

Overview of Vascular Closure

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This year's overview of vascular access and closure includes a summary of the vascular closure device (VCD) world overall, a commentary on the past year's platform changes by the already established manufacturers, and the status of new devices under development. As in the 3 previous years that I have had the opportunity to write this article, I have taken the liberty of commenting on other issues relevant to vascular access and closure. Last year, I emphasized a classification system to help make sense of the burgeoning devices and device concepts (Table 1), discussed the persistent high rate of vascular access and closure complications, and presented details of our fluoroscopic-guided approach to optimize vascular access. This year, I would like to comment on the increasing number of patients who undergo repeated instrumentation for endovascular procedures and on the learning curve associated with vascular closure. I will discuss several articles in the literature that provide insight into the persistent, and persistently fatal problem of retroperitoneal bleeding. Despite my overall enthusiasm for VCDs, I would like to again point out that the definitive word on vascular closure remains elusive. The genie has already escaped from the bottle—VCD use continues to grow, despite absence of a clearly compelling risk/benefit ratio. Each device, no matter how clever or easy to use, has potential drawbacks. In the interest of balance, I have tried to highlight these drawbacks. I also believe much more needs to be done to improve on the Achilles' heel of all endovascular procedures: less-than-optimal technique for vascular access and postprocedure access site management.

THE CLOSURE DEVICE MARKET

By most estimates, the VCD market is now a half billion dollars worldwide (Figure 1). Once classified as niche products, the persistent growth of VCDs has attracted the interest of progressively larger device companies (those without a closure device already in their portfolio appear to be actively looking at either existing technologies or developing them in-house), which in turn has

TABLE 1. CLASSIFICATION SYSTEM OF CLOSURE DEVICES

Glossary for closure device subclassification:

1. Invasive (I) or Noninvasive (N)
2. Active approximation (A) or Passive (P)
[For active approximation: Intraluminal (IL) vs Extraluminal (E)]
3. Clot inducing (C), Sealant (S), or neither (0)
4. Permanent (P), temporary (T), or no foreign body (0)

Thus, Angio-Seal would be classified as I-A-(IL)-C-T because it is placed inside the tissue track, actively approximates the vessel edges, leaves an intraluminal foreign body behind, incorporates collagen for thrombosis, and leaves behind a resorbable foreign body. Perclose is I-A-(IL)-0-P, StarClose and AngioLink are I-A-(E)-0-P, Duett is I-P-C-0, and Boomerang is I-P-0-0.

stimulated smaller start-up companies. Estimates for annual coronary and peripheral diagnostic and interventional procedures worldwide range widely from 8 to 13 million, and are influenced by inclusion of nonfemoral arterial access. Well over 3 million patients undergo VCD deployment, with more than 80% of closure device use occurring in the US.

The growth in vascular closure continues to exceed the steady rise in endovascular procedures. Thus, the percentage of patients undergoing closure has increased by most estimates. Interestingly, the majority of closure device use in the US remains focused on diagnostic catheterization, whereas overseas it is primarily reserved for intervention. As with much of the medical device market, the widest adoption has been in the US, where 40% to 50% of diagnostic and interventional patients undergo vascular closure, which is substantially higher than in Europe, which dwarfs Japan and the rest of Asia. Use of closure devices is relatively more common in coronary procedures than in

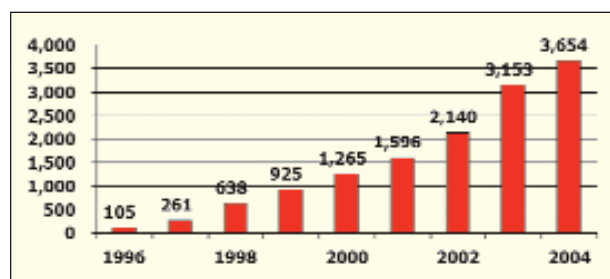


Figure 1. VCD sales in thousands worldwide. The estimated total annual number deployed will have passed 4 million this year. (Courtesy of Jeff Voigt, Medical Device Consultants, Ridgewood, NJ.)

peripheral procedures; however, it is significant (and appears to be growing) in both, particularly in the latter. Finally, the “invasive” devices outpace the “noninvasive” topical patches by a 4:1 ratio (we used a different nomenclature, “deep” and “surface,” respectively, last year): this ratio is much lower for diagnostic angiography alone. The reasons for the latter are severalfold: invasive devices are considered more effective for the more aggressive anticoagulation and antiplatelet environment associated with interventions, and cost considerations for the lower reimbursement diagnostic cases make the use of the less-expensive, noninvasive devices appealing. Invasive devices are in the \$200 or greater range, whereas noninvasive devices typically are one quarter the cost. Of the initial four invasive devices available since the 1990s, AngioSeal (St. Jude Medical, St. Paul, MN) continues to dominate the market, whereas Perclose (Abbott Vascular Devices, Redwood City, CA) is second, and VasoSeal (Datascope, Montvale, NJ) is a distant third followed by the Duett (Vascular Solutions, Minneapolis, MN). Of the topical devices, the Syvek patch (Marine Polymer Technologies, Tewksbury, MA) and D-Stat Dry (Vascular Solutions) appear to be dominating the market, with significant penetration by Chito-Seal (Abbott) and Closur-Pad (Medtronic, Santa Rosa, CA), along with the appearance of Stasys (St. Jude Medical) and Neptune (TZ Medical, Portland, OR).

The classification scheme (Table 1) introduced last year separated the invasive VCDs further to (1) differentiate those that worked by active approximation of the arteriotomy edges versus passive placement on top of the arterial surface, (2) those that incorporated a thrombosing or sealing agent versus those that did not, and (3) those that left behind a temporary or permanent foreign body versus those that did not. In this update, I will add one other differentiating element to further categorize devices that are invasive, active approximators, and leave behind a foreign body in the arterial wall—“intraluminal” (such as

Angio-Seal and Perclose, which leave a footplate and suture respectively inside the artery), or “extraluminal” (such as the new percutaneous metallic arterial closure [PMAC] devices that are designed to penetrate the arterial wall but not to be exposed inside the vessel itself).

EVOLVING TECHNOLOGIES

A number of platform changes or additions were introduced by the existing device manufacturers—in the PMAC category, Abbott introduced StarClose (a nitinol clip device) and Medtronic introduced AngioLink (a titanium staple). Both are designed to approximate the arteriotomy edges without leaving a foreign body within the arterial lumen. Otherwise, both devices share the same classification as Perclose, inasmuch as they leave behind a permanent foreign body and do not incorporate a thrombosing or sealing agent. A number of potentially important differences between the PMACs may have some bearing on the ultimate role of these devices, but a direct comparison has not been performed.

The StarClose device, currently FDA approved for diagnostic catheterization, has had extensive use overseas. The existing data for StarClose demonstrate the usual findings for this class of devices: early hemostasis, ambulation, and hospital discharge, and a good overall success rate, although the study included physicians early in their learning curve. Generic to the I-A-0 class of devices is a predisposition for residual tissue track oozing in fully anticoagulated patients. StarClose upsizes the tissue track to 12 F—if oozing does occur, several measures can be helpful: light manual pressure, topical anesthesia using lidocaine with epinephrine, or a noninvasive patch, although additional compression alone is usually effective. Nicking the skin and dilating the tissue track at the beginning of the catheterization may prevent oozing after device deployment.

The AngioLink device, FDA-approved last year for both diagnostic and interventional cases, has yet to be released by Medtronic, apparently because of manufacturing considerations. The titanium staple device was also subjected to a randomized trial, with similar overall results to those described for StarClose. There were several study differences: interventional results were included in the published series, sheath sizes of up to 8 F were allowed, and arterial punctures outside the common femoral artery were not excluded. Thus, the device has been touted as appropriate for closure of the bifurcation vessels. The evidence base, however, is quite thin, and I believe operators would be well served to avoid this “indication” until efficacy and safety are convincingly demonstrated. Similar considerations apply to use in patients with more than mild peripheral vascular disease. It should be noted that AngioLink upsizes the arteriotomy to 10 F, a theoretical concern that may or may not have impor-

tance once the device is established in clinical practice.

In general, leaving behind small metallic clips in the artery wall is a potential issue for both PMACs, although the evidence so far suggests that the ability to reintroduce sheaths into the artery is not significantly affected. In fact, an isolated case of inadvertent but benign introduction of sheaths *through* a StarClose device has been described, and bench studies in a porcine model are reported in the StarClose IFU. The PMAC devices leave relatively small footprints, so it remains to be seen whether this will be a practical concern.

St. Jude Medical introduced the VIP version of Angio-Seal. The design includes an increase in the size of the collagen footprint over the arterial wall (total amount of collagen remains the same) and a suture system that facilitates the tamping down of the collagen onto the arterial surface. Whether the changed collagen footprint further enhances hemostasis seems uncertain (the existing devices already had a high success rate), but this appears to be a design trend for other collagen and sealing devices. I remain concerned that any foreign body in the tissue track (collagen, suture, etc.) has the potential to increase the risk of infection because of the culture locus represented and the possibility of “wicking” open the tissue track.

Datascope revised its venerable VasoSeal platform in favor of the On-Site, incorporating a new locator system, a temporary disc inside the artery, their improved Elite collagen sponge, and a temporary retention clip to help maintain the sponge in place on top of the arteriotomy during the early postdeployment period. Although I believe the design improvements are useful, several considerations will need to be kept in mind. First, abandoning the old reverse J wire for location means that the minimal vessel size has increased from 4 mm to 5 mm, a factor in some patients with atherosclerotic disease in the common femoral artery or those with intrinsically small femoral arteries, most typically diabetic women. Because the On-Site device is entirely extra-arterial, it nevertheless may be particularly suitable for patients with peripheral vascular disease. The ACC-NCDR registry published in December 2005,¹ demonstrated a higher vascular complication rate than manual compression for the older VasoSeal design. Previous VasoSeal data, such as those published in the Nikolsky meta-analysis, compared VasoSeal in the large sheath/overaggressive anticoagulation era to closure devices deployed under much more favorable conditions.² The newer data still fit my conception that passive closure devices, such as VasoSeal, have a potential disadvantage in fully anticoagulated patients because they do not actively approximate the arteriotomy site.

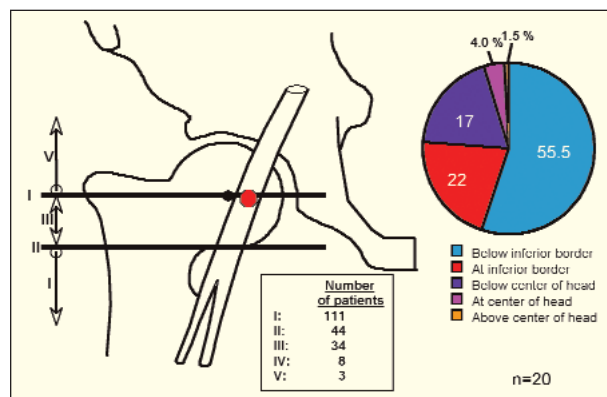


Figure 2. Distribution of location of femoral bifurcations based on analysis of 200 consecutive femoral angiograms in patients undergoing coronary angiography. The red circle denotes our current recommendation for puncture site of the femoral artery at or just slightly below a horizontal line drawn through the center of the femoral head. This should result in a <10% likelihood of sheath introduction into the bifurcation or one of the bifurcation vessels. Data reprinted with permission from Schnyder et al.⁵

These findings may be generic to the invasive-passive classification closure technologies, but results with the new On-Site system, as well as several competitors in the I-P category, will need to be examined.

Several devices are either in various stages of early release or are undergoing design changes. The former includes the Boomerang Closurewire (Cardiva Medical, Mountain View, CA), a device marketed in the US for diagnostic catheterization that tamponades the artery from inside the arterial lumen with a temporary disc that is recovered once coagulation has taken place at the arterial surface. The Superstitch (Sutura, Fountain Valley, CA) is a suture-based technology that has evolved to the Superstitch GW, a device that appears to facilitate the “Preclose” technique. Finally, the X-Site, previously acquired by Datascope, is a stitch closure device that is currently undergoing design changes.

TECHNOLOGY IN THE WORKS

SoundSeal (Therum Corporation, Seattle, WA), the most innovative of the vascular closure technologies, had a pivotal year. Along the lines of the concerns I described last year, the artificial intelligence on which the device is based has to adapt to the heterogeneous nature of tissue anatomy, including keeping the ultrasound beam focused on the arteriotomy during the sheath removal process. The company decided to change their platform to incorporate a locator system in a catheter inserted inside the artery. Whether this will affect the appeal of this still-revolution-



Figure 3. Right femoral angiograms in the left (A) and right (B) anterior oblique views of the same patient. The oval on the left depicts the sheath entry site; on the right, it depicts the location of the femoral bifurcation (about 5 mm lower). Arrows point to the inferior epigastric artery (IEA). The target for femoral puncture is quite small: above the bifurcation but below the inferior point of the IEA, a distance of <5 cm, on average. The ability to accurately strike this target is greatly enhanced by use of fluoroscopy. Adapted and reprinted with permission from Turi.⁶

ary technology, and whether other concerns can be addressed remain unknown.

A different approach for heating collagen is being pursued by Cardioidex (Tirat-Hacarmel, Israel); it combines the EpiClose system described last year with the addition of heat energy at the arteriotomy site delivered through the catheter. The original EpiClose was a double balloon; the distal portion was a temporarily placed locator inside the arteriotomy, which was deflated while the external balloon was used to compress the arteriotomy externally from inside the tissue track. Theoretically, the EpiClose Plus, like the SoundSeal device, will leave behind no foreign body, but will actively promote native arterial wall collagen sealing of the vessel. The issues for both SoundSeal and EpiClose Plus revolve around the following: Will the denatured collagen plug provide a seal as reliable as the currently available active approximator devices (Angio-Seal, Perclose, and StarClose)? Will the targeting schemes of the devices result in low single-digit failure rates to compare with current technology? Will the energy delivered to the arteriotomy site affect local nerve branches or cause thrombosis in adjacent vessels?

AccessClosure (Mountain View, CA) has also changed platforms, evolving from the Matrix VSG, a device that delivered a liquid polyethylene glycol hydrogel sealant to the arterial surface. The new platform incorporates a much-simplified method for delivering the sealant as a plug onto the arterial surface, using the existing proce-

dural sheath. Like the Elite and the Duett, it is a passive closure device, and its effectiveness in fully anticoagulated interventional patients will need to be demonstrated. Two other devices under development are a passive closure device using collagen rather than a sealant (Eclipse, Ensure Medical, Sunnyvale, CA) and a staple platform (X-Port, Cardica, Redwood City, CA).

FEMORAL PUNCTURE LOCATION

In last year's closure device update, an algorithm was presented for femoral puncture at an optimal site on the artery, and the use of fluoroscopy was emphasized. The association of imperfect access with subsequent complications is strong, whether manual compression or closure devices are used. The target is quite small, with the typical common femoral artery in the range of <5 cm in length from the inguinal ligament to the femoral bifurcation (Figure 2). Several studies published in the past year allow for expansion of our algorithm and are worthy of special mention. Farouque et al³ retrospectively analyzed 3,508 patients undergoing percutaneous coronary intervention and identified 26 patients with retroperitoneal hemorrhage (RPH), of whom one (4%) died of associated complications. Female gender, low body weight, and high sticks were independent predictors. Importantly, 45% of RPHs were associated with sticks "well below" the inguinal ligament. Sticks were considered high if they were over the upper third of the femoral head. Sherev et al⁴ reviewed 1,570 patients undergoing either diagnostic or interventional catheterization and identified six with RPH, all from the 702-patient subset undergoing intervention.

All six instances of RPH were associated with punctures that were either high over the femoral head over an area defined by the most inferior point of the IEA up to its origin (Figure 3), or above the origin of the IEA. The theme here is important: one need not puncture the external iliac artery to have a retroperitoneal bleed. In all likelihood, there is a propensity for extravasation back into the retroperitoneal space from sticks that are in the common femoral artery but within a few centimeters of the inguinal ligament. The two studies cited previously, and the clear association between poorly placed femoral punctures and complications after percutaneous coronary interventions have required a revision to the access algorithm, as shown in Table 2.

TABLE 2. RECOMMENDED ALGORITHM FOR OPTIMAL FEMORAL ACCESS

Identify bony landmarks by using fluoroscopic guidance prior to femoral puncture.

After insertion of needle subcutaneously, but just prior to actually puncturing the artery, remove hand from the field and repeat fluoroscopy to confirm needle position described in text, over the medial half of the femoral head, and at or below a horizontal line defining the “equator” of the femoral head (Figure 2).

Perform femoral angiography on every case, regardless of intention to use vascular closure device.

Perform femoral angiography prior to a coronary or peripheral intervention rather than at the end of the case. If the puncture is not in the common femoral artery, especially if it is high, abort the intervention if the case is elective. It is far easier to bring the patient back another day than deal with a high stick after anticoagulation and/or use of a IIb/IIIa inhibitor.

THE IMPLICATIONS OF REPEATED VASCULAR ACCESS: ADVENT OF THE VASCULAR “GRAND MULTIP”

We are beginning to see increasing numbers of patients who have had five, 10, or more procedures at the same access site. The typical manifestations are becoming familiar to most invasive cardiologists and interventional radiologists: diseased-appearing common femoral arteries and fibrotic tissue tracks with difficult access. Most catheterization laboratories are oriented for the convenience of right-handed operators, hence most access is via the right femoral artery. After three or four interventions, vascular access in the right femoral artery becomes increasingly problematic in some patients. Switching to the other side only delays the inevitable time when groin access becomes nonviable. On occasion, operators who feel uncomfortable with the radial or brachial approach are forced to attempt arm access. The time may come when we see increasing numbers of patients who undergo invasive procedures run out of access sites, much the same as the problem that dialysis patients now face. An increasingly important consideration with both access and closure will be to find methods that are least disruptive to the vessels being cannulated, and utilize closure techniques, whether manual compression or VCDs, that trigger the least vessel deformity and tissue track fibrosis. The influence of manual compression versus VCDs on this problem is unknown. It also remains to be learned how the healing process for the artery and for the surrounding tissue is influenced by the suture, collagen, sealing, and topical agents, and whether the extraluminal nature of PMACs

will decrease luminal deformity that in some patients seems to be progressive over multiple catheterizations. This is an important area of investigation; as repeated catheterizations for a variety of cardiac and endovascular procedures grow in frequency, leaving arteries in pristine condition will become an important issue.

THE LEARNING CURVE FOR VASCULAR CLOSURE

The learning curve for VCDs has been studied or indirectly noted in a number of publications. Two types of learning curves apply. One is generic learning in the use of vascular closure: patient selection, interpretation of preprocedure angiography, assessment of individual patients' body habitus, tissue tracks, and the clinical picture for suitability for device closure. Generic learning also includes periprocedure management of these patients. The second type of learning curve is device specific. High early failure rates (typically 10% to 15%) have been reported with the most commonly used closure devices. Significant subsequent improvement has occurred as individuals and institutions have adapted to the new technologies. Achieving low, stable failure rates may require 50 or more patients. Much of the literature on VCDs is contaminated by studies performed while investigators were in their learning curve with one or more closure devices. Further credence to the importance of the learning curve is lent by the finding in the previously referenced ACC-NCDR data¹ of twice the vascular complication rate in lower-volume institutions. The learning curve issue would suggest that operators would be wise to limit their use of VCDs to at most two technologies. ■

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