Clinical Studies

Endovascular Management of Inadvertent Subclavian Artery Catheterization during Subclavian Vein Cannulation

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PURPOSE: To retrospectively review a 9-year experience with endovascular management of inadvertent subclavian artery catheterization during subclavian vein cannulation.

MATERIALS AND METHODS: From June 2000 through July 2009 (109 months), 13 patients underwent endovascular management of inadvertent subclavian artery catheterization. All catheters were still in situ, including one 7-F catheter, six 8-F catheters, and six large-bore 10–11-F catheters. Treatment was performed with an Angio-Seal device ($n = 6$) or balloon catheters ($n = 7$) and by additional stent-graft placement ($n = 4$).

RESULTS: Mean follow-up was 27.3 months (range, 0.4–78 months). The 30-day mortality rate was 7.7% and the late mortality rate was 46.1%. Primary technical success was achieved in nine patients (69.2%), in four with the use of a compliant balloon catheter and in the other five with an Angio-Seal device. Complications required additional stent-graft placement in four patients (30.8%), one because of stenosis after Angio-Seal device deployment and three as a result of insufficient closure of the puncture site by balloon tamponade. Stent-graft repair was successful in all four patients, for a primary assisted technical success rate of 100%.

CONCLUSIONS: Endovascular techniques offer a less invasive alternative to surgery. The present limited experience shows that the use of the Angio-Seal device is not without risks, whereas balloon tamponade is not always reliable in closing the puncture site. Stent-graft placement may be required in patients in whom balloon tamponade fails or in whom the use of the Angio-Seal device is contraindicated.

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CANNULATION of the subclavian vein for the insertion of a central venous catheter is a frequently used technique, especially in patients requiring long-term administration of drugs, hemodialysis, parenteral nutrition, or volume support during extensive surgery. As the subclavian vein lies inferior and anterior to the subclavian artery (1), the puncture of the vein is a comparatively safe procedure, with reported rates of inadvertent arterial puncture as high as 3.7% (2). Real-time ultrasound guidance (US) allows visualization of the vein during catheter insertion and therefore reduces the risk of arteriotomy, but it requires training and the necessary equipment (1,3). Therefore, some institutions prefer blind micropuncture via Seldinger technique (4), which substantially reduces the risk of arterial cannulation and is unlikely to lead to serious complications unless the patient's clotting is markedly abnormal (5). First, a thin needle is used to locate the vein. After the vein is located, successful venous puncture is verified by aspiration of venous blood without any pulsatile flow. Only then is a large-bore catheter inserted over a guide wire. If inadvertent arterial puncture is recognized, the thin needle can be withdrawn, immediately followed by manual compression of the puncture site (6).

If inadvertent arterial misplacement of a large-bore catheter has occurred, it has to be treated as soon as possible, as it may lead to potentially fatal complications such as hematoma, arterial dissection, hemothorax, arteriovenous fistula, pseudoaneurysm, emboli, and stroke (7,8). Treatment can be performed by removal of the catheter and compression of the puncture site, or by endovascular or open surgical repair. Endovascular techniques offer a less invasive alternative to open surgery and a safer option than manual compression (9).

The purpose of this retrospective study was to review our 9-year experi-

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Patient Characteristics and Results

Pt. No.	Age (y)/ Sex	Puncture Side	Arterial Calcification	SCA Size (mm)	Wall Injury	Catheter Size (F)	Balloon	Angio Seal Device	Stent-graft	Success			Comment
										PTS	PATS	CS	
1	70/M	R	No	7	Single	8	0	1	0	Y	N	Y	—
2	74/M	L	No	7	Single	8 (n = 2)*	1	0	0	Y	N	Y	—
3	59/M	L	No	6	Single	11	1	0	0	Y	N	Y	—
4	64/M	R	No	7	Single	11	1	0	0	Y	N	Y	—
5	76/F	R	No	8	Single	8	0	1	0	Y	N	Y	—
6	60/M	R	No	7	Single	11	1	0	0	Y	N	Y	—
7	67/F	R	No	8	Double	8	1	0	1	N	Y	Y	Double wall injury, noncompliant balloon
8	76/M	L	No	7	Single	8	1	0	1	N	Y	Y	Undersized noncompliant balloon
9	46/M	R	No	7	Single	8	0	1	0	Y	N	Y	—
10	77/F	R	No	6	Single	11	0	1	0	Y	N	Y	—
11	83/M	L	Yes	9	Single	11	0	1	1	N	Y	Y	Stenosis after AngioSeal (dissection of arteriosclerotic vessel due to subclavian catheter)
12	61/F	L	No	7	Double	11	1	0	1	N	Y	Y	Noncompliant balloon (balloon too short to cover both puncture sites simultaneously)
13	78/F	L	No	7	Single	7	0	1	0	Y	N	Y	—

Note.—CS = clinical success; PATS = primary assisted technical success; PTS = primary technical success; SCA = subclavian artery.
* Two 8-F catheters were inserted into the SCA, one beside the other.

ence with the removal of subclavian vein catheters inadvertently placed into the subclavian artery with endovascular techniques including deployment of the Angio-Seal device (St. Jude Medical, Minnetonka, Minnesota), balloon catheters, and stent-grafts.

MATERIALS AND METHODS

Patients

From June 2000 through July 2009 (109 months), 17 patients were referred to our department for the removal of a subclavian vein catheter inadvertently placed into the subclavian artery. In the early period of this study, when endovascular methods were not yet a firmly established alternative to surgery, four of these patients underwent surgical catheter removal under direct vision via a supraclavicular approach and subsequent repair of the artery by two pledgeted "U" stitches. The remaining 13 patients (eight men, five women; mean age, 69 years; range, 46–83 y), underwent endovascular treatment (**Table**). As the purpose of this study was the evaluation of endovascular treatment options, the following data refer to these techniques only.

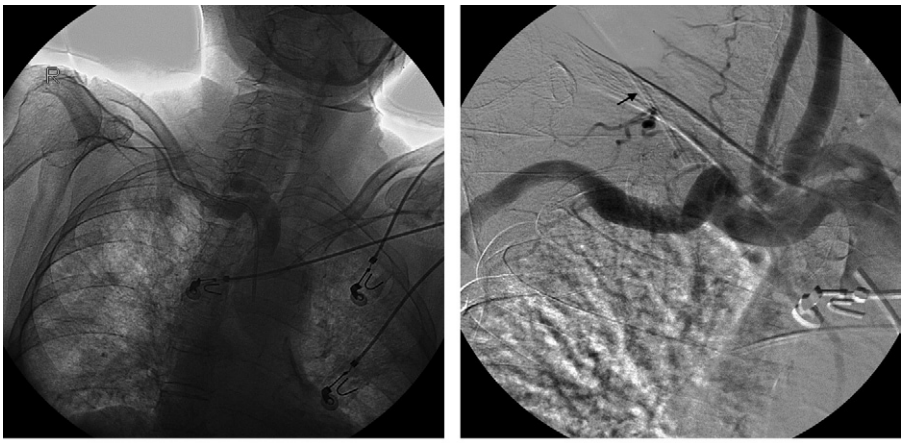
In all patients, the catheter was still in situ. Radiographs showed misplaced large-bore 10–11-F catheters in six patients, 8-F catheters in six patients, and a 7-F catheter in one patient. In one of them, two 8-F catheters were placed into the subclavian artery, one behind the other.

Catheter misplacement became obvious in 10 patients as a rush of pulsatile blood flow came through it at its first use, and in two patients because no adequate amount of blood could be aspirated through the catheter. In one patient who had developed acute infarction of the cerebellar and occipital regions, computed tomography (CT) studies showed air embolism in the posterior cerebral artery and a repeat chest radiograph revealed the misplaced catheter.

Indications for subclavian vein catheterization were preparation for surgery in six patients, infection in three patients, acute renal failure necessitating hemodialysis in two patients, malignancy in one patient, and acute resuscitation in one patient. All catheterizations were performed by anesthesiologists without sonographic guidance, seven of them in an intensive care unit and six in an operating room.

The catheter was placed into the right subclavian artery in seven patients and the left subclavian arteryin six. In all patients, an infraclavicular approach had been used for catheter placement (7). Both arterial walls were perforated in two patients, and in both of them the tip of the catheter protruded into the mediastinum.

All patients were treated within 24 hours, except for the patient with cerebral infarction, in whom the correct diagnosis was established as late as 2 days after the event (**Fig 1**). During the pre-



a. b.

Figure 1. Images from a 76-year-old female patient. (**a**) Angiography (nonsubtracted image) with direct injection of contrast medium into the misplaced catheter demonstrates the catheter within the right subclavian artery, the aortic arch, and the supraaortic vessels. (**b**) Selective angiography (subtracted image) of the right subclavian artery shows successful removal of the misplaced catheter and complete closure of the puncture site by the Angio-Seal device. The tamper tube of the 8-F Angio-Seal device can be seen (arrow).

interventional period the patients underwent moderate heparinization to achieve a target activated partial thromboplastin time of 50–60 seconds. During this time, the catheters were not used and therefore there was only a minimal risk of cerebral events. Written informed consent was obtained from those six patients who were conscious. In the other seven patients, who were under general anesthesia, the decision for endovascular management was made by the team of vascular surgeons, anesthesiologists, and interventional radiologists involved in the treatment.

Because of the retrospective nature of the present study, it was not necessary to present it to the local ethical review board.

Diagnostic Workup

In all patients, the misplaced catheter was identified by preoperative chest radiography. However, one patient required additional skull CT and repeat chest radiography to establish the correct diagnosis.

Technique

All procedures were performed in an angiographic suite (Integris BV 3000; Philips, Eindhoven, The Netherlands). Six patients were treated under local anesthesia. Seven patients were referred to our department under general anesthesia because of intended treatment for severe underlying medical conditions. During the intervention, all patients were monitored by means of electrocardiography, blood pressure measurements, and pulse oximetry.

In all patients, transarterial access was obtained via a right femoral approach. In all of them, the exact position of the catheter within the artery and that of its tip were identified by diagnostic angiography with a 5-F multipurpose Headhunter catheter or a vertebral catheter (Cordis, Roden, The Netherlands). In one patient, an additional catheter was introduced through the left femoral artery to allow angiography during temporary balloon occlusion. Direct injection of contrast medium into the misplaced catheter was performed as needed. However, it was not done routinely to avoid embolic events, as the misplaced catheter may contain thrombotic material.

Diametric measurements of the subclavian artery were performed by means of a semiautomatic vessel analysis software using the diameter of the diagnostic catheter as a reference.

Endovascular repair was performed with the use of compliant balloon catheters in four patients, Angio-Seal devices in five patients, noncompliant balloon catheters followed by stent-graft placement in two patients, a compliant balloon catheter followed by stent-graft placement in one patient, and an Angio-Seal device followed by stent-graft placement in one patient. Whereas the access site has remained the same, the treatment technique has changed over time. Until 2007, we mainly used balloon catheters to remove the misplaced catheter and to achieve hemostasis, but for more than 2 years now, we have preferred the use of the Angio-Seal device in most cases. Stent-grafts were inserted only when balloon occlusion or Angio-Seal device repair failed.

In all patients, completion angiography was performed to document arterial patency, normal vessel appearance (with or without a stent-graft), and absence of extravasation.

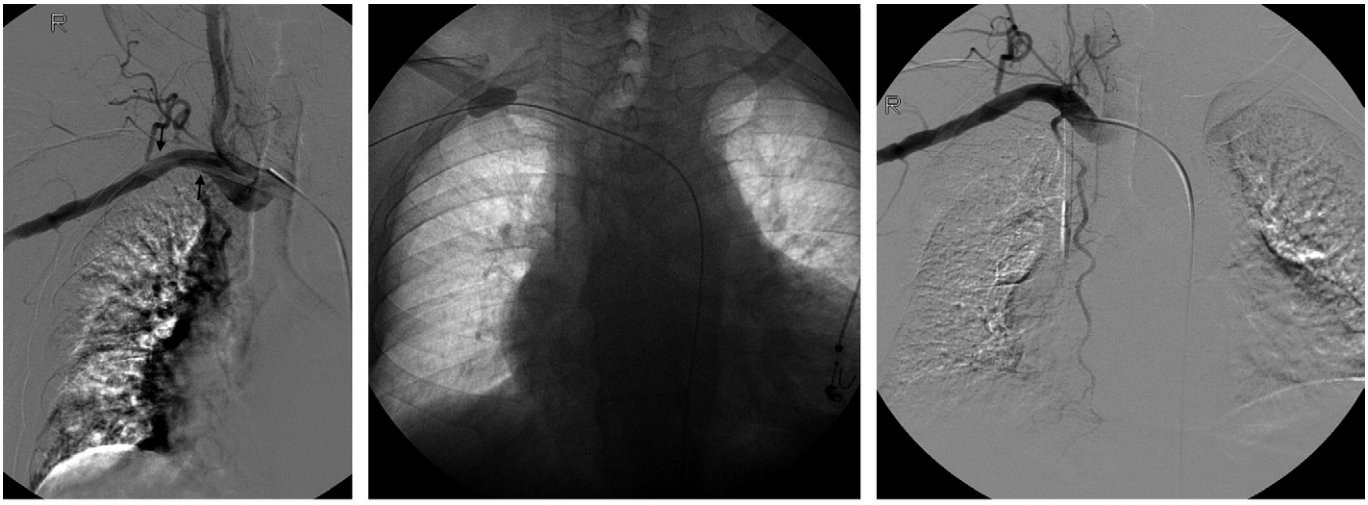
Balloon Catheters

Five patients were treated with a temporary occlusion balloon catheter (Fig 2), consisting of a soft, compliant 11.5-mm latex balloon with a 7-F catheter shaft (Boston Scientific, Natick, Massachusetts) and two patients with a conventional, noncompliant angioplasty balloon catheter (Opta; Cordis, Miami Lakes, Florida) introduced through a short femoral sheath.

The balloon catheters were placed across the level of the catheter entry site and balloon inflation and catheter removal were performed simultaneously. After a mean inflation time of 12 minutes (range, 10–15 minutes), the balloons were deflated and removed, maintaining guide wire access for completion angiography. Inflation time depended on the diameter of the arterial puncture caused by the misplaced catheter. For catheter sizes up to 8 F, we chose an inflation time of 10 minutes; beyond this size, we increased inflation time to 15 minutes. If hemostasis could not be achieved during the first attempt, a second attempt was made immediately after the first one. After the treatment, the balloon catheter was removed and replaced with a diagnostic catheter for completion angiography.

Stent-grafts

Three patients received Fluency stent-grafts (C.R. Bard, Murray Hill, New Jersey) with a length of 60 mm and a diameter of 8 or 10 mm and one patient received a Wallgraft (Boston Scientific) with a length of 50 mm and a diameter of 10 mm. In all patients, access was obtained through the right femoral artery and the devices were introduced



a. b. c.

Figure 2. Images from a 64-year-old male patient. (**a**) Selective angiography (subtracted image) of the right subclavian artery shows the misplaced catheter (arrows). (**b**) Fluoroscopy shows temporary balloon occlusion of the arterial puncture site with a compliant latex occlusion balloon. (**c**) Selective angiography (subtracted image) of the artery after temporary balloon occlusion demonstrates normal findings without extravasation of contrast medium.

over a 0.035-inch stiff Amplatz guide wire with a length of 260 cm with use of a 10–12-F sheath.

The stent-grafts were deployed under fluoroscopic control, with use of roadmap technique and landmarks and without subsequent balloon dilation. In the three patients in whom selective catheter angiography showed failure of balloon tamponade with ongoing hemorrhage, a 10–12-F femoral sheath was inserted and the stent-graft was prepared while manual compression of the puncture site was performed at the same time. After stent-graft placement, completion angiography was performed to document correct stent-graft position and the status of the branch arteries and to detect possible endoleaks. The femoral puncture sites were closed by endovascular repair, except for the patient in whom a 12-F femoral sheath was used. In this patient, the sheath was removed surgically and the puncture site was closed by suture. All patients received a bolus injection of 5,000 IU heparin and then underwent anticoagulation for 24 hours with 10,000 U of heparin. In addition, lifelong antiplatelet therapy with a daily dosis of 100 mg acetylsalicylic acid was prescribed. Stent-graft patency was monitored by US studies or clinical examination and by questioning the patients on their state of health at regular telephone interviews.

Angio-Seal Devices

The Angio-Seal hemostatic puncture closure device (St. Jude Medical) is a collagen-based, plug-mediated arterial closure device that consists of a biodegradable anchor, a small bovine collagen plug, and a traction suture to ensure fixation (10). It is introduced over a 0.035-inch guide wire. However, in our experience, the guide wire that is added to the package is often too short and too floppy. Therefore, we use a 0.035-inch stiff Amplatz guide wire. All components are fully bioabsorbable and dissolve within 60–90 days (11,12).

In six patients, the subclavian puncture site was closed with an 8-F Angio-Seal device. The first two were treated by means of the Angio-Seal STS device and the other three by means of the modified Angio-Seal VIP device (ie, "V-twist integrated platform"). The diagnostic catheter placed before Angio-Seal device deployment was left in place for completion angiography after the procedure.

Follow-up Protocol

The follow-up protocol included clinical examination, laboratory tests, and chest radiography before discharge, with CT was performed as needed. After discharge, no specific follow-up protocol was required. However, as most patients had severe comorbidities, they were closely observed and underwent frequent imaging for their underlying diseases. In addition, they were questioned on possible symptoms of arm ischemia and neurologic complications at regular telephone interviews, which also allowed a fixed study endpoint to be set.

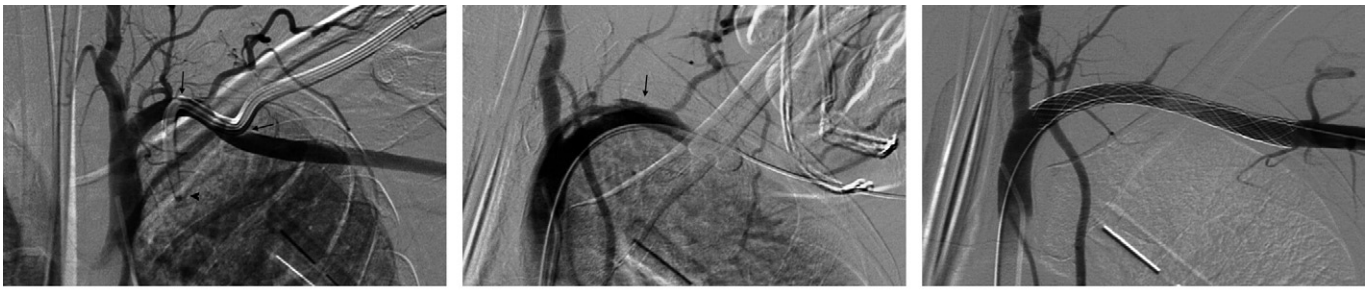
Definitions

Primary technical success was defined on an intent-to-treat basis as successful removal of the misplaced catheter in a first attempt without need for secondary intervention. Primary assisted technical success was defined as successful secondary intervention during the same session. Clinical success was defined as successful removal of the catheter without procedure-related morbidity or mortality and without need for surgical reconstruction.

RESULTS

Follow-up

Retrospective analysis of the postinterventional course extended for a mean of 27.3 months (range, 0.4–78 months). One patient died within 30 days, which leaves a total of 12 patients who were observed for more than 30 days. One of them was lost to follow-up 37.4 months after the intervention.



a. b. c.

Figure 3. Images from a 61-year-old female patient. (**a**) Selective angiography (subtracted image) of the left subclavian artery demonstrates the misplaced catheter perforating both arterial walls (arrows) and protrusion of the catheter tip into the anterior mediastinum (closed arrowhead). (**b**) Selective angiography (subtracted image) during temporary balloon occlusion of the artery with a compliant balloon shows extravasation of contrast medium at the proximal puncture site (arrow). (**c**) Selective angiography (subtracted image) after stent-graft (Wallgraft) deployment shows complete closure of both puncture sites without extravasation of contrast medium.

Mortality

The 30-day mortality rate was 7.7 %. One patient died of chronic renal failure and myocardial infarction. Late mortality rate was 46.1% ($n = 6$). Three patients died 1.5, 1.7, and 3.4 months after the intervention, respectively, one of sepsis resulting from infection with *Clostridium difficile* after antibiotic treatment, one of sepsis and renal failure after pneumonia, and one of sepsis and acute respiratory failure resulting from plasmocytoma. One patient died of myocardial infarction 8.7 months after the intervention. Two patients died 57 months after the intervention, one of sepsis after pneumonia and the other of myocardial infarction. Currently, five patients are alive and well.

Primary Technical Success

Primary technical success rate was 69%. In nine of 13 patients, hemostasis was achieved at the first attempt to close the puncture site, in four by means of a compliant balloon catheter and in the other five by means of an Angio-Seal device.

Primary Assisted Technical Success and Complications

Primary assisted technical success rate was 100%. The complication rate was 30.8%. Four patients required additional stent-graft placement, three after unsuccessful balloon tamponade and the other after Angio-Seal device deployment.

In the patient in whom the Angio-Seal device was used, completion angiography showed stenosis of the subclavian artery as a result of a localized dissection that was certainly caused by manipulation during the attempted subclavian vein catheterization. The true reason for the stenosis remained undetected on diagnostic angiography because the misplaced large-bore catheter (11 F) itself caused stenosis as a result of its thickness and the dissection could be visualized only after removal of the catheter. Although the bleeding was stopped by Angio-Seal device deployment, the patient required additional stent-graft placement to prevent vessel occlusion. The patient is alive and well 2.7 months after the intervention with normal clinical and US findings.

In three patients, balloon tamponade failed. In one of them, who was treated with a noncompliant balloon, the balloon was clearly undersized as documented on completion angiography. In a second attempt, the vessel was blocked for more than 10 minutes with a correctly sized balloon. However, after deflation, angiography still showed extravasation of contrast medium necessitating stent-graft insertion, which was successful. The patient is alive and well 27.3 months after the intervention and reported no clinical symptoms of stent-graft stenosis. In the other two patients, both arterial walls were perforated by the catheter, resulting in protrusion of the catheter tip into the mediastinum. One of them was treated by a compliant balloon and the other by a noncompliant balloon.

In the patient treated with a noncompliant balloon, tamponade failed despite the use of an adequately sized balloon and hemostasis could be achieved only by insertion of a stent-graft. The patient died of sepsis 1.7 months after the intervention. In the patient treated with a compliant balloon, the balloon was too short to cover both puncture sites simultaneously because the puncture site in the opposite arterial wall was located 2 cm proximal to the catheter entry site. Angiography performed during the procedure via an additional left femoral approach showed extravasation from the proximal uncovered puncture site, which had to be closed by stent-graft insertion (**Fig 3**). This patient was lost to follow-up 37.4 months after the intervention. At the last follow-up, the patient showed no clinical symptoms of stent-graft stenosis.

The patient with infarction of the cerebellar and occipital regions first underwent heparinization, and after the correct diagnosis was established, the patient was successfully treated by deployment of an 8-F Angio-Seal device. After the procedure, she recovered but experienced hemianopsia and finally died of sepsis after severe pneumonia 57 months after the intervention.

Clinical Success

Clinical success rate was 100%. None of the patients showed procedure-related morbidity or mortality. There were no conversions to surgery, and none of the patients except for the one mentioned earlier showed clinical signs of cerebral ischemia. Therefore, no cranial imaging had to be performed.

DISCUSSION

Arterial misplacement of a venous catheter may lead to significant morbidity and mortality including hematoma, arterial dissection, hemothorax, arteriovenous fistula, pseudoaneurysm, emboli, and

stroke (13–16). Therefore, it should be treated as soon as possible. It can be managed by removal of the catheter and compression of the puncture site or by endovascular or open surgical repair. Manual compression may be difficult to perform as a result of overlying bony structures and is advisable only for small punctures. In case of large-bore catheter injuries, surgical or endovascular repair is indicated to avoid serious complications. However, patients requiring central venous catheterization are often critically ill and therefore poor candidates for highly invasive surgery possibly involving sternotomy or a supraclavicular approach. Endovascular therapy offers a less invasive alternative compared with surgery and a safer approach compared with the "pull and pressure" method.

However, misplacement is not always recognized immediately. Shah et al (17) worked out three factors for delayed diagnosis of catheter misplacement: failure in differentiation of venous from arterial blood, failure in the interpretation of the chest radiograph, and initiation of infusion with a volumetric pump. They described three patients in whom intraarterial misplacement was not suspected and who, as a consequence, developed neurologic symptoms. In one of our patients, the catheter was introduced during resuscitation and therefore low blood pressure masked the arterial misplacement and failure in the interpretation of the chest radiograph and initiation of infusion with a volumetric pump led to cerebral air embolism and infarction.

Stent-grafts are a valuable tool for endovascular repair of inadvertent subclavian artery injury. Technical success rates have been reported to range from 94% to 100%, with procedure-related complications between rates 0% and 22% (15). However, despite excellent results reported in the literature and our own experience, stent-graft treatment of the subclavian artery is not without risks, including the potential for thromboembolism in cerebral arteries during intervention (15,18), intimal hyperplasia within the stent-graft leading to diminished blood flow to the arm in the area between the clavicle and the first rib (15,19), and injury of the brachial artery during device insertion (18–21). Furthermore, if the origin of the vertebral artery has to be covered by the stent-graft, the patency of the contralateral vertebral artery must be confirmed to avoid neurologica complications.

Another issue with stent-grafting is prolonged anticoagulation to ensure patency of the stent-graft, which is obviated by the use of balloon catheters or arterial closure devices. There are almost no reports on patency after stent-graft repair of subclavian artery injuries caused by misplaced catheters. In a long-term study, du Toit et al (22), who did not administer short- or long-term antiplatelet therapy, reported significant stent-graft stenosis or occlusion in eight of 25 patients (32%) after the repair of subclavian artery injuries. In our series, we prescribed lifelong antiplatelet therapy and none of our patients developed clinical symptoms of stenosis.

Temporary balloon tamponade of the subclavian artery is still an effective and safe technique in the management of inadvertent subclavian artery catheterization (5), especially in cases in which the use of an arterial closure device is contraindicated, such as perforation of both arterial walls (as seen in two of our patients) or when its deployment is not successful.

Alexander et al reported four cases of successful balloon tamponade performed for arterial misplacement of subclavian venous catheters. They used noncompliant balloons in three cases and a compliant balloon in one. One of those three patients in whom noncompliant balloons were used required three 15-minute sessions of balloon inflation and one change to a larger balloon to seal the injury. Moreover, a non–flow- limiting small dissection was detected after the procedure. However, no problems were encountered in the other two patients.

In the present series, balloon tamponade was performed in seven patients and three of them required additional stent-graft placement. One of these three patients was treated by a compliant balloon and two were treated by a noncompliant balloon. We do not know exactly why balloon tamponade did not succeed in these two patients. Retrospectively, we think that, in one of them, the failure may have been caused by the complexity of the injury to the subclavian artery. However, in both patients, the use of the hard, noncompliant balloon catheters may also have contributed to the failure. In our view, compliant balloons are generally better suited for endovascular repair of arterial injuries because they adapt to the contour of the vessel and reduce stress to the vessel wall. However, they are too short to cover two puncture sites simultaneously when the distance between them is 2 cm or more. Based on our experience, we now think that primary stent-graft insertion seems to be the best solution when both arterial walls are perforated and the distance between the puncture sites is too long to use a compliant balloon. After balloon tamponade has failed, stent-graft insertion is the only option to seal the puncture site because the use of arterial closure devices is no longer possible as soon as the misplaced catheter has been removed.

In recent years, the use of arterial closure devices has been emerging as a safe and effective approach to the repair of inadvertent arterial cannulation, provided the misplaced catheter is left in situ. However, repair by an arterial closure device is contraindicated when both walls of the artery have been perforated by the catheter, as seen in two of our patients. This may remain unrecognized on preinterventional chest radiographs, and therefore careful diagnostic angiography is mandatory before an arterial closure device is used (23).

Arterial closure devices are available in various designs, including suture-mediated (Perclose; Abbott Laboratories, Abbott Park, Illinois) and plug-mediated devices (Angio-Seal; St. Jude Medical). Each of these devices has its own advantages and disadvantages depending on the site and the size of the arteriotomy that has to be closed and on the patient's coagulation status. With experience in its use, the Angio-Seal device is associated with a high technical success rate by immediate hemostasis without manual compression. Therefore, it is a good solution in the subclavian artery, where effective compression is difficult to achieve (24). Nicholson at al (5) reported successful Angio-Seal device deployment in four patients who were referred with in situ subclavian artery catheters. None of the patients developed any complications and all recovered without long-term sequelae. Dowling et al (25) and Railo et al (26) reported successful use of the Angio-Seal device for the repair of a subclavian artery injury after misplacement of an 11-F hemodialysis catheter. Kirkwood et al (24) also reported successful use of the Angio-Seal device for the repair of an inadvertent subclavian artery puncture in a patient with severe congestive heart failure.

We used the Angio-Seal device in six patients and only one of them required secondary stent-graft placement as a re-

sult of stenosis caused by a localized dissection of the subclavian artery.

Although complications are rare, several risks have been associated with the use of the Angio-Seal device. Kadner et al (27) reported complete occlusion of the femoral artery in seven of 1,600 patients (0.4%). Other authors (28–33) reported foreign body infection, distal embolization, and ischemia secondary to dislodgment of the intravascular component. Therefore, the Angio-Seal device is not recommended for use in the carotid artery. None of our patients developed any of these previously reported complications.

Limitations to this study prevent us from drawing final conclusions. First, it was not a prospective, controlled, randomized study, and second, our sample size was small. Therefore, results of further studies including larger patient cohorts will be of great interest.

In conclusion, endovascular techniques offer a less invasive alternative to surgery in the treatment of inadvertent subclavian artery catheterization. Our limited experience shows that the use of the Angio-Seal device is effective but not without risks, whereas balloon tamponade is not always reliable in closing the puncture site. Stent-graft placement may be required in those patients in whom balloon tamponade fails or in whom the use of Angio-Seal device is contraindicated or leads to stenotic complications. Further studies will be required to determine the optimum solution.

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