A Cost-Minimization Analysis of the Angio-Seal Vascular Closure Device Following Percutaneous Coronary Intervention

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The Angio-Seal vascular closure device has been shown to be safe and effective in decreasing the time to hemostasis after percutaneous coronary intervention (PCI). The health economic implications of routinely using Angio-Seal after PCI have not been explored. We performed a cost-minimization analysis comparing routine Angio-Seal use after PCI with mechanical compression using a decision analytic model. The relative probabilities of 7 vascular access complications were derived from pooled analysis of published randomized trials. The incremental hospital cost of each vascular complication was estimated by a matched case-control analysis of 3,943 patients who underwent PCI at our center from January 2002 and December 2004. Appropriate sensitivity and uncertainty analyses were performed. After accounting for differences in expected rates of specific complications between the 2 strategies and the incremental costs of each vascular event, the routine use of Angio-Seal was associated with a lower cost per PCI procedure of $44. Probabilistic sensitivity analysis of all model assumptions using second-order Monte Carlo simulation confirmed the economic advantage of Angio-Seal in 74% of model replications. In conclusion, after PCI, the routine use of Angio-Seal for femoral vascular access management was associated with net cost savings compared with mechanical compression. This cost savings was in addition to the previously demonstrated advantages of Angio-Seal in terms of patient comfort and preference.   © 2007 Elsevier Inc. All rights reserved. (Am J Cardiol 2007;99:766–770)

Over the past 10 years, there has been widespread adoption of vascular closure devices (VCDs) after coronary angiography and intervention in the United States[1,2]; however, the cost implications of this practice have not been carefully assessed. Although the cost of a VCD in the United States is approximately $200, the costs of specific vascular complications after percutaneous coronary intervention (PCI) have been poorly characterized. Because of uncertainty over the costs of vascular access complications after PCI and whether VCDs truly decrease the frequency of these complications,[2–4] it is unclear whether the previously demonstrated advantages of VCDs in terms of patient comfort and preference are financially attractive. We studied the economic effect of routine arterial closure after PCI using the Angio-Seal device (St. Jude Medical, St. Paul, Minnesota) by synthesizing published and locally collected data in a decision analytic model.

Methods

A decision analytic model was constructed to evaluate the routine use of Angio-Seal after PCI from the perspective of total hospital costs. This model was designed to incorporate the probability of 7 potential vascular complications and the incremental hospital costs associated with each complication. Vascular complications studied included access site bleeding (associated with need for transfusion or decrease in hemoglobin by ≥ 3 g/dl), large hematoma formation (>5 cm in maximal diameter), pseudoaneurysm (confirmed by vascular ultrasound), arteriovenous fistula (confirmed by vascular ultrasound), retroperitoneal hemorrhage (confirmed by radiologic evaluation), acute limb ischemia (necessitating vascular evaluation), and access site infection (confirmed by culture). The model assumed that vascular events were mutually exclusive and that the costs of minor complications occurring simultaneously with major complications would be dominated by the costs of the major complication.

Rates of each vascular complication after PCI were estimated from a pooled analysis of all randomized studies of the use of Angio-Seal published from 1996 to 2005 based on a Medline search.[5–11] Technical aspects of the PCI procedures, such as anticoagulation practices and sheath sizes, varied considerably among these studies and were not consistently reported. Because of their rare occurrence in randomized studies, expected probabilities of acute limb ischemia and access site
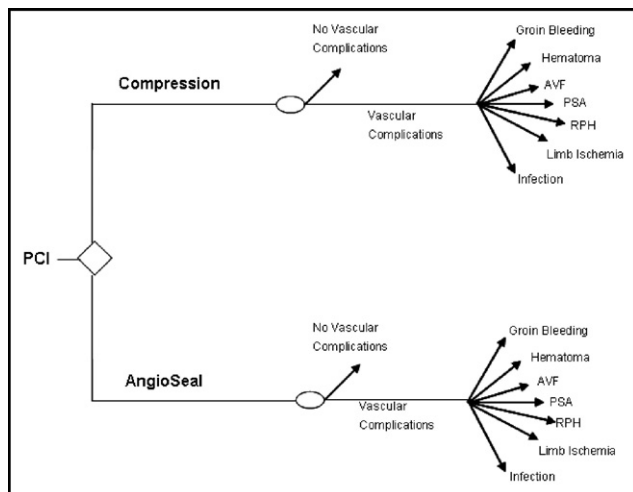
Figure 1. Decision analytic tree structure with decision node *(diamond)*. For each main limb of the tree, patients can have no complication or 1 of 7 distinct complications based on chance. AVF = arteriovenous fistula; PSA = pseudoaneurysm; RPH = retroperitoneal hemorrhage.

infection were estimated by pooling rates from the largest published registries and case series.[4,12–15]

The cost attributable to each vascular complication was derived from an evaluation of the direct costs incurred by patients with that complication at Brigham and Women's Hospital (Boston, Massachusetts) from January 2002 to December 2004 through a case-control analysis. This was accomplished for each specific complication as described in the following.

Encounter-level costs for each PCI admission were derived from the hospital's cost accounting system (TSI System, Eclipsys Corp., Delray Beach, Florida). Costs included all dispensed medication, disposable inventory, nursing time, nonprofessional labor, procedural costs, and allocated proportions of hospital fixed and operating costs. Professional fees and costs potentially incurred beyond the index hospitalization were therefore not measured.

All cases in which a vascular event occurred underwent detailed chart review to identify potential confounders of total hospital cost. Outliers in hospitalization cost (>2 SDs from mean) were excluded from analysis as nonrepresentative. The remaining cases of vascular complications were considered representative of complications after the PCI procedure, and summary measurements of direct hospital costs were generated for each complication.

A matched case-control analysis was used to identify control patients, from the procedures in which the patient did not develop a vascular complication, in a 4:1 ratio. Matching was based on age (within 5 years), gender, history of peripheral vascular disease, diabetic status, acute myocardial infarction on presentation, use of drug-eluting stents, use of glycoprotein IIb/IIIa inhibitors, and Charlson comorbidity index score[16] (within 2 points). Median control cost was calculated in a manner identical to that used for cases. Patients who did not undergo PCI on the day of admission or had a length of stay >2 days after PCI (in the absence of acute myocardial infarction) were excluded.

The incremental cost for each adverse vascular outcome was calculated as the difference between the median cost of

hospitalization for patients with a particular vascular complication and the median of the matched control subjects who had not develop a vascular complication. The interquartile range for each complication cost was calculated by subtracting the median cost of admissions without the complication from the 25th and 75th percentile costs for admissions with the complication.

Expected values for costs of mechanical compression and costs of the Angio-Seal VCD were calculated using the decision tree shown in Figure 1.[17] The model was constructed and all related analyses were performed using DATA 4.0 decision analytic software (TreeAge, Inc., Williamstown, Massachusetts). For our base case analysis, the tree was calculated using the point estimates for each event probability and cost, derived as previously described. Hospital equipment costs assumed were those for our center, i.e., $190 for the Angio-Seal STS device and $110 for the FemoStop mechanical compression device (RADI Medical Systems, Wilmington, Massachusetts), which is used routinely at our center for patients not receiving a VCD after PCI. The base case was conservatively modified by decreasing the assumed rate of access site bleeding to be 50% of the rate derived from the pooled randomized trial data, because this rate was significantly higher than an internal review of the rates of bleeding after mechanical compression at our center.

One-way sensitivity analyses were performed on all model inputs.[18] Upper and lower bounds for event probabilities were taken from the 95% confidence intervals of observed binomial event rates in randomized trials whenever possible (Table 1). For event costs, upper and lower bounds were taken from the interquartile range for event costs, derived as described earlier (Table 2). Overall model uncertainty was also explored using probabilistic sensitivity analysis. Second-order Monte Carlo simulation[19,20] was performed by replacing each model input with a probability distribution. Beta distributions were used for event probabilities, and log-normal distributions were used for costs. Expected values for each limb of the decision tree were calculated by drawing 1 time at random from each of those distributions, and this process was repeated for 10,000 iterations. Costs of the Angio-Seal VCD and mechanical compression were not changed in this analysis.

Results

The probability and 95% confidence interval of each vascular outcome for the Angio-Seal and mechanical compression, derived from pooled analysis of available randomized control trial data, are presented in Table 1. For each outcome, pooled analysis included 1 to 6 studies, representing prospective evaluation of 612 to 10,113 study patients (all studies did not assess the same outcomes or use consistent outcome definitions). Rates of access site bleeding, large hematoma, and arteriovenous fistula were significantly higher in the mechanical compression group than in the Angio-Seal group, whereas rates of other complications were similar between groups.

From January 2003 to December 2004, 4,672 patients who underwent PCI at our facility were followed prospectively for vascular complications through time of discharge

Table 1
Vascular complications by vascular access management strategy: A pooled analysis of published data

Complication	Angio-Seal-treated Patients			Mechanical Compression-treated Patients			Sources
	Patients	Events (%)	95% CI	Patients	Events (%)	95% CI	
Bleeding	480	8 (1.67%)	0.52–2.81%	561	43 (3.00%)*	2.00–5.46%	7,9,10
Hematoma	463	22 (4.75%)	2.81–6.69%	549	31 (5.65%)	3.72–7.58%	8,9,10
Arteriovenous fistula	1,471	3 (0.20%)	0.00–0.43%	8,642	72 (0.83%)	0.64–1.02%	3,4,14,15
Pseudoaneurysm	627	6 (0.96%)	0.19–1.72%	699	12 (1.72%)	0.75–2.68%	6–11
Retroperitoneal hemorrhage	627	2 (0.32%)	0.00–0.76%	699	1 (0.14%)	0.00–0.42%	6–11
Acute limb ischemia	1,471	2 (0.14%)	0.00–0.32%	8,642	8 (0.09%)	0.03–0.16%	3,4,14,15
Access site infection	306	1 (0.33%)	0.01–0.97%	306	0 (0.05%)†	0.015–0.29%	9

* The bleeding rate in compression-treated patients was assumed to be only half the rate obtained from the pooled result of randomized trial data. This conservative assumption was made after comparison of pooled results with contemporary registry data and local bleeding rates at our institution.

† Although there were no observed access site infections in the compression-treated patients in the 1 randomized trial reporting this outcome, the rate for compression-treated patients was assumed to be non-zero for the purposes of this analysis, although substantially lower than the rate in the Angio-Seal-treated patients.

CI = confidence interval.

Table 2
Costs of vascular complications at Brigham and Women's Hospital

Complication	Total Events	Representative Cases	Median Cost		Attributable Cost	95% CI
			Case	Control		
Bleeding	71	6	$17,167	$11,727	$5,440	$2,250–$10,226
Hematoma	35	24	$14,347	$12,948	$1,399	$700–$6,959
Arteriovenous fistula	5	2	$15,521	$14,106	$1,415	$700–$4,409
Pseudoaneurysm	5	5	$19,602	$13,245	$6,357	$4,900–$10,408
Retroperitoneal hemorrhage	25	20	$18,688	$11,990	$6,698	$3,038–$12,751
Acute limb ischemia	3	2	$23,238	$17,704	$5,534	$5,200–$14,000
Access site infection*	1	1	N/A	N/A	$5,127	
Compression					$2,400	$1,500–$3,300
Angio-Seal					$4,200	$3,000–$6,000

* There were limited cost data for access site infections. Costs of access site infection were estimated from the cost of admission for similar surgical site infections and were assumed to be lower (by 50%) for mechanical compression-treated patients compared with Angio-Seal-treated patients to account for the likelihood of a more complex perivascular infection in the presence of the device.

Abbreviation as in Table 1.

and had complete cost accounting and hospital admission records available. Estimated attributable cost for each outcome is presented in Table 2 and ranged from $1,399 for a hematoma to $6,698 for a retroperitoneal hemorrhage.

The base case decision analytic model yielded a net cost savings of $44 per case for those patients treated with the Angio-Seal VCD compared with patients treated with mechanical compression (Figure 2).

One-way sensitivity analyses demonstrated that the model was insensitive to all estimated event probabilities, except rates of access site bleeding and pseudoaneurysm. The model was also sensitive to the relative cost of compression compared with the Angio-Seal device. Threshold values of these parameters representing the point at which the model result changes from favoring Angio-Seal to favoring compression are listed in Table 3. Holding all else equal, the Angio-Seal lowered cost compared with compression as long as the cost of performing compression was >$66.

To further explore the robustness of the base case results, probabilistic sensitivity analysis was performed based on random resampling of all model inputs (Monte Carlo simulation). The Angio-Seal closure strategy was found to be cost saving compared with mechanical compression in 74% of model iterations. The distribution of expected cost savings with the Angio-Seal from the Monte Carlo simulation is shown in Figure 3.

Discussion

In this analysis, the routine use of the Angio-Seal VCD after PCI was associated with a savings in direct hospital costs of $44 per patient compared with routine mechanical compression. Net cost savings were preserved unless the rate of access site bleeding or rate of pseudoaneurysm formation varied significantly from estimates from the pooled analysis. In addition, estimated cost savings associated with use of the Angio-Seal was preserved for all analyses of cost estimates, unless the cost of bleeding after mechanical compression was significantly below the estimated 25th percentile cost. The strategy of routine use of the Angio-Seal in appropriate candidates after PCI was associated with a net cost savings, unless the cost of mechanical compression could be decreased <$66 per case.

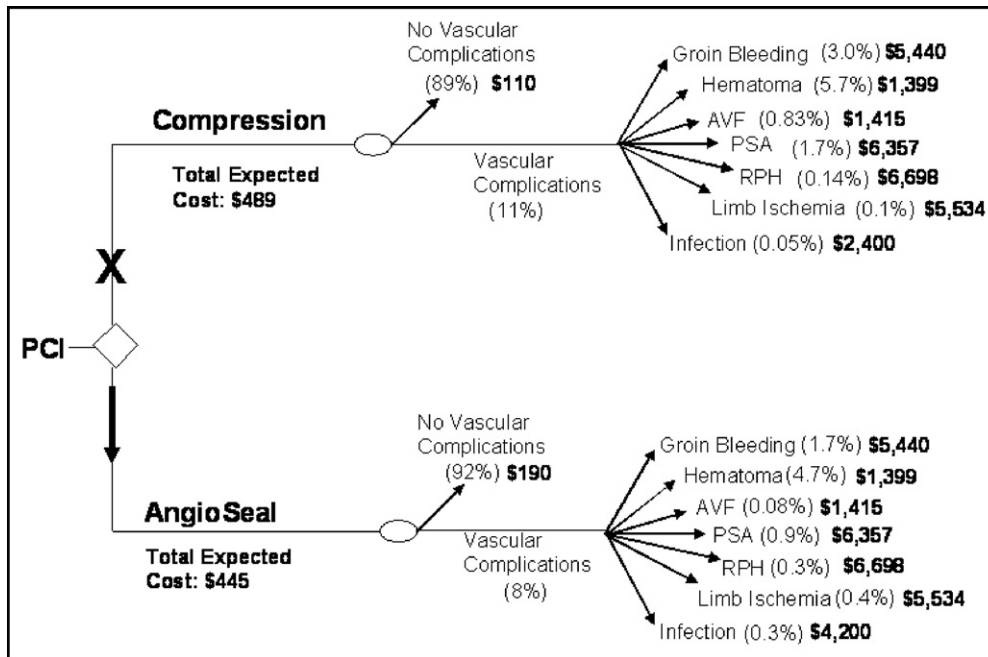Although estimates of the incremental cost of each reported complication have not been published, our estimates

Figure 2. Final cost estimates from base case analysis indicate a relative cost savings of $44 per patient receiving the Angio-Seal device after PCI compared with mechanical compression. Abbreviations as in Figure 1.

Table 3
One-way sensitivity analysis: summary of model inputs to which overall model result was sensitive*

Model Input	Base Case Value	Sensitivity Analysis	Threshold Value[†]
Complication rates			
Access site bleeding			
Angio-Seal	1.67%	0.52–2.81%	>2.49%
Compression	3.00%	2.00–5.46%	<2.19%
Pseudoaneurysm			
Angio-Seal	0.96%	0.19–1.72%	>1.66%
Compression	1.72%	0.75–2.68%	<1.02%
Cost inputs			
Access site bleeding	$5,440	$2,250–$10,226	<$2,105[‡]
Compression cost	$110	0–$150	<$66
Angio-Seal cost	$190	$100–$300	>$234

  * No other base case assumptions affected model results through the ranges of values analyzed.

  † Base case results indicated cost savings for routine use of the Angio-Seal. Changes in the direction indicated in the threshold value column would change the result toward favoring routine compression.
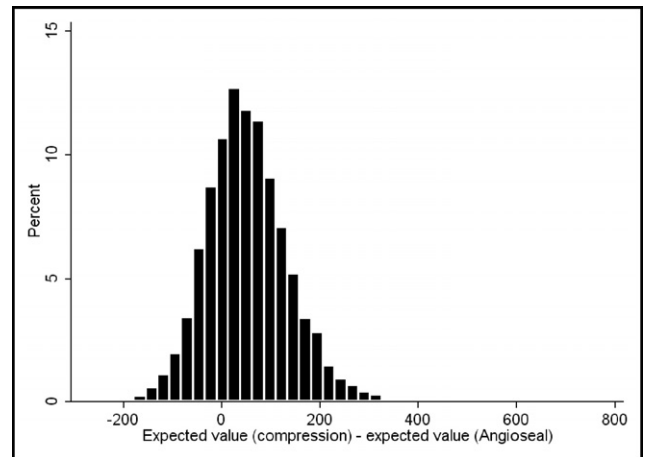
  ‡ Value outside of estimated range.

Figure 3. Monte Carlo simulation results. Histogram represents the relative frequency of cost-saving estimates from routine use of the Angio-Seal compared with mechanical compression after PCI. The simulation was run for 10,000 iterations.

appear consistent with recent data regarding of the cost of vascular complications in general after PCI (~$4,800) based on Medicare claims data.[21] The attributable cost method used for this analysis provides a quantitative basis for estimating costs of specific inpatient hospitalization costs incurred by patients with these events compared with matched control patients who did not have the event. Although median cost differences appeared reasonable, several findings were unexpected. The relatively high cost of "minor" vascular complications, such as significant access site bleeding ($5,440) and hematoma formation ($1,400), likely represent the increased length of hospitalization as-

sociated with transfusion and routine evaluation of such patients with vascular ultrasound at our institution. It is the relative high cost of the minor complications, which occur with greater frequency than major vascular complications, that drives the net cost savings result of use of the Angio-Seal found in this analysis. Supporting this hypothesis are findings from the REPLACE 2 trial, in which minor bleeding without transfusion was estimated to cost approximately $400 per event; decreases in this event accounted for 33% of the cost offset with the use of bivalirudin.[22]

The generalizability of this analysis may be affected by several important study limitations. First, probabilities of vascular complications for the Angio-Seal and mechanical compression strategies were derived from a pooled analysis

of a heterogenous group of small randomized trials of the devices, which may not accurately represent observed differences in practice at a particular center. Second, costs of vascular complications were derived from a limited number of cases, with detailed cost accounting data from a single high-volume tertiary care medical center. In addition, evidence that use of the Angio-Seal VCD may be associated with a lower risk of femoral vascular access complications compared with compression may not easily be extended to other types of VCDs. Third, there was limited information on rare events, such as access site infection or acute limb ischemia, and estimates of event rate probability and cost, based on few observed cases, may be inaccurate. However, the model was not sensitive to varied estimates of these low-frequency events.

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