Multidetector Computerized Tomography for the Evaluation of Cerebrovascular Disease
A Case Study

Corey Goldman, MD, PhD
Director of Vascular Medicine, Ochsner Heart and Vascular Institute, New Orleans, Louisiana


Intracranial Middle Cerebral Artery Percutaneous Intervention Using a Drug-Eluting Stent

Jacqueline Saw, MD, Jay S. Yadav, MD, Cameron Haery, MD, Derek W. Krieger, MD, Alex Abou-Chebl, MD.
Department of Cardiovascular Medicine and Interventional Neurology, the Cleveland Clinic Foundation, Cleveland, Ohio.

ABSTRACT: The use of bare-metal stents for intracranial vessels is associated with relatively high restenosis rates. We report the first human use of a sirolimus-eluting stent for a symptomatic proximal middle cerebral artery stenosis. This stent was successfully delivered and deployed without complications, with excellent one month angiographic results.

Intracranial angioplasty and stenting are increasingly being used to treat patients with recurrent cerebral ischemia due to intracranial atherosclerosis, which is a cause of 8-10% of all ischemic strokes. Since there are no commercially available stents designed specifically for the cerebral vasculature, all such procedures have utilized conventional coronary stenting systems. However, the incidence of stent restenosis in the intracranial circulation can be up to 40%. Since the FDA approval of the Cypher™ sirolimus-eluting stent (Cordis Corporation, Miami, Florida) on April 24, 2003, it has rapidly become the dominant coronary stent in use today in the United States. By the end of 2003, approximately 350,000 patients in the US had received a Cypher stent, representing about half of all coronary stents used. Its popularity is due to its marked reduction of restenosis. The only reported use of drug-eluting stents in intracranial vessels was in canine models. We report the first human use of a Cypher™ stent during percutaneous intervention of an intracranial stenosis in the middle cerebral artery (MCA).

CASE REPORT
A 43 year-old Caucasian female with hyperlipidemia, hypertension, and a twenty pack-year history of smoking presented seven months earlier with an infarct involving the right parietal lobe. Noninvasive imaging with transcranial Doppler (TCD) ultrasound showed elevated velocities in the right MCA (192 cm/s). Cerebral angiography showed a diffuse diffuse 80% distal right internal carotid artery (RICA) stenosis continued on page xx

Bivalirudin in Peripheral Vascular Interventions: A Single Center Experience
Nicolas W. Shammas, MS, MD, Jon H. Lemke, PhD, Eric J. Dippel, MD, Dawn E. McKinney, MA, Vickie S. Takes, RN, Monica Youngblut, RN, Melodee Harris, RN

ABSTRACT: Unfractionated heparin is a widely utilized anticoagulant during peripheral angioplasty procedures (PTA). In contrast to heparin, bivalirudin is a direct thrombin inhibitor with predictable anticoagulation, does not activate platelets, and inhibits both soluble and bound thrombin. The experience with bivalirudin during PTA remains limited. In this single-center prospective study, 48 consecutive patients (60.4% males, mean age 70.0 ± 12.1) received bivalirudin as the primary anticoagulant during PTA (0.75 mg/kg bolus, 1.75 mg/kg/h during the procedure). Thirty-four (70.8%) had claudication and 6 (12.5%) had ulceration. Thrombus was angiographically seen in 3 (6.3%) patients. In-hospital serious procedural complications were limited to 2 (4.2%) (exact 95% confidence interval: [0.5%,14.3%]) patients with major bleeding; none (0.0%) of the other following endpoints occurred: death, limb loss, emergent need for revascularization of the same vessel, embolic strokes, and vascular complications (exact 95% confidence intervals: [0.0%,6.1%]). This compared favorably to previously reported data using unfractionated heparin and the same serious procedural complications endpoints from our group at the same institution (9.2%). We conclude that the use of bivalirudin during PTA continued on page xx
Vascular Interventions

appears feasible and safe. Large prospective registries are needed to confirm these findings.

This article is reprinted with permission from the Journal of Invasive Cardiology 2003;15:401-404.

Unfractionated heparin (UFH) is the current antithrombotic agent utilized during peripheral angioplasty procedures (PTA). UFH has an unpredictable anticoagulation response, is an indirect thrombin inhibitor, does not inhibit bound thrombin and activates platelets. We have recently reported our procedural complication rate (9.2%) during PTA with the use of UFH as a primary anticoagulant. Our experience was in concordance with multiple published reports showing a complication rate of 3.5–32.7%. In contrast to UFH, bivalirudin has a half-life, provides predictable anticoagulation response, and inhibits free and bound thrombin. These properties provide potential benefits over UFH during PTA where thrombin activation is expected to be significant given the extent of atherosclerotic burden and large vessel size dilated with balloon angioplasty. The short half-life of bivalirudin might also allow early sheath removal, less bleeding complications than UFH, and a more reliable anticoagulation with no need for frequent activated clotting time (ACT) measurements during long procedures. Early experience with bivalirudin in the periphery has been recently presented at scientific meetings. The data appear favorable showing low major bleeding rate and adverse events compared to historical data with UFH. In this single-center experience, we report on our in-hospital complication rate during PTA in 48 consecutive patients who received bivalirudin as their primary anticoagulant, and compare this rate to a published historic control from the same institution using the same adverse events endpoints.

Methods

Forty-eight consecutive patients underwent PTA from February 5, 2002 through August 6, 2002 at our institution, using bivalirudin as a primary anticoagulant (0.75 mg/kg bolus, 1.75 mg/kg/hour during the procedure) and did not meet one of the following exclusion criteria: 1) planned staged two or more peripheral procedures during the same hospital stay; 2) acute myocardial infarction (MI) preceding the PTA; 3) the use of elective adjunctive intravenous glycoprotein (GP) IIb/IIIa inhibitors during the procedure; 4) concomitant coronary procedures; or 5) being on continuous intravenous heparin drip prior to the procedure. Clinical, angiographic, and serious event rates were collected prospectively. An interventional cardiologist not involved in the procedure adjudicated the in-hospital serious procedural complications (SPC). SPC were defined as follows:

- Major bleed: defined as requiring ≥ 2 units of PRBC transfusion, retroperitoneal bleed, or a drop of hemoglobin (Hb) after the procedure by more than 3 g/dL;
- Vascular complications: defined as an AV fistula or pseudoaneurysm after the procedure when suspected clinically and confirmed by duplex ultrasound;
- Death due to procedural complications;
- Limb loss;
- Need for in-hospital salvage revascularization (angioplasty or surgery) of the same treated vessel;
- Embolic stroke.

The following clinical variables were collected: age, gender, history of diabetes, MI, angina, hypertension, hyperlipidemia, smoking (ever, prior to the past year, and within the past year), prior cerebrovascular events, body mass index, blood pressure at onset of procedure, the presence of peripheral vascular disease with ulceration, recent onset of claudication (≤ 1 month), claudication ≤ 200 feet of walking, and pre-procedure ankle-brachial indices (ABI). The following angiographic criteria were collected: presence or absence of visible thrombus during the intervention, ACT (10 minutes after bivalirudin bolus using the Hemochron machine), vessels treated and procedure time. The Institutional Review Board of the Genesis Health System approved the protocol.

Statistical analysis. Descriptive statistics on all variables are initially summarized as proportions or mean ± SD. The primary analysis of the study was to estimate the rate of SPCs. Kruskal-Wallis tests were used to compare age and body mass indices across pre-existing conditions. Kaplan-Meier plots and exact log-rank tests were used to contrast procedure times and lengths of stay. Fisher’s exact tests were performed for comparisons of dichotomous and unordered categorical variables. SPC rates are estimated with exact 95% confidence intervals.

Results

Demographic and health history characteristics of the population studied are shown in Table 1. Twenty nine (60.4%) patients were males. The mean age was 70.0 ± 12.1 years; however, the age distribution is skewed with ages ranging from 41-89 and a median age of 73 (Figure 1). There were 32 (66.7%) patients with a documented history of smoking (17 [35.4%] current smokers, that is, smoked within the past year). Embedded in the histogram is the age distribution of recent smokers. All patients below the age of 59 are current smokers. In Figure 2, the boxplots demonstrate how the age distribution for previous smokers is the same as the never smokers and significantly different from the current smokers.

Of these 48 patients, 35.4% (17) had a history of heart disease (either MI, angina, or previous percutaneous coronary intervention) and 43.8% (21) had diabetes. There were 12.5% (6) of patients with lower leg ulceration, 4.2% (2) of patients with a recent onset of claudication (≤ 1 month), and 70.8% (34) of patients with symptomatic claudication. Baseline pre-procedure creatinine was 1.2 ± 0.6.

Intra-procedural thorbum occurred in 6.3% of patients. Even though the previous smokers were older than current smokers, their durations of surgery were similar. Any smoking (past and current) had longer procedure times (Figure 3). The difference in median procedure times was only 8 minutes, but the difference is over an hour in the last quartiles of completed procedures for the “never” versus “ever” smokers. The mean time of the procedure was 82.4 minutes for “never” smokers, but 108.1 minutes for the “ever” smokers.

A total of 80 vessels were treated in 48 patients (mean of 1.7 vessels per patient). The 80 primary vessels treated were categorized as follows: suprainguinal (n = 33), superficial femoral arteries and popliteal (n = 36), and tibials (n = 11). The mean Ankle-Brachial index was 0.7 ± 0.2. Closure devices were used in 41 patients (85.4%). There were 90.2% of them who received the Perclose suturing device and 9.8% who received AngioSeal. Forty-seven patients had an ACT measured 10 minutes after the bivalirudin bolus. The ACTs were distributed as follows: 38 (80.8%) > 400 seconds and 9 (19.2%) between 300–399 seconds.

Overall, there were 2 (4.2%) with a 95% confidence interval of (0%, 16.4%) of the patients with at least one SPCs, both of which were major bleeding (Table 2). There were no deaths, amputations, urgent limb salvage revascularization, vascular complications or embolic strokes. With bivalirudin, we are 95% confident that the true underlying SPC rate for each of these none-occurring

continued on page xx
events and these two physicians is less than 6.1%.

Discussion

In this single-center experience from February 5, 2002 through August 6, 2002, we had two experienced peripheral interventionalists (each of the 2 experienced operators has performed a minimum of 200 peripheral procedures) who used bivalirudin exclusively during PTA. The overall complication rate with bivalirudin in this series was 4.2% (2 patients out of 48 met at least one of the endpoints). Previously, we have reported that peripheral vascular complications are not trivial with unfractionated heparin as the base anticoagulant (SPCs were 9.2% using the same definitions as in this study).2 Our in-hospital outcomes with bivalirudin during PTA compare favorably with UFH. The complication rate appeared doubled with UFH when compared to bivalirudin. This is also in concordance with data recently reported in scientific meetings.12-14 Grubbs and colleagues12 reported their experience with 69 PTA patients receiving bivalirudin as a primary anticoagulant. In their series, there were no adverse events reported, including no major bleeding, acute thrombosis, or death. Knopf et al.13 also reported on 72 patients receiving bivalirudin during PTA. There were no deaths, major bleeding, strokes, or distal embolization in their series. Furthermore, Allie et al.14 have used bivalirudin in 180 renal and 75 iliac interventions with no major complications reported. In contrast, complication rates with UFH have ranged from 3.5-32.7% in several published series.15

The differences between smoking history cohorts make it difficult to make global claims across all patients, as well as difficult to simply estimate the effect of accepted risk factors on SPCs. It is likely that the much older previous smokers quit a long time ago. This is one of many survivorship effects; older patients continue to have fewer co-morbid conditions, especially histories of cardiovascular diseases.

The safer profile of bivalirudin over heparin during percutaneous procedures has been shown in several studies. In the Bivalirudin Angioplasty Trial (BAT),10 bivalirudin reduced the risk of bleeding by 62% when compared to UFH (p < 0.001). The recently published Replace-2 trial11 also showed a major bleeding rate of 2.4% in the bivalirudin arm versus 4.1% in the heparin plus GP IIb/IIIa arm (p < 0.001). A recent meta-analysis by Yusuf et al.15 has shown that bivalirudin has a significant advantage over UFH in reducing major bleeding during percutaneous procedures. Our preliminary experience and others seem to support the safety of bivalirudin during PTA procedures. A large registry or a randomized trial against UFH during PTA is now needed to confirm these small observations.

Limitations of this study. This is a single center experience and might not be shared by other operators. The data is preliminary and needs to be validated in a large, multi-center prospective study. Nevertheless, this study was prospective and data collection was timely and accurate. Although the

### Table 1: Patients’ Demographics and Health History on Presentation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD)</td>
<td>70.0 ± 12.1</td>
</tr>
<tr>
<td>Body mass index (mean ± SD)</td>
<td>27.8 ± 4.1</td>
</tr>
<tr>
<td>Highest heart rate prior to procedure (mean ± SD)</td>
<td>72.2 ± 11.4</td>
</tr>
<tr>
<td>Male (%)</td>
<td>60.4</td>
</tr>
<tr>
<td>Peripheral vascular disease with ulceration (%)</td>
<td>12.5</td>
</tr>
<tr>
<td>Claudication &lt; 1 month of presentation (%)</td>
<td>4.2</td>
</tr>
<tr>
<td>Claudication &lt; 200 feet</td>
<td>70.8</td>
</tr>
<tr>
<td>New York Class (%)</td>
<td>93.7</td>
</tr>
<tr>
<td>I</td>
<td>6.3</td>
</tr>
<tr>
<td>II</td>
<td>0.0</td>
</tr>
<tr>
<td>III &amp; IV</td>
<td>18.8</td>
</tr>
<tr>
<td>History of MI (%)</td>
<td>33.3</td>
</tr>
<tr>
<td>Prior history of angina (%)</td>
<td>26.7</td>
</tr>
<tr>
<td>Previous PCI (%)</td>
<td>85.4</td>
</tr>
<tr>
<td>History of hypertension requiring treatment (%)</td>
<td>31.3</td>
</tr>
<tr>
<td>History of smoking (%)</td>
<td>35.4</td>
</tr>
<tr>
<td>Never smoked</td>
<td>27.7</td>
</tr>
<tr>
<td>Smoked &gt; 1 year ago</td>
<td>43.8</td>
</tr>
<tr>
<td>Smoked &lt; 1 year ago</td>
<td>23.4</td>
</tr>
</tbody>
</table>

### Table 2: Descriptive Statistics for Serious Procedural Complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>% (N)</th>
<th>Exact 95% CI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>0.0% (0)</td>
<td>[0.0%, 6.1%]</td>
</tr>
<tr>
<td>Limb loss</td>
<td>0.0% (0)</td>
<td>[0.0%, 6.1%]</td>
</tr>
<tr>
<td>Bleeding (major)</td>
<td>4.2% (2)</td>
<td>[0.5%, 14.3%]</td>
</tr>
<tr>
<td>Revascularization needed</td>
<td>0.0% (0)</td>
<td>[0.0%, 6.1%]</td>
</tr>
<tr>
<td>Embolic Stroke</td>
<td>0.0% (0)</td>
<td>[0.0%, 6.1%]</td>
</tr>
<tr>
<td>Vascular complications</td>
<td>0.0% (0)</td>
<td>[0.0%, 6.1%]</td>
</tr>
<tr>
<td>Patients who had any of the above complications</td>
<td>4.2% (2)</td>
<td>[0.5%, 14.3%]</td>
</tr>
</tbody>
</table>

* CI = confidence interval
Continued from page 1

Vascular Interventions

References

Commentary

Bivalirudin in Peripheral Vascular Intervention

Nicolas W. Shammas, MS, MD
Genesis Heart Institute, Cardiovascular Medicine, P.C., Davenport, Iowa

Percutaneous peripheral vascular procedures have increased exponentially over the past 10 years. Anderson et al. reported a 979% growth in peripheral vascular interventions since 1995, with a simultaneous drop in the number of surgical vascular procedures. Despite the sharp rise in peripheral vascular interventions (PVI), complication rates have continued to be significant and, in fact, limb loss has trended upwards.1

There are many potential predictors of complications in PVI. These predictors potentially include the state of the limb (rest ischemia versus claudication), distal runoff, lesion characteristics (length, occlusion vs. stenosis, location), intra procedural thrombus, renal insufficiency, age, gender, smoking history, procedure length, number of lesions and vascular beds treated in one setting, and the presence of various comorbidities (diabetes and coronary artery disease). Until recently,1,2 the choice of the anticoagulant has not been considered as a potential predictor of complications in PVI.

Unfractionated Heparin in PVI

Despite changes in techniques and equipment in the angiographic suite, the use of unfractionated heparin (UFH) has remained the most widely utilized and unchallenged antithrombin during PTA.4 We have recently pooled data from 39 studies (15 prospective and 23 retrospective) published in the literature from 1980 to 2000 in order to better define the various complication rates during PVI with UFH as a primary anticoagulant.7 All complications within 30 days of PVI were recorded. Only lower extremity and renal procedures were included. Patients who received a primary anticoagulant other than UFH were excluded. Death, stroke, myocardial infarction, major bleed (>3 gm/dl loss of hemoglobin, retroperitoneal bleed and bleed requiring >2 units of packed RBC transfusion), renal failure, and limb loss were calculated with patient number as the denominator. Distal embolization, early occlusion, in-situ thrombosis, vascular complications (pseudoaneurysms and AV fistula) were calculated with the number of vessels angioplastied as the denominator.

The total number of patients reported in this study was 7545 (64.5% males), and the number of vessels angioplastied was 9489. Infrainguinal treatment and total occlusions accounted for 60.9% and 30.8% of all vessels, respectively. There was a high proportion of rest limb ischemia (58.1%), diabetics (38.4%), and coexisting coronary artery disease (41.9%) in these peripheral vascular patients. The overall reported success rate was 89.2% (93.2% for stenosis and 71.7% for occlusions).

In this pooled analysis, complications with UFH were as follows: early occlusion (3.1%), embolization (2.3%), vascular complications (0.7%), major bleed (2.1%), renal failure (1.7%), death (1.6%), limb loss (1.9%), in-situ thrombosis (2.6%), stroke (0.4%), and myocardial infarction (0.7%). The 30-day limb loss and mortality for limb ischemia patients were higher than claudicants (9.1% versus 0.2%) and 2.3% versus 0.1% respectively. This analysis indicates the wide and significant range of complications seen during PVI in patients receiving UFH as a primary anticoagulant and warrants a search for a better and safer replacement.

Bivalirudin in PVI

Bivalirudin, a direct thrombin inhibitor, is a 20-aminoc acid synthetic peptide that inhibits thrombin directly by binding to both its catalytic site and anion-binding exocite. It produces a dose-dependent prolongation of the ACT with an almost immediate anticoagulant activity following an intravenous injection. The elimination half-life of bivalirudin is approximately 25 minutes in patients with normal renal function.

In contrast to UFH, bivalirudin has a short half-life, provides predictable anticoagulation response, and inhibits free and bound thrombin as well as thrombin-induced platelet activation, aggregation and granule release.8 These properties might provide potential benefits over UFH during PTA where thrombin activation is expected to be significant, given the extent of atherosclerotic burden and large vessel size dilated with balloon angioplasty. Furthermore, the short half-life of bivalirudin might also allow early sheath removal, less bleeding complications than UFH.
Commentary

Continued from page xx

and a more reliable anticoagulation, with no need for frequent ACT measurements during long pro-
cedures.\(^ {7,8} \)

Several small studies have evaluated bivalirudin in PVI with encouraging findings.\(^ {9,10} \) Recently, data from the APPROVE (Angiomax Peripheral Procedure Registry of Vascular Events) multi-center registry (25 US centers, 305 patients) was presented by Dr. David Allie, primary inves-
tigator, at a recent scientific meeting. In this reg-
istry, bivalirudin was utilized as the primary anti-
coagulant in PVI of renal, iliac and femorals. The
REPLACE-2 dose was utilized, and consisted of 
an 0.75 mg/kg intravenous bolus, followed by 
1.75 mg/kg/hour infusion during the length of the 
procedure. The data from APPROVE appears 
consistent with previously published bivalirudin data in the periphery where the composite inci-
dence of death, limb loss, unplanned urgent revas-
cularization, and major bleeding appears favor-
able compared to the historic control UFH. A 
pooled analysis of published and presented data 
on bivalirudin in PVI is shown in Table 1.

The bivalirudin group (n= denominator of 
patients’ number with available data) consisted of 
38.2% diabetics (n=808 patients), 36.4% with 
history of coronary artery disease (n=807), 
72.2% suprainguinal vessels (n=832) with 
46.4% renals (n=760). Unfortunately, a clear distinc-
tion between claudicants and limb ischemia patients was available only on a small number of 
patients (n=123, excluding renals) and was 
4.9%. It is clear, however, that the early experi-
ence with bivalirudin seems to be in a low risk 
population (mostly suprainguinal with a low per-
centage of limb ischemia patients), which could explain some of the complication differences 
between it and UFH.

Given the heterogeneous patient populations in 
both the bivalirudin and UFH groups, and the 
potential selection bias, a randomized, double-
blind trial of bivalirudin versus UFH is warranted.

Early data with bivalirudin is promising, but ran-
domized studies are needed to determine whether 
this pharmacologic agent is superior to UFH.

The author can be contacted at: 
shammas@mchsi.com

Dr. Shammas discloses that he is a member of 
the speakers bureau and has received a research 
grant from The Medicines Company.

References

1. Anderson PL, Gelijns A, Moskowitz A, Arons R, Gupta L, 
Weinberg A, Faries PL, Nowsyrd R, Kent KG. Understanding 
trends in inpatient surgical volume: vascular interventions, 

2. Shammas NW, Lemke JH, Dippel EJ, McKinney D, Takes VS, 
Youngblut M, Harris M, Harb C, Kapulis M, Holdsen J. In-hos-
ital complications of peripheral vascular interventions using 
unfractionated heparin as the primary anticoagulant. J Invasive 
Cardiol. 2003;15(5):242-6

3. Allie DE, Littman MD, Wyatt CH, Keller VA, Khan MI, Khan 
MA, Fiel PS, Hebert CJ, Ellis SD, Mitran E, Chaussion G, Stagg 
S J; Allie AA, Walker CM. Bivalirudin as a foundation anti-
coagulant in peripheral vascular disease: a safe and feas-
ible alternative for renal and iliac interventions. J Invasive 

4. Shammas NW. An overview of antithrombins in peripheral vas-

5. Shammas NW, Dippel EJ, Lemke JH. Complications of perip-
eral interventions with unfractionated heparin. Presented as an 
abstract at Cardiovascular Interventions and Practice Guidelines 
Scientific Sessions 2004, Lincolnshire, Illinois, August 5-6, 
2004. In Shammas NW; Cardiovascular Interventions and 
Practice Guidelines 2004 proceedings handbook, Midwest 
Cardiovascular Research Foundation, page 300.

6. Marmur JD. Direct versus indirect thrombin inhibition in percu-
taneous coronary intervention. J Invasive Cardiol 2002;14 
(Suppl B):8B-18B

7. Direct Thrombin Inhibitor Trialists’ Collaborative Group. Direct 
thrombin inhibitors in acute coronary syndromes: principal 
results of a meta-analysis based on individual patients’ data. 

8. Grubbs G. Single center experience with bivalirudin anticoag-
ulation in peripheral vascular interventions: possible benefits 
over unfractionated heparin. Poster presented at Cardiovascular 
Revascularization Therapy conference; January 26-29, 2003, 
Washington, D.C.

9. Knopf W. Joseph’s Hospital experience: Direct thrombin 
inhibitors in ACS and PCI: the case for bivalirudin replacing 
unfractionated heparin in PCI. Paper presented at Transcatheter 
Cardiovascular Therapeutics 14th Annual Scientific 
Symposium; September 24-28, 2002;Washington D.C.

10. Shammas NW, Lemke JH, Dippel EJ, McKinney DE, Takes VS, 
Youngblut M, Harris M. Bivalirudin in peripheral vascular inter-
2003;15:401-404

<table>
<thead>
<tr>
<th>Author</th>
<th>Patients</th>
<th>Vessels</th>
<th>Success</th>
<th>Death</th>
<th>Limb loss</th>
<th>Major Bleeding</th>
<th>Acute Thrombosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grubbs</td>
<td>28</td>
<td>28</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Knopf‡</td>
<td>72</td>
<td>88</td>
<td>88</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Allie#</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Shammas^</td>
<td>48</td>
<td>80</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>APPROVE trial</td>
<td>505</td>
<td>505</td>
<td>475</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>908</td>
<td>956</td>
<td>925</td>
<td>0</td>
<td>1</td>
<td>18</td>
<td>2</td>
</tr>
</tbody>
</table>

Percent

- 96.76
- 0.11
- 1.98
- 0.21

* only non-AAA, non—carotid arterial interventions included ; number of vessels and patients presumed the same
† no distinction between lesions and vessels
‡ Major bleed in all 4 patients was a hematoma>5 cm with no apparent transfusions needed.
^ Major bleeding defined as >3 gm/dl Hb drop, 2 or more units of PRBC transfusion, Intracranial bleed or retroperitoneal bleed, similar to protocol definition of APPROVE

AAA=Aortic Aortic Aneurysm

### Table 1

<table>
<thead>
<tr>
<th>Author</th>
<th>Patients</th>
<th>Vessels</th>
<th>Success</th>
<th>Death</th>
<th>Limb loss</th>
<th>Major Bleeding</th>
<th>Acute Thrombosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grubbs</td>
<td>28</td>
<td>28</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Knopf‡</td>
<td>72</td>
<td>88</td>
<td>88</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Allie#</td>
<td>255</td>
<td>255</td>
<td>255</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Shammas^</td>
<td>48</td>
<td>80</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>APPROVE trial</td>
<td>505</td>
<td>505</td>
<td>475</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>908</td>
<td>956</td>
<td>925</td>
<td>0</td>
<td>1</td>
<td>18</td>
<td>2</td>
</tr>
</tbody>
</table>

- 96.76
- 0.11
- 1.98
- 0.21

* only non-AAA, non—carotid arterial interventions included ; number of vessels and patients presumed the same
† no distinction between lesions and vessels
‡ Major bleed in all 4 patients was a hematoma>5 cm with no apparent transfusions needed.
^ Major bleeding defined as >3 gm/dl Hb drop, 2 or more units of PRBC transfusion, Intracranial bleed or retroperitoneal bleed, similar to protocol definition of APPROVE

AAA=Aortic Aortic Aneurysm