Endovascular management of inadvertent brachiocephalic arterial catheterization

Clinical article

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Object. Inadvertent catheterization of brachiocephalic arteries (carotid artery, subclavian artery, or vertebral artery) during attempted placement of a central venous catheter can have potentially disastrous complications. While removal of the catheter in the operating room is almost always an option, there are circumstances in which a less invasive approach may be more appropriate. The authors present their experience using endovascular techniques for removal of inadvertently placed central venous catheters to elucidate potential options for successful nonsurgical management.

Methods. The authors reviewed their database of interventional procedures that occurred between January 1, 2000, and February 1, 2009. All cases referred for management of suspected brachiocephalic arterial catheterization or arterial injury after attempted placement of a central venous catheter were included. Medical records and radiological imaging were reviewed to determine patient demographics, clinical situation, methods for removal, as well as clinical and imaging follow-up.

Results. A total of 13 patients, ranging in age from 31 to 88 years old, were referred to interventional radiology for management of suspected inadvertent arterial catheterization of the brachiocephalic arteries. Angiography confirmed arterial catheterization in 9 patients. Three patients were referred after developing uncontrolled hemorrhage or expanding hematomas following attempted catheterization. One patient who had an arterial waveform after placement of an internal jugular catheter was found to have early venous filling from a dialysis fistula requiring no intervention. Ten patients were treated in the interventional suite using angiographically monitored manual pressure (1 patient), balloon tamponade (3 patients), use of a percutaneous closure device (1 patient), stent grafting (4 patients), or embolization of the injured vessel alone (1 patient). One patient was taken to the operating room for removal of the inadvertently placed catheter due to vessel thrombosis. No procedural complications were encountered, and no patient required sacrifice of a major brachiocephalic vessel.

Conclusions. Angiographic evaluation of patients who underwent inadvertent catheterization of brachiocephalic arteries or their branches allowed successful endovascular treatment or excluded the need for intervention in 12 (92%) of 13 patients. The choice and use of specific endovascular techniques should be dictated by patient factors and the vessel inadvertently catheterized. (DOI: 10.3171/2009.10.JNS099940)

Key Words • central venous catheterization • inadvertent arterial injury • carotid angiography • subclavian artery angiography • brachiocephalic artery

Percutaneous placement of a central venous catheter is a common procedure performed for monitoring of vascular status as well as infusion of medications and volume resuscitation. Whereas inadvertent puncture of an artery is generally benign if immediately recognized, placement of a large-bore catheter can have potentially disastrous complications. This is particularly true with catheterization of brachiocephalic arteries (CA, SA, or VA) due to the risks of stroke, airway compromise, and hemothorax. The management of inadvertent brachiocephalic arterial catheterization depends in part on patient factors such as general medical condition or bleeding diathesis, as well as the vessel catheterized. A recent review of the treatment of 13 patients with inadvertent brachiocephalic arterial catheterization found that in those patients in whom the catheters were removed and the site compressed, the risk of hematoma, airway obstruction, stroke, or pseudoaneurysm was 100%. 3 The authors of that study advocated surgical exploration for all inadvertent arterial catheterizations without consideration of endovascular options. However, a number of successful endovascular techniques for dealing with this urgent problem have been published for the most part as case reports, including our own report of the successful management of an inadvertent arterial puncture at the VA-SA junction. 13 In this paper we describe the utility of routine catheter angiography for this condition and de-
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scribe the various methods we have used in the management of these complications.

Methods

After obtaining approval from our institutional review board to perform the study, our database of interventional procedures was reviewed for those that occurred between January 1, 2000, and February 1, 2009. Cases were included if they were referred for management of suspected arterial catheterization or arterial injury after attempted placement of internal jugular or subclavian central venous catheters. The electronic medical records of these cases were reviewed for demographic data, medical history, clinical status at the time of attempted central venous catheterization, and hospital course following the interventional procedure. Relevant imaging was also collected.

A total of 13 patients were taken to the interventional suite for management of suspected inadvertent brachiocephalic arterial injury from attempted placement of a central venous catheter (Table 1). There were 6 women and 7 men, ranging in age from 31 to 88 years. Patients had a variety of medical conditions including CAD (4 patients), cardiomyopathy (2 patients), Type 2 DM (3 patients), ESRD (2 patients), and pneumonia (2 patients). Central venous catheterization was attempted in the ICU (9 patients), the operating room (2 patients) and the emergency department (2 patients). Arterial catheterization or arterial injury was suspected because of the presence of an arterial waveform transduced from the catheter (6 patients), an abnormal postprocedure chest radiograph (5 patients), or the presence of a hematoma (2 patients).

All procedures were performed from a right common femoral artery approach. Arch aortography was performed in most patients, followed by selective catheterization of the vessel suspected of injury or containing the central venous catheter in all patients. Anticoagulation was not routinely performed, although 1 patient (Case 6) with an inadvertent CA catheterization had been placed on a heparin infusion by the primary team. When an abnormality was noted on angiography, 5 possible endovascular treatment options were considered: manual pressure alone, temporary balloon occlusion for tamponade, use of a percutaneous closure device, placement of a covered stent, and vessel occlusion. Possible treatment options including surgery were discussed with the clinical team prior to proceeding.

Manual pressure (Fig. 1) was considered if the artery was amenable to compression, which essentially consists of the CCA and theoretically branches of brachiocephalic vessels positioned such that complete manual occlusion of the artery is nearly assured. Temporary balloon occlusion (Fig. 2) was performed with an 8.5-mm standard occlusion balloon (Boston Scientific) placed at or just proximal to the site of arterial (subclavian) injury (catheter insertion site). The balloon was inflated to completely occlude flow based on injection of contrast material through the occlusion balloon catheter lumen. The balloon was left inflated for 15 to 20 minutes with evaluation via angiography through the catheter lumen after deflation of the balloon.

A percutaneous closure device was chosen for a single case (Case 5; Fig. 3). The device chosen (Starclose, Abbott) was used at the discretion of the interventionist. As with manual compression, placement of the device and successful hemostasis was monitored using angiography from the femorally placed angiographic catheter. Placement of a covered stent (Fig. 4) was performed across the area of vessel injury (catheter insertion site) in the standard fashion and consisted of iCast covered stents (Atrium Medical Corporation) in 2 cases (5 × 20 mm and 6 × 16 mm in Case 6; 7 × 22 mm in Case 7), a Fluency Plus tracheobronchial stent graft (C.R. Bard) in 1 case (10 × 40 mm in Case 8) and a WallGraft endoprosthesis (Boston Scientific) in 1 case (12 × 30 mm in Case 10). These stents were placed into the CA in 1 case and the SA in 3 cases. Injury to branches of the brachiocephalic vessels (Fig. 5) occurred in 2 cases and the VA and a muscular branch of the axillary artery were sacrificed using electrolytically detachable coils (Boston Scientific). Complete vessel occlusion was obtained in both cases.

Results

Arterial catheterization was confirmed by angiography in 9 patients (involving 6 SAs and 3 CAs). Three patients (Cases 10, 11, and 12; Table 1) were referred for angiographic evaluation after developing uncontrolled hemorrhage or expanding hematomas after attempted catheter placement or removal at the bedside. In 1 patient (Case 10) the catheter had been removed at the bedside and the patient was only brought to the interventional suite after manual pressure failed to control the bleeding. In another patient (Case 11), a large axillary hematoma developed after attempted subclavian vein catheterization from injury to a distal axillary artery muscular branch. Another patient (Case 12) also developed an expanding hematoma after attempted subclavian vein catheterization but no arterial injury was found on angiography. Finally, 1 patient (Case 13) who had an arterial waveform after placement of an internal jugular catheter was found to have early filling of her venous system from an ipsilateral arm dialysis fistula and required no therapy.

Of the 10 patients in whom an inadvertent catheter or vessel abnormality was found, 9 underwent endovascular measures. Successful treatment for the 9 inadvertent arterial catheterizations included manual pressure (1 patient), temporary balloon tamponade from within the injured artery (3 patients), use of a percutaneous closure device (1 patient), and placement of a covered stent within the injured artery (4 patients). The tenth patient (Case 9) was taken to the operating room because of extensive thrombus around the catheter, where open thrombectomy and primary repair of the arteriotomy was performed. In the patient (Case 10) who developed uncontrolled hemorrhage after removal of the catheter at the bedside, covered stent placement was performed. Embolization of an injured vessel was performed in 2 patients (Cases 8 and 11), one of whom (Case 8) also underwent placement of a covered stent.
Case 1. Images obtained in a 69-year-old man undergoing chemotherapy treatment for lymphoma who underwent attempted placement of a 7 Fr triple lumen catheter in the left IJV. Suspicion was raised regarding arterial catheterization when it was noted that the catheter transduced an arterial pressure waveform. 

A: A DS midarterial aortogram (left anterior oblique projection) revealed the attempted left IJV catheter within the left CCA (arrow), entering just below the carotid bifurcation. There was no thrombus associated with the catheter. 

B: The decision was made to remove the catheter and hold manual pressure. The unsubtracted midarterial left CCA arteriogram (AP projection) revealed active contrast material extravasation from the site of the arteriotomy (arrow) because manual compression (arrowhead) was too high. 

C: Manual compression was adjusted and the unsubtracted midarterial left CCA arteriogram (AP projection) revealed no contrast material extravasation (arrow). Doppler ultrasonography performed the next day showed no evidence of intimal flap and the patient remained at his neurological baseline level.

Case 2. Images obtained in a 76-year-old woman with a recent non-ST elevation myocardial infarction who underwent attempted placement of an 8 Fr single lumen catheter in the right IJV. The subsequent chest radiograph was concerning for arterial catheterization. 

A: A DS midarterial right SA arteriogram (right anterior oblique projection) revealed the attempted venous catheter entering the SA (arrow) approximately 1 cm distal to the origin of the right VA (arrowhead). 

B: An occlusion balloon was positioned within the SA at the puncture site and the single lumen catheter removed. A DS midarterial brachiocephalic artery arteriogram (AP projection) obtained during balloon inflation (arrow) revealed patency of the VA (arrowhead) and no extravasation of contrast material. 

C: After 15 minutes of balloon occlusion, a DS late arterial brachiocephalic artery arteriogram (AP projection) revealed no intimal injury or extravasation of contrast material. The patient remained neurologically normal and MR imaging of the brain 10 days later showed no evidence of posterior circulation infarction.
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Patients were followed up for between 2 days and 2 months with no sequelae noted. No complications of the endovascular procedure were encountered.

Discussion

The true incidence of inadvertent catheterization of the CAs, SAs, or VAs during attempted central venous catheterization is unknown. Whereas an arterial puncture is usually recognized before dilation and catheterization, given a particular patient’s clinical status (such as hypotension, decompensated CHF, and others) it is understandable that a catheter may be placed inadvertently.

Fig. 3. Case 5. Images obtained in a 38-year-old woman with aneurysmal subarachnoid hemorrhage who underwent attempted placement of a 7 Fr triple lumen catheter in the left subclavian vein. The subsequent chest radiograph revealed a left pneumothorax and was concerning for arterial catheterization. **Left:** An unsubtracted midarterial left SA arteriogram (right anterior oblique projection) revealed the attempted left subclavian venous catheter within the left SA (arrow) entering approximately 3 cm distal to the origin of the VA. **Right:** The triple lumen catheter was removed over a wire and a percutaneous closure device was used to close the arteriotomy. Seven days later, a DS midarterial left SA arteriogram (right anterior oblique projection) revealed the percutaneous closure device (arrow) with no evidence of contrast material extravasation. The patient had an otherwise unremarkable recovery and was discharged home after 21 days in the hospital.

Fig. 4. Case 6. Images obtained in a 65-year-old man with pneumonia who underwent attempted placement of a 7 Fr triple lumen catheter in the right IJV. There was immediate concern for arterial catheterization given the pulsatile nature of the blood return. **Left:** A DS midarterial right CCA arteriogram (right anterior oblique projection) revealed the attempted right IJV catheter within the right CCA (arrow) approximately 4 cm from its origin. **Right:** Two balloon-expandable covered stents were placed in the proximal right CCA after removal of the triple lumen catheter. The poststent-placement magnified unsubtracted digital midarterial right CCA arteriogram (right anterior oblique projection) revealed a fistula (arrow) between the right CCA and the right IJV (arrowheads). Cerebral angiography revealed no evidence of thromboembolism and Doppler ultrasonography performed 4 hours later showed no evidence of fistulous flow. The patient was discharged home after 10 days in the hospital.
in an artery. While records are maintained for central vene-
sous catheter placement, we do not know how often arte-
rial puncture or catheterization is recognized, the catheter
removed, and hemostasis obtained with manual pressure
before successful placement of the line into the venous
system. The cases that have come to our attention are the
ones that the clinical team have recognized and sought
the aid of vascular and endovascular surgeons. As such, it
is extremely difficult to design a study comparing the var-
ious means of managing inadvertent brachiocephalic ar-
terial catheterization. Consequently, in this paper we have
only sought to describe a variety of clinical scenarios of
inadvertent brachiocephalic arterial catheterization and
how these cases were managed by endovascular means.

Patients did not undergo noninvasive imaging such as CT
or ultrasonography prior to angiography. Such im-
aging may have obviated the need for angiography in 2
patients. Certainly, the patient in Case 13 would have not
been subjected to angiography to confirm venous catheter
placement proximal to a functioning dialysis graft. This
patient, however, closely followed a case of another inad-
vertent arterial placement of a triple lumen catheter from
the same ICU, had a concomitant history of decreasing
hematocrit after catheter placement, and placement was
performed as an emergency late-night procedure. Non-
invasive imaging may have also negated angiography for
Case 9 with SA thrombosis, opting instead for immedi-
ate surgery. However, this option was discussed with the
vascular surgery team prior to the procedure and we all
agreed to proceed initially with diagnostic angiography
while allowing for possible endovascular therapy, know-
ning that as with all cases surgery may be a better option
once angiography is obtained.

We do not recommend simply removing an inad-
vertent arterial catheter and holding pressure outside the
confines of the interventional suite. We are aware anec-
dotally of several cases at our center in which significant
patient morbidity and even death have resulted. Although
it is readily apparent where the catheter enters the skin,
it is unknown where the catheter enters the artery or, for
that matter, which artery is catheterized. Taking the pa-
tient directly to the operating room for open exploration,
catheter removal, and direct vessel repair may always be
considered. However, the patient’s hemodynamic stabil-
ity and the suspected vessel injury may warrant catheter
angiography and potential endovascular intervention.
This is particularly true in relatively surgically inacces-
sible regions such as the SAs and CAs within the chest
and the VA.

Once catheter angiography has confirmed inadvertent
arterial catheterization, there are several options. If the
catheter enters at an easily compressible site (for example,
the distal CCA), the patient’s airway is secure, and there
are reasonable coagulation parameters, it is reasonable to
consider removing the catheter and holding manual pres-
sure. However, we recommend this be undertaken in the
interventional suite using angiographic monitoring, where
additional endovascular means are readily available, and
the patient can be closely monitored. Intermittent angiog-
raphy during manual compression allows for compression
directly at the arterial puncture site and reassurance that
extravasation is not occurring. The duration of manual
compression depends on the size of the catheter and any
coagulopathy, platelet dysfunction, or other bleeding
diathesis. In the event that manual compression is inade-
quate, balloon tamponade of the bleeding point may be
performed either alone or as a transition to covered stent
placement.

Several authors have described successful manage-
ment of inadvertent brachiocephalic arterial catheteriza-
tion with percutaneous closure devices. Suture-mediated
(Perclose, Abbott) and collagen-plug mediated (Angio-
Seal, St. Jude Medical) devices have been described in
the treatment of inadvertent SA catheterization, whereas
a temporary vessel tamponade device (Boomerang, Car-
diva Medical) has been described for CA catheterization.
Although diagnostic catheter angiography was not used
in some of these circumstances to determine which vessel

![Image](image_url)
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had been inadvertently catheterized, it is very important to determine which vessel is injured prior to attempting percutaneous closure and we recommend such closure be performed in the interventional suite. As mentioned above, the injured vessel may not be readily apparent based solely on where the catheter enters the skin. We do not recommend use of a percutaneous closure device with catheterization of the CAs or VAs due to the potential risk of vessel stenosis or thromboembolism. Additionally, it is prudent to be prepared for stent placement and/or temporary balloon tamponade before deploying the percutaneous closure device.

The placement of a covered stent at the site of inadvertent arterial catheterization is a very attractive management option for interventionalists. We are very comfortable with their placement and it results for the most part in immediate puncture site hemostasis. Successful stent placement has been described by others for the treatment of inadvertent arterial catheterization in the setting of a catheter in situ, hemorrhage, or failure of a vascular closure device. Stent placement as a first-line treatment may be reasonable in situations in which the patient is at high risk for hematoma if only manual compression is used (such as SA puncture or bleeding diathesis) or if the airway is not secured. In cases of SA puncture it is important to keep in mind the proximity of the VA origin as it may not be possible to cover the site of injury without also covering the VA origin. Temporary balloon tamponade with or without stent placement may also be an option if attempted manual compression is inadequate in preventing the development of a hematoma. We routinely recommend 6 weeks of treatment with oral clopidogrel and life-long treatment with oral aspirin following covered stent placement in the CAs or SAs because thrombosis has been reported.

Finally, depending on the injured vessel, embolization may be a reasonable treatment option. This approach has been described by others for injury to the internal thoracic artery during attempted subclavian vein catheterization. We have described this option for injury at the origin of the nondominant VA and performed embolization of a bleeding distal axillary artery muscular

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Comorbidities</th>
<th>Care Unit</th>
<th>Vein</th>
<th>Artery</th>
<th>Endovascular Procedure†</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>69, M</td>
<td>lymphoma, ARF, AF, DM</td>
<td>ICU</td>
<td>lt IJV</td>
<td>lt CCA</td>
<td>manual pressure</td>
<td>discharged to SNF after 24 days</td>
</tr>
<tr>
<td>2</td>
<td>76, F</td>
<td>CAD, ESRD, DM, AF</td>
<td>ICU</td>
<td>rt IJV</td>
<td>rt SA</td>
<td>balloon tamponade</td>
<td>discharged home after 10 days</td>
</tr>
<tr>
<td>3</td>
<td>79, M</td>
<td>lung cancer</td>
<td>ICU</td>
<td>rt subclavian</td>
<td>rt SA</td>
<td>balloon tamponade</td>
<td>terminal extubation after 2 months</td>
</tr>
<tr>
<td>4</td>
<td>61, F</td>
<td>CAD, AVR, TCC of bladder</td>
<td>OR</td>
<td>lt subclavian</td>
<td>lt CCA</td>
<td>balloon tamponade</td>
<td>discharged home after 3 days</td>
</tr>
<tr>
<td>5</td>
<td>38, F</td>
<td>aneurysmal SAH</td>
<td>ICU</td>
<td>lt subclavian</td>
<td>lt SA</td>
<td>percutaneous closure device</td>
<td>discharged home after 21 days</td>
</tr>
<tr>
<td>6</td>
<td>65, M</td>
<td>CAD, CHF, pneumonia</td>
<td>ICU</td>
<td>rt IJV</td>
<td>rt CCA</td>
<td>covered stent</td>
<td>discharged home after 10 days</td>
</tr>
<tr>
<td>7</td>
<td>78, M</td>
<td>Parkinson disease, CAD</td>
<td>ED</td>
<td>rt IJV</td>
<td>rt SA</td>
<td>covered stent</td>
<td>terminal extubation after 2 days</td>
</tr>
<tr>
<td>8</td>
<td>36, M</td>
<td>cardiomyopathy, CHF</td>
<td>ICU</td>
<td>rt IJV</td>
<td>rt SA</td>
<td>covered stent and VA coiled</td>
<td>discharged home after 14 days</td>
</tr>
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<td>9</td>
<td>66, M</td>
<td>cervical intradural, meningioma</td>
<td>OR</td>
<td>lt subclavian</td>
<td>lt SA</td>
<td>surgery</td>
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</tr>
<tr>
<td>10</td>
<td>84, F</td>
<td>ischemic, cardiomyopathy, AF</td>
<td>ED</td>
<td>rt subclavian</td>
<td>rt SA</td>
<td>covered stent</td>
<td>discharged to LTAC after 18 days</td>
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<tr>
<td>11</td>
<td>88, M</td>
<td>sigmoid volvulus, pneumonia</td>
<td>ICU</td>
<td>rt subclavian</td>
<td>rt axillary branch</td>
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<td>terminal extubation after 21 days</td>
</tr>
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<td>12</td>
<td>69, F</td>
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<td>ICU</td>
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<td>no injury</td>
<td>none</td>
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</tr>
<tr>
<td>13</td>
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<td>lupus, ESRD s/p OKT</td>
<td>ICU</td>
<td>lt IJV</td>
<td>none</td>
<td>none</td>
<td>discharged home after 8 days</td>
</tr>
</tbody>
</table>

* AF = atrial fibrillation; ARF = acute renal failure; AVR = aortic valve replacement; COPD = chronic obstructive pulmonary disease; ED = emergency department; LTAC = long-term acute care facility; OKT = orthotopic kidney transplant; OR = operating room; s/p = status post; SAH = subarachnoid hemorrhage; SNF = skilled nursing facility; TCC = transitional cell carcinoma.
† All patients underwent attempted placement of a triple lumen catheter except Case 2, who underwent placement of an 8 Fr single lumen catheter
branch for a patient in this series (Case 11). Proximal VA occlusion is often well tolerated as is occlusion of other branches of the SA and external CA. Occlusion of the CCA is also an option of last resort, but should only be considered when there are no other endovascular and/or open surgical options.

We did not have to sacrifice any of the major brachiocephalic arteries. Occlusion of the SA could certainly be undertaken if the clinical scenario warranted, but may require occlusion at or distal to the VA, thereby losing important collateral flow. Such occlusion is usually not symptomatic, although upper extremity ischemia may occur, requiring revascularization.15 Sacrifice of the CCA is tolerated in approximately 70% of patients based on the Cooperative Study of Intracranial Aneurysms and Subarachnoid Hemorrhage.8 However, collateral supply both intracranially via the circle of Willis and extracranially to the ipsilateral external CA should be carefully evaluated using angiography. Formal balloon test occlusion should be undertaken if the clinical situation allows and would be essential if any question exists regarding adequacy of the collateral supply.

Our study is limited by the sample size and its retrospective nature. Regarding the number of patients in the study, although it is one of the larger case series published to date, our overall study population size remains small. As noted previously, we do not know the number of inadvertent brachiocephalic arterial catheterizations that occur and are removed without difficulty. Even though we used a variety of treatment options that provide a good example for publication, they were chosen by the attending interventionist based on the patient and his or her particular clinical situation. Although this is certainly sound practice medically, it makes reporting unsystematic.

Conclusions

Inadvertent brachiocephalic arterial catheterization during attempted central venous catheterization of the IJV or subclavian vein may have catastrophic consequences. Once such an event has occurred, prompt intervention is warranted. Open surgical exploration and repair is a very reasonable plan in almost every circumstance. However, in circumstances in which a patient may not tolerate general anesthesia or if the suspected puncture site is relatively surgically inaccessible, catheter angiography allows for a variety of management options. In this case series we have described the effective use of manual pressure, the use of percutaneous closure devices, stenting of the injured vessel, and coil embolization of the injured vessel. The use of any of these options is dictated by patient factors such as general medical condition, airway status, bleeding diathesis, and others, and the vessel that has been inadvertently catheterized. We do not believe that there is one right answer for inadvertent brachiocephalic arterial catheterization, rather that there are many options that must be tailored to the particular patient’s circumstance.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings described in this paper.

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