Currently Approved Vascular Closure Devices

A summary of the arterial closure devices that are currently available for clinical use in the United States.

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Vascular sheaths were introduced in the early 1980s to allow for repeated access into vessels while maintaining intraprocedural hemostasis and minimizing vessel trauma. This major advance was accompanied by the challenge of effecting arterial hemostasis after sheath removal. The initial method of hemostasis was manual compression. Manual compression is the US Food and Drug Administration (FDA) standard of care for hemostasis and remains the leading method of hemostasis today.

Vascular closure devices (VCDs) have been available in the United States since 1995, when the VasoSeal device (St. Jude, Medical, Inc., St. Paul, MN) was approved for diagnostic and interventional procedures. The next device to receive FDA approval was the Prostar XL device (Abbott Vascular, Santa, Clara, CA) (both 9 and 11 F) in 1997.[1] Since that time, numerous devices have been introduced, and the VCD market has experienced substantial growth. The global VCD market increased from just over $400 million in 2005 to approximately $825 million in 2010, with the United States receiving nearly 85% of the revenue and unit share.[2,3]

Despite this substantial market growth, it is estimated that only 38% of the approximated 9.6 million catheter-based procedures performed globally utilize VCDs.[2,3] Several reasons likely contribute to this, including (1) a lack of clear demonstrated benefit for VCDs in reducing bleeding and vascular complications when compared to manual compression, (2) the continued requirement for postprocedure bed rest, (3) complexity in device deployment often resulting in a long learning curve (a particular problem for low-volume operators), (4) cost, and (5) the increased utilization of transradial arterial access.

Although transradial access offers a solution to many of the previously mentioned problems, transfemoral access continues to be utilized in 30% to 50% of cases—even in very mature international transradial markets.[4] Despite these issues, future market growth for VCDs will likely be driven by two major factors: (1) the stated Centers for Medicare & Medicaid Services' objective for an increase in the number of outpatient percutaneous coronary intervention (PCI) procedures, which will necessitate safe and early ambulation, and (2) the growth of large-device procedures (eg, endovascular aneurysm repair and transcatheter aortic valve replacement) and the desire to avoid arterial cut-down procedures.

CLINICAL DATA

Manual compression remains the standard against which all currently approved VCD implants have been measured. When studies comparing VCDs to manual compression are examined, numerous variables must be taken into account, such as sheath size, level of anticoagulation, arteriotomy location (common femoral artery, superficial femoral artery, bifurcation, etc.), the need for adjunctive manual compression, time to

TABLE 1. CURRENT FDA-APPROVED AND MARKETED VCDS[a]

Device	Active	Passive	Indication	Manual Compression in Instructions for Use	Arteriotomy Size (F)	Steps	Manufacturer
Angio-Seal Evolution, VIP and STS Plus	+	+	Diagnostic, PCI	No	6, 8	11	St. Jude Medical
Perclose ProGlide	+		Diagnostic, PCI	No	5–8	12	Abbott Vascular
Prostar XL	+		Diagnostic, PCI	No	8.5–10	> 30	Abbott Vascular
Starclose SE	+		Diagnostic, PCI	No	5, 6	6	Abbott Vascular
MynxGrip		+	Diagnostic, PCI	As needed	5–7	10	AccessClosure
Exoseal		+	Diagnostic, PCI	Yes	5–7	5	Cordis Corporation
FISH	+	+	Diagnostic	No	5–8	7	Morris Innovative
Axera	+		Diagnostic	Yes	5–6	8	Arstasis
Catalyst II		+	Diagnostic, PCI	Yes	5–7	5	Cardiva Medical
Catalyst III		+	Diagnostic, PCI	Yes	5–7	5	Cardiva Medical

[a]Categorized by active or passive mechanism of closure, FDA indication for closure by type of procedure and sheath/arteriotomy size, need for manual compression in the instructions for use, and the practical number of steps needed for device deployment as determined by the author's experience and review of instructions for use.

hemostasis, time to ambulation, and exact adverse event definitions. Conclusions drawn from randomized studies that were performed for regulatory approval must also take into account the strict adherence to multiple restrictive inclusion and exclusion criteria that generally do not simulate the "real-life" clinical application of these technologies.

Taken in aggregate, randomized VCD studies uniformly demonstrate significantly shorter times to hemostasis and ambulation compared to manual compression, with comparable vascular complication rates.[5-9] Similarly, large registry and meta-analysis data do not reveal a consistent benefit of VCDs for reducing vascular complications.[10-20] Consequently, the conclusion of the American Heart Association statement on VCDs is that it is reasonable to use approved VCDs after PCI to improve patient comfort and reduce time to hemostasis and ambulation. A class III recommendation was given for using VCDs to reduce vascular complications.[21]

CURRENT VCDs

The potential benefits of a VCD when compared to manual compression are (1) increased patient comfort, (2) immediate or early postprocedure mobility, and (3) reduced bleeding and vascular complications. Attempts to attain these goals for a VCD have been made using several engineering solutions. Conceptually, it is helpful to broadly categorize these devices according to the two distinct methods of closure. The strategy of active closure mechanically secures the arteriotomy and effects closure either through the approximation of the margins of the arteriotomy or the mechanical fixation of a "plug" in, or over, the arteriotomy. Examples of active closure are VCDs that utilize staples, sutures, clips, etc. Passive closure relies on the delivery of material through the tissue tract that is placed directly adjacent to the arteriotomy in an unsecured fashion.[1,22]

The FDA-approved devices discussed in this article can be found in Table 1. There have been several VCDs

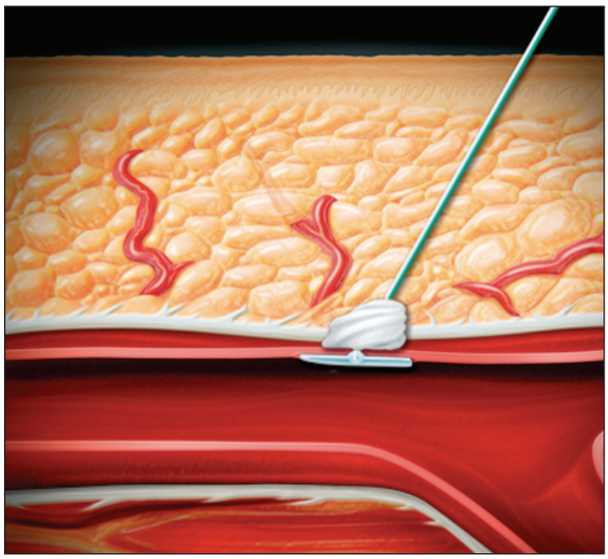

Figure 1. Longitudinal section of the common femoral artery during Angio-Seal closure device deployment. The intravascular anchor and epivascular collagen are tethered by a polymer filament. Reprinted with permission from Turi Z. Overview of vascular closure. Endovasc Today. 2010;5:65.

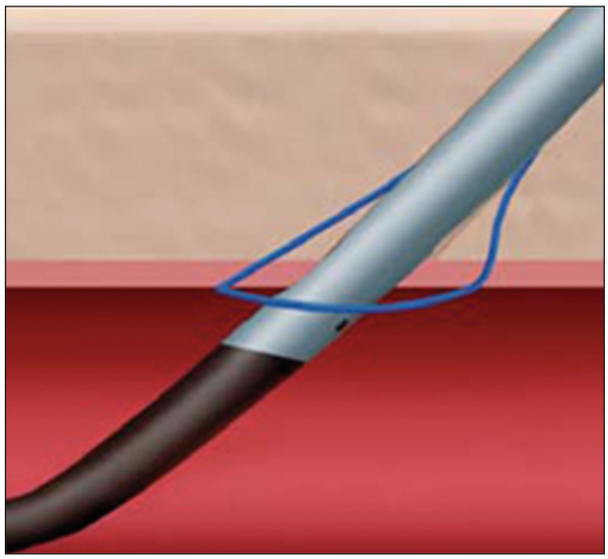

Figure 2. Longitudinal section of the common femoral artery during Perclose ProGlide device deployment. A single suture is deployed through the artery at the margins of the arteriotomy. After device removal, the suture is tied, approximating opposing edges of the arteriotomy. Reprinted with permission from Turi Z. Overview of vascular closure. Endovasc Today. 2010;5:65.

approved by the FDA that are not currently marketed (eg, Duett [Vascular Solutions, Inc., Minneapolis, MN], Sutura [Sutura, Inc., Fountain Valley, CA], VasoSeal, Quick-Close [Interventional Therapies, LLC, Westport, CT], Angiolink [Medtronic, Inc., Minneapolis, MN], etc.). These devices will not be addressed in this article. Also, many topical patches and pads have been developed as aids to manual compression; these are not true closure devices and also will not be included in the following discussion.

Angio-Seal

The Angio-Seal VCD (St. Jude Medical, Inc.) combines both active and passive closure strategies. Angio-Seal utilizes a resorbable intra-arterial polymer anchor that is tethered by a polymer filament to an extravascular collagen plug that is applied directly over the arteriotomy (Figure 1). The collagen provides a procoagulant effect, further aiding in hemostasis. These components all degrade by hydrolysis and are resorbed within 60-90 days. Angio-Seal and the latest iteration (Evolution) are the VCD market leader by a large margin (50.6% in 2010),[2] due to both a high rate of primary success, as well as its intuitive deployment mechanism. Several studies have demonstrated closure success rates > 95%.[5,16,17,23-27] Potential concerns particular to this device are misplacement or misalignment of the anchor within the arterial lumen, embolization of the anchor, and deployment of procoagulant collagen into the arterial lumen. Fortunately, it appears that these complications are very rare.[23-27]

Perclose ProGlide

The Perclose ProGlide and Prostar XL suture-based devices (Abbott Vascular) earned an approximate 20% share of the VCD market in 2010.[2] The Perclose ProGlide device drives two needles through the anterior wall of the femoral artery (Figure 2). The needles are deployed into an intra-arterial footplate, engaging a nonbiodegradable polypropylene suture that is then pulled back through the arterial wall. The arteriotomy is closed by approximation of the wound margins when a slipknot is advanced down to the arteriotomy, resulting in true active mechanical closure. The Perclose ProGlide device is suitable for use after procedures that utilize 5- to 8-F access. A unique feature of the Perclose ProGlide device is its ability to "preclose" the arteriotomy. With this technique, sutures from two or more devices are deployed, but not tied, before insertion of the working sheath. Closure occurs when the knots are tied after sheath removal at the end of the case. This technique allows for closure of large arteriotomies through the deployment of multiple sutures at different radial orientations around the arteriotomy. The Prostar XL device uses four needles and two

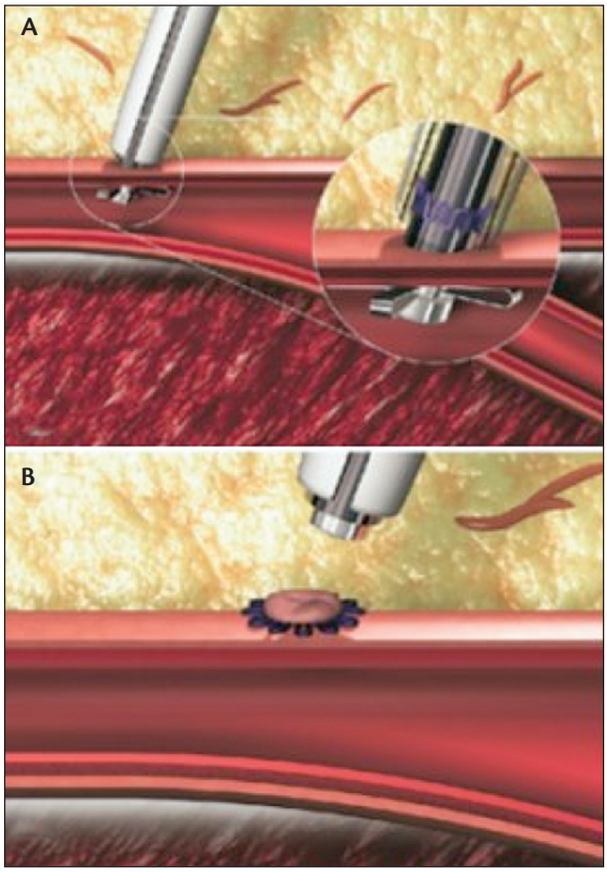

Figure 3. Longitudinal section of the common femoral artery during StarClose SE deployment. The device is positioned at the arteriotomy (A). An extraluminal nitinol disc is deployed, approximating the edges of the arteriotomy (B). Reprinted with permission from Weintraub JL. Vascular closure update. Endovasc Today. 2012;1:51.

sutures and is indicated for closure of 8.5- to 10-F arteriotomies, although closure of 24-F arteriotomies has been described.

Advantages of these suture-based devices include active closure, the option for immediate reaccess, and the lack of any intra- or extraluminal implant material. The major disadvantage of these devices is the technical expertise required for their deployment. Relatively large, nonrandomized studies comparing Angio-Seal to Perclose ProGlide have been published but do not demonstrate consistent findings in regard to success rates or rates of major complications.[10,17,23] However, one randomized study by Martin et al comparing Angio-Seal to Perclose ProGlide demonstrated an advantage for Angio-Seal in regard to deployment success. This underscores the complexity associated with Perclose ProGlide device deployment.[24]

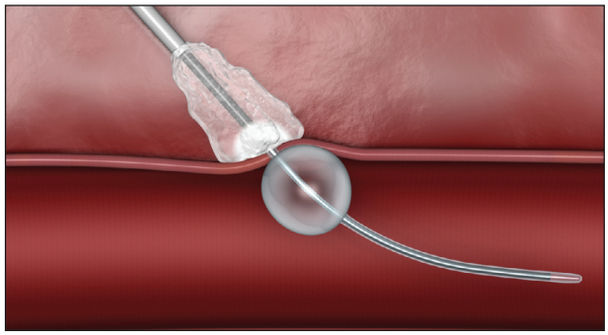

Figure 4. Longitudinal section of the common femoral artery during deployment of the MynxGrip device demonstrates positioning of extravascular PEG. The intra-arterial positioning element is pulled back through the PEG plug after deployment.

StarClose SE

The StarClose SE device (Abbott Vascular) is deployed through the procedural sheath and effects active closure through deployment of a disc-shaped nitinol clip that actively approximates the edges of the arteriotomy (Figure 3). An advantage of this device, similar to that of the Perclose ProGlide devices, is a lack of device implantation into the arterial lumen. An additional advantage with StarClose SE is its deployment through the procedural sheath, obviating the need for any sheath exchange. A disadvantage of this device is that it is a permanent implant, which potentially impacts reaccess and the ability to use some magnetic resonance imaging protocols. StarClose SE has gained significant popularity and had a 19.4% market share in 2010.[2] The StarClose Clip has been shown to be MRI conditional immediately after implantation under the following conditions: (1) static magnetic field of 3-Tesla or less; (2) spatial gradient magnetic field of 720-Gauss/cm or less; and (3) maximum MR system reported whole body-averaged specific absorption rate of 3-W/kg for 15 minutes of scanning. There are limited data comparing StarClose SE to the market leader Angio-Seal; however, one small (N = 410), single-center, randomized study demonstrated similar hemostasis success rates, complication rates, and patient satisfaction with both devices.[26,28]

MynxGrip

The MynxGrip device (AccessClosure, Inc., Mountain View, CA) is a passive closure device that utilizes the nonbiologic sealant material polyethylene glycol (PEG). The device advancer tube (sheath) has a tip that softens with body temperature and pH level, effectively gripping the artery, and providing (by the manufacturers description) "active" closure. This is not considered in Table 1

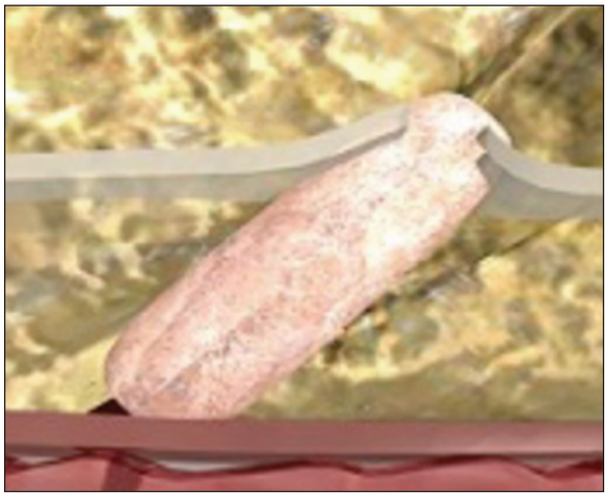

Figure 5. The Exoseal polyglycolic acid plug resting above the common femoral arteriotomy after deployment. Reprinted with permission from Turi Z. Overview of vascular closure. Endovasc Today. 2010;5:66.

as an active device because it remains extravascular and does not modify the artery wall. PEG degrades by hydrolysis similar to collagen but at a faster rate (< 30 days) and possibly with less inflammation due to the additional enzymatic degradation of collagen. The sealant is positioned over the arteriotomy by deployment through the procedural sheath (Figure 4). The device is available in 5- and 6/7-F sizes, and it is approved for use in the United States for both diagnostic and interventional cases. In 2010, MynxGrip had 8.8 % of the VCD market and assumed an even greater proportion in 2011.[2] The MynxGrip device was compared to the Angio-Seal device in a retrospective, single-center study (N = 428), which demonstrated no difference in major vascular complications (2.1% vs 2.1%; *P* = NS) but an increase in minor vascular complications with the MynxGrip device (3.7% vs 9.2%; *P* = .03).[27] These minor vascular complications

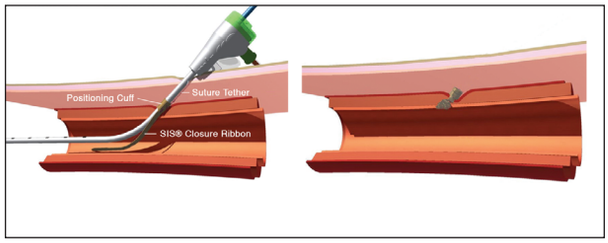

Figure 6. FISH device deployment in a common femoral arteriotomy (longitudinal section). The small intestinal submucosa ribbon (A) forms a plug in the artery wall when the sheath is withdrawn (B). The resorbable plug remains deployed across the arteriotomy. Reprinted with permission from Turi Z. Overview of vascular closure. Endovasc Today. 2010;5:68.

were mainly hematomas > 5 cm and the need for > 30 minutes of postprocedure manual compression.

Exoseal

The Exoseal VCD (Cordis Corporation, Bridgewater, NJ) is another passive extravascular closure device that relies on the deployment of a polyglycolic acid plug over the arteriotomy for hemostasis (Figure 5). The plug is completely absorbed via hydrolysis within 60 to 90 days. The Exoseal device is also delivered through the procedural sheath and is indicated for closure of 5-, 6-, and 7-F arteriotomies in both diagnostic and interventional procedures. It must be kept in mind that this device cannot be used through sheaths that are longer than 12 cm, and the instructions for use suggests that it should not be used in vessels of diameters < 5 mm. A multicenter study (ACCESS trial) comparing Exoseal with Angio-Seal in diagnostic and PCI cases is ongoing.

FISH

The FISH (Femoral Introducer Sheath and Hemostasis) device (Morris Innovative, Inc., Bloomington, IN) provides an active method of closure

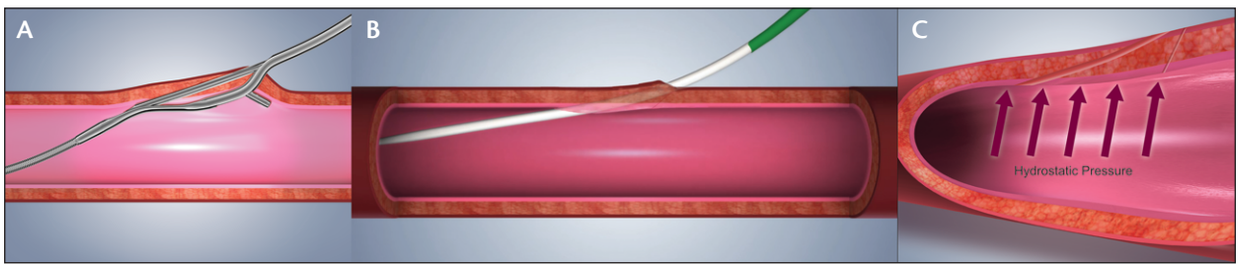

Figure 7. Deployment of the Axera device in the common femoral artery (longitudinal section). A micropuncture hole is created using conventional technique (A). The deployment device is placed through this small hole, and a needle is deployed that travels in a shallow diagonal across the vessel wall (arrow) (A). A guidewire is then placed through that needle, and the assembly is withdrawn. A sheath (white arrow) is then placed conventionally (B). At the end of the procedure, the sheath is withdrawn, and hydrostatic pressure facilitates hemostasis (C).

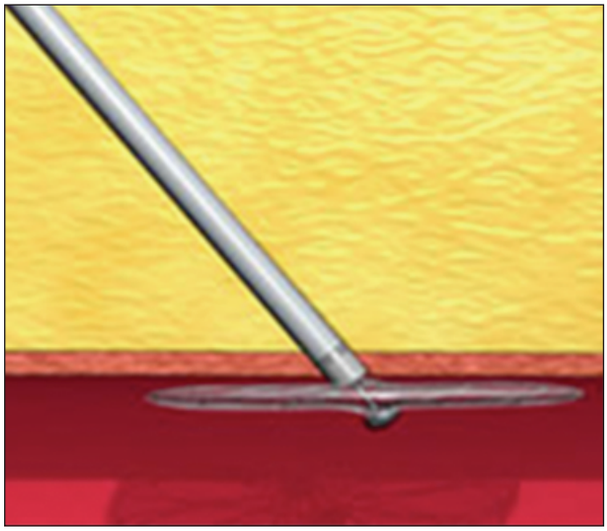

Figure 8. The Catalyst disc placed inside the lumen of the common femoral artery (longitudinal section). The disc is ultimately folded and removed through the arteriotomy as hemostasis is supported by manual compression. Reprinted with permission from Turi Z. Overview of vascular closure. Endovasc Today. 2010;5:66.

that is implemented using the intraluminal deployment of a ribbon created from porcine small intestinal submucosa. This ribbon folds up as it is withdrawn into the arteriotomy through backward tension on a compression suture, creating a resorbable plug in the artery wall (Figure 6). The intravascular plug absorbs in 30 days. The FISH device also allows for the option of delayed sheath removal after transport of the patient out of the catheterization laboratory and discontinuation of anticoagulants.

The FISH device is currently only indicated for diagnostic cases and is available in 5- to 8-F sizes. The device can be used as a combined procedural sheath and closure device, or placed after the procedure and used as a closure device only. The FISH device is currently approved for diagnostic procedures only, which could present an issue when considering a strategy of ad hoc intervention. There has been no study comparing the FISH device to the market leader, to date.

Axera

The Axera device (Arstasis, Redwood City, CA) provides active closure and also employs a strategy of pre-

procedure deployment of the closure apparatus. The associated implications of closure prior to assessment of the femoral and coronary anatomy were previously mentioned. The Axera device utilizes a novel strategy whereby a controlled preprocedure arteriotomy results in an overlap of arterial tissue after sheath removal that is reinforced by hydrostatic arterial pressure that creates closure (Figure 7). This novel approach leaves no foreign material behind, providing a potential advantage regarding reaccess. The Axera device was approved for use in diagnostic cases with 5- or 6-F sheaths through a 510(k) pathway. To date, there are few published data regarding clinical outcomes with this device, but with commercial availability, published experience is anticipated to grow.[29] As with the FISH device, there has been no published comparison with this device to Angio-Seal.

Catalyst

The Catalyst II and III (Cardiva Medical, Inc., Sunnyvale, CA) are passive closure devices that are designed to be adjunctive aids to manual compression. These devices are newer generations of the original Boomerang device (Cardiva Medical). Closure is accomplished using the patient's inherent anticoagulation facilitated by hemostasis, which is provided by a removable intravascular disc (Figure 8). After a predetermined dwell time, the nitinol disc is folded and withdrawn. The two Catalyst devices are only different in that there is a protamine sulfate component on the coating applied to the extravascular anchor element in Catalyst III, in addition to the two other proprietary coatings in the Catalyst II. Advantages of this device are a lack of biologic material or permanent implant, as well as the ability to apply it to a wide variety of anatomical conditions.[30] A significant disadvantage is the need for the device to stay in place for a minimum of 15 minutes for a diagnostic case and 120 minutes for an interventional case. As the disc passes through the arteriotomy and tissue tract after the dwell time, there is a chance that the hemostatic plug could be disturbed.

CONCLUSION

Although VCDs have been an integral part of the catheterization laboratory environment now for almost 2 decades, market penetration has traditionally been low. This is due in part to cost, operator unfamiliarity, complex instructions for use, and questions regarding efficacy. In the future, the use of VCDs may be expected to increase due to a demand for earlier ambulation and improvements in both device ease of use and efficacy. ■

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