutritional support or to manage perioperative fluids. Central venous access procedures are associated with inadvertent arterial puncture or catheterisation in up to 6% of patients when using external landmark techniques,[1] with subsequent development of haemorrhage,[2] pseudoaneurysm,[3] arteriovenous fistulation,[4] arterial dissection,[5] neurological injury[6,7] and severe[3,8] or even lethal[9,10] airway obstruction.

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Use of ultrasound guidance for placement of central venous catheters is still infrequent[11] despite higher success rate and fewer complications.[12]

Arterial injury due to inadvertent catheterisation can be managed with open surgical techniques, although minimally invasive techniques have emerged as treatment options using stent grafts,[2] percutaneous closure devices[13,14] and balloon tamponade.[15] The uncontrolled removal of intra-arterial catheters followed by external compression (pull and pressure) is associated with high complication rates.[16]

The purpose of this study was to identify potential risk factors for and clinical signs of inadvertent arterial catheterisation after attempted central venous catheterisation and to review our experience of minimally invasive clinical management.

Methods

The study design was approved by the Human Research Ethics Committee of the Medical Faculty at the Lund University and carried out at a Swedish tertiary referral centre with a catchment population of approximately 1.6 million inhabitants.

Prospective information on techniques, equipment and outcome from an endovascular database of a total of 1079 patients undergoing intervention for carotid ($n = 114$), subclavian ($n = 35$) or femoral ($n = 930$) artery disease or injury between 1January 2003 and 29 February 2008 were obtained. Patients referred for surgical or endovascular management of inadvertent arterial catheterisation after central venous catheterisation were identified by analysis of conventional angiography and also by computed tomographic angiography in six patients.

Patient characteristics and information on the reason for central venous catheterisation, emergency or non-emergency procedure, site of catheterisation, type and size of catheter, detection and diagnosis of inadvertent arterial catheterisation and clinical management before referral were all obtained from patient charts and radiological reports. All angiograms of the initial procedure and all

Table 1 Demographic, technical and clinical characteristics of the ten patients of inadvertent arterial catheterization after attempted central venous cannulation found in the present study. All stent-grafts were placed from the common femoral artery.

Age (years)	Gender	Complicating factor for central venous access	Outer diameter of catheter (Fr)	First sign of arterial catheterization	Technical device and vascular approach
Common carotid artery					
70	Male	None	7	Excessive back flow	No device (Angiography via inadvertent catheter → external compression)
81	Female	None	7	Excessive back flow after three days	8 × 40 mm Fluency® stent graft
67	Female	Short neck	10	Bleeding	8 mm JoStent™ stent graft
37	Male	Major trauma	12	Excessive back flow	6 Fr Perclose® catheter suture device via inadvertent catheterization site
Subclavian artery					
69	Male	None	5	Peri-operative X-ray	6 Fr Perclose® catheter suture device via inadvertent catheterization site
55	Male	Major trauma	7	Pseudo-aneurysm after 26 days	Hybrid surgery (Balloon occlusion of injury via right brachial and femoral arteries → direct arterial suture)
77	Female	Major trauma	7 (bilateral)	CT	6 Fr Perclose® failed → 8 × 40 and 8 × 60 mm Fluency® stent grafts (right side) and 8 × 38 mm Advanta™ V12 stent graft (left side)
79	Female	Body mass index $> 40\ kg/m^2$	10	Excessive back flow, bleeding after 4 days	Two 10 × 40 mm Fluency® stent grafts
61	Female	None	16	Excessive back flow	8 × 50 mm Gore Viabahn® stent graft
Superficial femoral artery					
63	Male	Body mass index $> 40\ kg/m^2$	11 Fr	Excessive back flow	Angiography via inadvertent catheter → 10 Fr Perclose® catheter suture device failed → direct arterial suture

follow-up examinations were retrospectively evaluated by an endovascular specialist.

Results

Patients

The study comprised 11 inadvertent arterial catheterisations made in 10 patients (five females) with a median age of 69 (range 37—81) years. Two patients had a body mass index exceeding 40 kg m^{-2}, another patient had an unusually short neck and four catheters were inserted during emergency procedures (Table 1).

Catheterisations

Four catheters had been placed in the common carotid, six in the subclavian (bilateral catheters in one patient) and one in the superficial femoral artery.

Four catheters had been intended for haemodialysis, another four for rapid restitution of plasma volume in major trauma and the remaining three for total parental nutrition, cardiac pacing or measurement of central venous pressure. Depending on the type of catheter, their outer diameter varied from 5 to 16 Fr.

Five patients were catheterised under general and five under local anaesthesia. Ten catheterisations were made using external landmarks. Guidance by ultrasound was used in one patient for an intended subclavian access.

Excessive or pulsatile backflow through the catheter (six patients) or local haematoma (two patients) were reported within 4 days of inadvertent arterial catheterisation in seven patients. Partial paralysis of the arm due to subclavian pseudoaneurysm was found in another patient soon after withdrawal of the catheter 26 days after catheterisation. Subclinical inadvertent arterial catheterisation was detected by computed tomography or fluoroscopy in the remaining three catheterisations made in two patients.

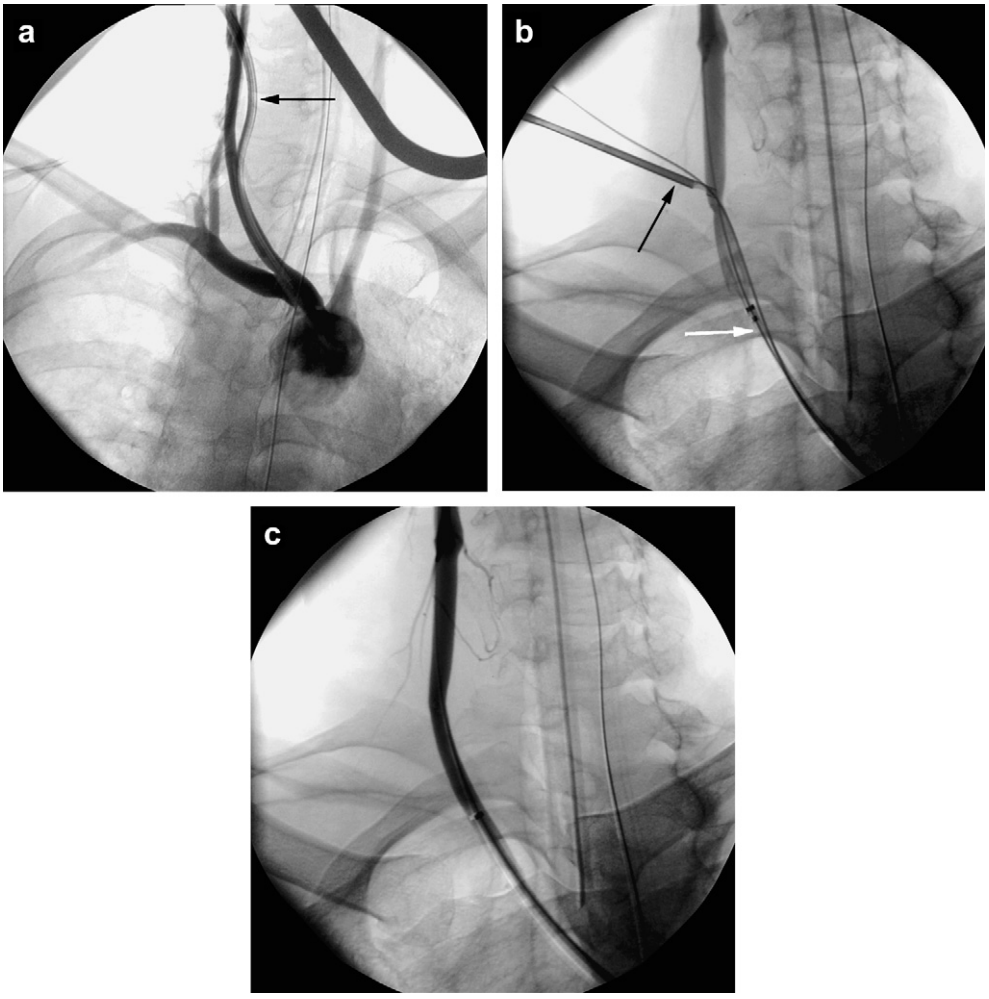

Figure 1 a. Angiogram made via a 12 Fr catheter (arrow), inadvertently placed in the proximal right common carotid artery with the tip positioned in the aortic arch of a 37 year-old male patient. b. The central venous catheter, inadvertently placed in the carotid artery, replaced by a Perclose® suturing device, and arterial sutures applied to the puncture site. The sliding knot was tied with a knot pusher (black arrow). The guide wire was withdrawn after haemostasis had been confirmed. A transfemorally introduced angioplasty balloon catheter (white arrow) in its introducer sheath was kept at ready for inflation in case of haemorrhage. c. Completion angiogram showing no extravasation or stenosis.

Of 11 catheters, 10 were left in the intra-arterial position on referral for surgical or endovascular intervention (Table 1).

Common carotid injury

All four interventions were made under general anaesthesia. Two injuries were successfully repaired with stent grafts. A self-expanding Fluency® stent graft (Bard Peripheral Vascular, Inc., Tempe, AZ, USA) was used in a distal part of the vessel in the first patient and a balloon-expanded Jomed Stentgraft™ (Abbott Laboratories, Abbott Park, IL, USA) was used in a lesion close to the brachiocephalic trunk in the second patient.

Perclose® percutaneous suture device (Abbott Laboratories) was successfully used in the third patient with a 12 Fr dialysis catheter introduced in the middle portion of the vessel (Fig. 1a–c).

In the fourth patient, the catheter was safely withdrawn under manual compression after vascular access for angiographic mapping and instant management of haemorrhage (Table 1).

Subclavian injury

Two patients underwent arterial repair with stent graft or Perclose® device under local anaesthesia, whereas the remaining four patients were treated under general anaesthesia. Four injuries were repaired with stent grafts.

Bilateral arterial catheterisations in a 77-year-old female patient with major trauma were revealed *en passant* by CT after emergency resuscitation. The left injury was successfully excluded with a balloon-expanded Advanta™ V12 stent graft (Atrium Medical Corp., Hudson, NH, USA). A Perclose® percutaneous suture device failed to seal the right subclavian artery injury. A Fluency® stent graft was then placed but required further extension with another Fluency® stent graft due to continued extravasation (Fig. 2a–c).

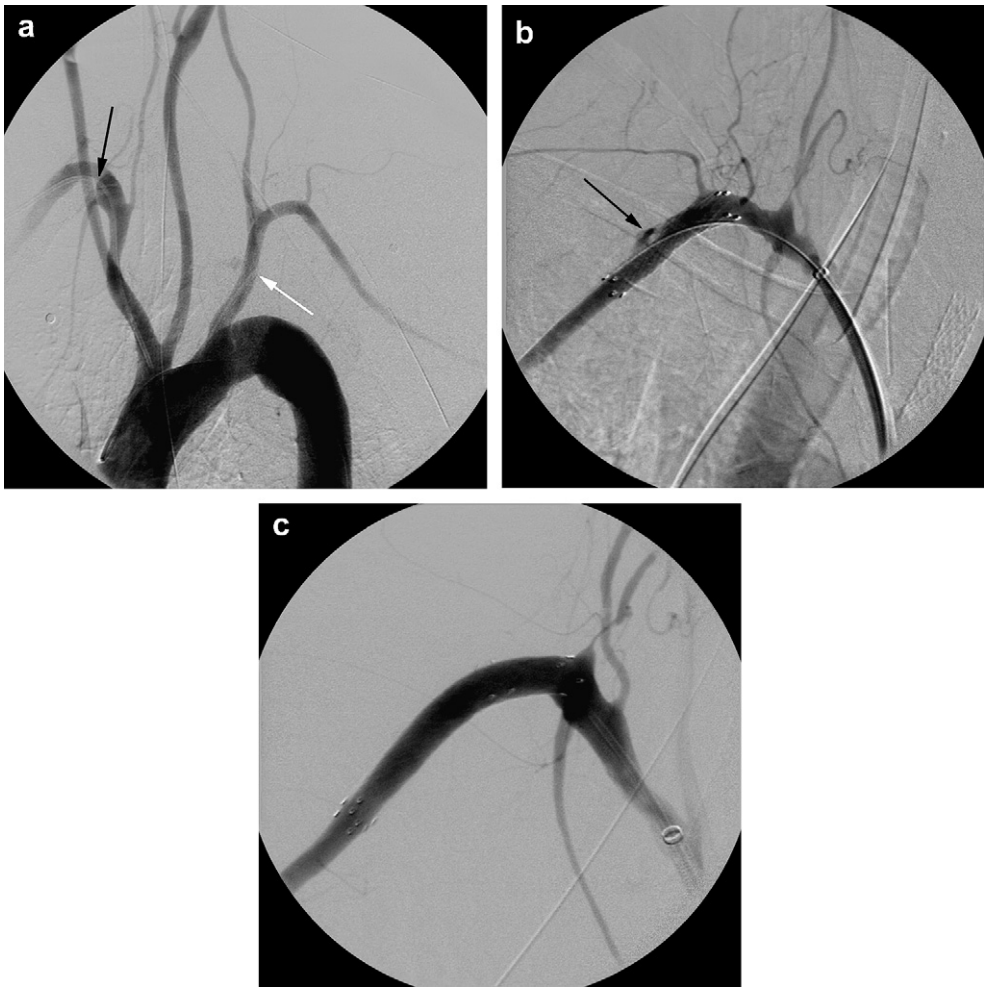

Figure 2 a. Angiogram showing inadvertent bilateral catheterisations of the subclavian arteries with 7 Fr catheters intended for central venous catheterisation in a 77 year-old female with major trauma. Black and white arrows indicate vascular sites of catheter entry. b. Angiogram showing continuous extravasation (arrow) despite an 8 × 40 mm Fluency® stent graft introduced transfemorally into the right subclavian artery. c. Angiogram showing no extravasation after a second 8 × 60 mm Fluency® has been positioned as an extension to seal the subclavian vessel wall.

A 16 Fr catheter injury involving the origin of the right thyreocervical trunk in a 61-year-old female patient was managed by coil embolization of its major branches followed by placement of a self-expanding Gore Viabahn® stent graft (WL Gore & Associates, Inc., Flagstaff, AZ, USA). Because of continuous extravasation after placement of the stent graft, caused by backbleeding, the thyrocervical trunk was further embolised with *N*-butyl cyanoacrylate (Histoacryl; Braun, Melsungen, Germany) mixed with iodised oil (Lipiodol; Laboratoire Guerbet, Roissy, France) and haemostasis was achieved (Fig. 3a–f, Table 1).

An obese patient (body mass index 58) with a 10 Fr haemodialysis catheter in the left subclavian artery was treated with two Fluency® Plus stent grafts.

One subclavian injury was successfully treated with a Perclose® percutaneous suture device.

The remaining injury, close to the origin of the right vertebral artery, was managed by a combined surgical and endovascular procedure. A balloon catheter was first inserted transfemorally and inflated at the puncture site while the artery was exposed and repaired by open arteriorrhaphy (Table 1).

Superficial femoral injury

A Prostar® percutaneous suture device (Abbott Laboratories) was used in a failed attempt to close the vascular injury in a uraemic, obese patient with an 11 Fr haemodialysis catheter placed in the right superficial femoral artery. Open surgical repair was then made by arteriorrhaphy under general anaesthesia (Table 1).

Clinical follow-up

One patient with major trauma died within 24 h, corresponding to 9% in-hospital mortality. Another patient with pseudoaneurysm and compression of the brachial nerve plexus had partial paralysis of the right arm at the time of diagnosis with little improvement at 20 months' follow-up after hybrid surgery. No other patient had clinical signs of local complications. The median in-hospital stay was 2 (range 1–11) days without procedure-related complications and the surviving patients were followed up for 16 (2–50) months.

Radiographic follow-up

Patients were not routinely followed by vascular imaging techniques, but two patients were evaluated by radiography at the site of repair for other reasons.

An unaltered position without stenosis or fracture of a Jomed Stentgraft™ in the right common carotid artery was confirmed by CT angiography after 44 months in a 71-year-old female patient (Fig. 4). No signs for stenosis was detected by CT angiography 50 months after repair of the subclavian artery with a Perclose® percutaneous suture device in a 69-year-old male patient.

Discussion

Accidental arterial puncture may follow one out of 20 central venous catheterisation attempts.[17] Because this complication is often recognised before the catheter is introduced into the blood vessel, inadvertent arterial catheterisation is much less common. In agreement with our findings, obesity,[18] short neck[19] and urgent catheterisation[19] have been proposed to be risk factors for complications in central venous catheterisation. The hypovolaemic state, calling for immediate action, might have rendered accidental arterial puncture more likely and more difficult to detect, due to less pulsatile backflow of less oxygenated blood in our three patients with major trauma. Patients with hypotension and/or low haemoglobin saturation should thus be considered at particular risk for inadvertent arterial catheterisation.

Current clinical guidelines[20] state that guidance by ultrasound, applied in one of 11 central venous catheterisations in the present study, reduces the risk of arterial puncture during central venous catheterisation. This has been convincingly shown for the internal jugular route,[18,21] in agreement with reported inter-individual variation of the anatomical relationship between the internal jugular vein and the common carotid artery,[22,23] but less so for the subclavian approach.[18,21]

Accidental arterial catheterisation should be suspected immediately on excessive or pulsatile backflow of well-oxygenated blood through the catheter or local haematoma at the site of catheterisation. Delayed diagnosis increases the risk of serious complications.[13,14,24] An intra-arterial catheter position is confirmed by CT angiography or by angiography through the inadvertently inserted catheter.

Treatment strategies after inadvertent arterial catheterisation include local compression, open surgical treatment with direct arterial repair and percutaneous/endovascular treatment. Withdrawal of an arterial catheter may result in considerable haemorrhage,[25] stroke[26] or, as in one of our patients, pseudoaneurysm.[27] Factors that are associated with an increased risk for serious complications after catheter removal are catheter diameter, time since catheter insertion and the puncture site. Open surgical treatment has been shown to be safe but can add significant morbidity as patients are often seriously ill and open repair can be complex, requiring general anaesthesia and perhaps sternotomy. Less invasive percutaneous or endovascular treatment of inadvertent catheterisation of the carotid, subclavian or femoral artery can even be performed under local anaesthesia. A number of recent case reports and small case series have drawn attention to these options of treatment with percutaneous closure devices or stent grafts.[28,29] We report on 11 inadvertent arterial injuries in 10 patients and support the findings that endovascular management is feasible and safe.

The percutaneous suture device (Perclose®) technique has an almost 99% success rate for repair of the femoral artery after catheterisation with 12–16 Fr catheters and less than 2% late complications.[30] As indicated by the present and previous[31] findings, obesity is a risk factor for failure in achieving haemostasis with this technique. Failure of the technique after right subclavian catheterisation in the present study might have been caused by severe angulation of the device at the site of insertion. However, percutaneous closure devices have been reported to be successful in subclavian injury as well.[13,32,33]

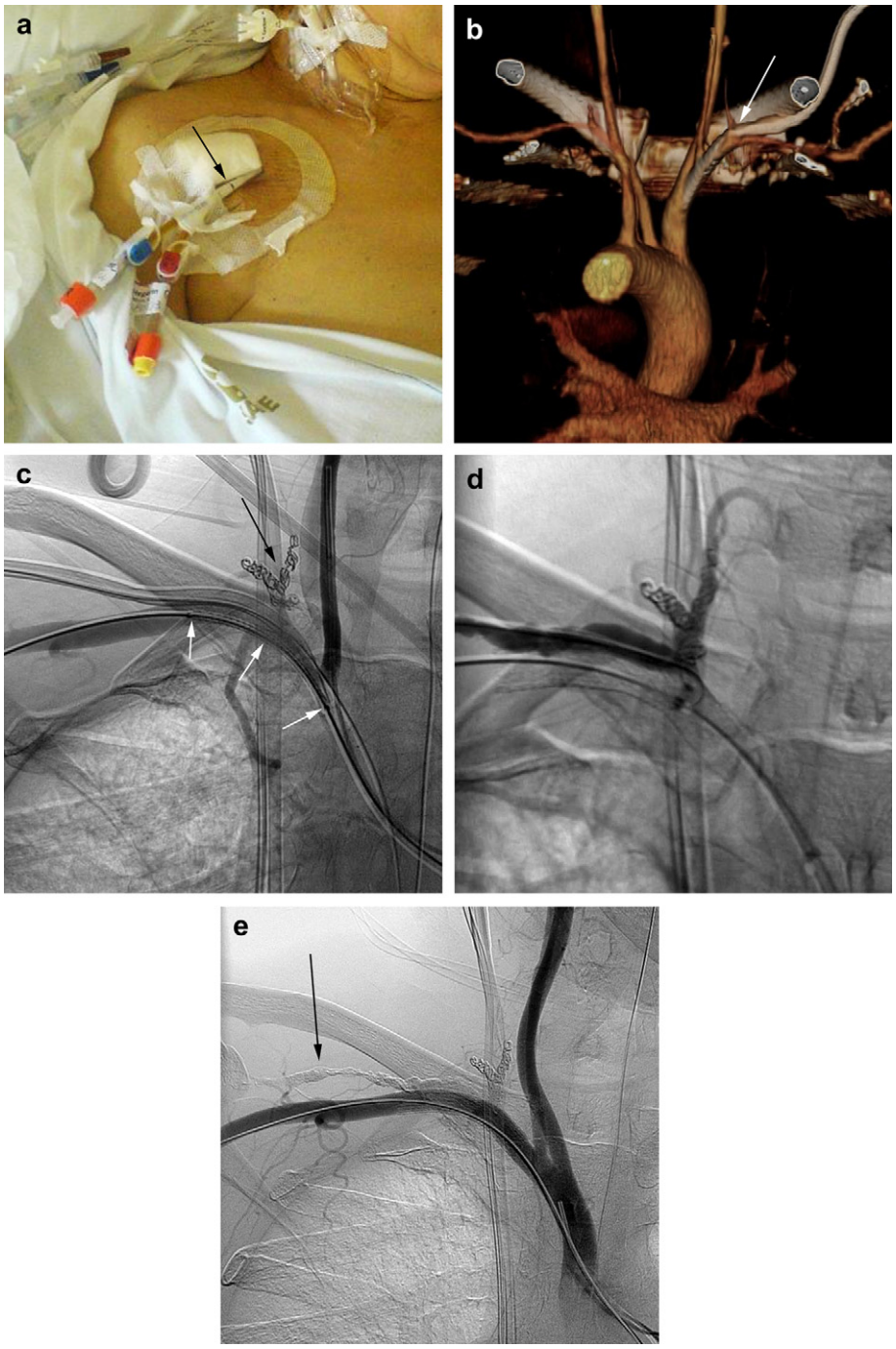

Figure 3 a. In a 61 year old female a 16 Fr double-lumen catheter (arrow) was inadvertently inserted into the subclavian artery, and thereafter another 16 Fr double-lumen catheter was correctly positioned in the internal jugular vein. b. Posterior—anterior three-dimensional reconstruction of computed tomographic angiography showing the 16 Fr double-lumen catheter inadvertently passing caudally to the right clavicle into the right subclavian artery. The arrow indicates the vascular site of catheter entry at the branching of the thyreocervical trunk from the right subclavian artery. c. Angiogram made before withdrawal of the 16 Fr catheter inadvertently placed in the right subclavian artery. An 8 × 50 mm Gore Viabahn® stent graft (white arrows) was placed across the puncture site distally to the right vertebral artery, catheterised separately to secure access in case of overstenting. A 0.018-inch guide-wire passing through the inadvertently placed 16 Fr catheter proved to be most useful after withdrawal of the catheter (d and e). The thyreocervical trunk was embolized with metallic coils (black arrow) to prevent retrograde bleeding. d. Angiogram after withdrawal of a catheter inadvertently placed in the right subclavian artery showing continuous extravasation along the 0.018-inch safety guide partially withdrawn into the subcutaneous channel. e. Completion angiogram showing no further extravasation after embolization with N-butyl cyano-acrylate (Histoacryl; Braun, Melsungen, Germany) mixed with iodised oil (Lipiodol; Laboratoire Guerbet, Roissy, France). The arrow points at the glue in the subcutaneous channel of the inadvertently placed catheter.

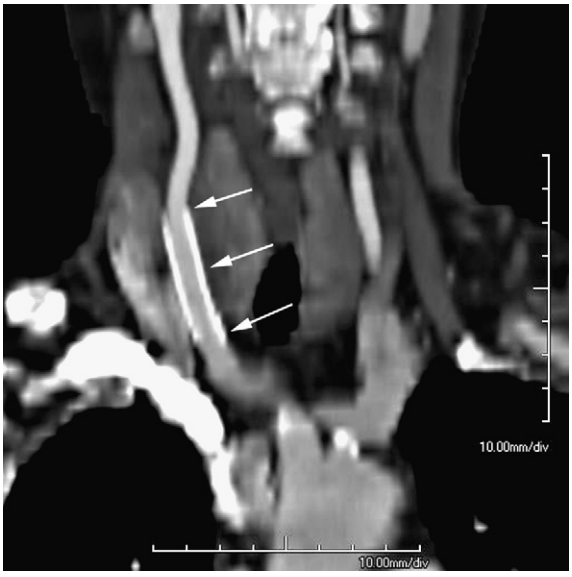

Figure 4 Multiplanar reconstruction of computerized tomographic angiography of the neck region showing unimpeded flow through the stent graft in the right common carotid artery (arrows) at four-year follow-up in a 71 year-old female patient.

The technical success rate for stent grafts was high, although the technique calls for caution when used close to major arterial side branches.

Little is known about the long-term durability in terms of stenosis, kinking and fracture, although recent findings suggest that their use can be comparable to that of open surgery for carotid or subclavian injuries.[34,35] None of our patients had clinical signs of local complications to the intervention. Hence, although stent grafts might not be the first choice in younger patients, their use can be advantageous when the puncture site is not compressible and difficult to access with open surgery.

Conclusions

Inadvertent arterial positioning of central venous catheters might be associated with obesity, emergency puncture, severe hypotension or low haemoglobin saturation, and the risk has been reported to be lower under ultrasound guidance. Useful clinical warning signs of arterial catheterisation are excessive or pulsatile backflow, local haematoma or sudden neurological deficit. Any suspected intra-arterial catheter position should be verified radiographically and the catheter be left in place on referral for repair. Percutaneous/endovascular management of inadvertent arterial catheterisation appears to be safe and feasible and seems to offer advantages over open surgical repair in selected patients.

Conflict of Interest\Funding

None.

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None.

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