Relationship Between Regional Spending on Vascular Care and Amputation Rate

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**IMPORTANCE** Although lower extremity revascularization is effective in preventing amputation, the relationship between spending on vascular care and regional amputation rates remains unclear.

**OBJECTIVE** To test the hypothesis that higher regional spending on vascular care is associated with lower amputation rates for patients with severe peripheral arterial disease.

**DESIGN, SETTING, AND PARTICIPANTS** Retrospective cohort study of 18,463 US Medicare patients who underwent a major peripheral arterial disease–related amputation during the period between 2003 and 2010.

**EXPOSURE** Price-adjusted Medicare spending on revascularization procedures and related vascular care in the year before lower extremity amputation, across hospital referral regions.

**MAIN OUTCOMES AND MEASURES** Correlation coefficient between regional spending on vascular care and regional rates of peripheral arterial disease–related amputation.

**RESULTS** Among patients who ultimately underwent an amputation, 64% were admitted to the hospital in the year prior to the amputation for revascularization, wound-related care, or both; 36% were admitted only for their amputation. The mean cost of inpatient care in the year before amputation, including costs related to the amputation procedure itself, was $22,405, but it varied from $11,077 (Bismarck, North Dakota) to $42,613 (Salinas, California) ($ < .001). Patients in high-spending regions were more likely to undergo vascular procedures as determined by crude analyses (12.0 procedures per 10,000 patients in the lowest quintile of spending and 20.4 procedures per 10,000 patients in the highest quintile of spending; $ < .001) and by risk-adjusted analyses (adjusted odds ratio for receiving a vascular procedure in highest quintile of spending, 3.5 [95% CI, 3.2-3.8]; $ < .001). Although revascularization was associated with higher spending ($ = 0.38, $ < .001), higher spending was not associated with lower regional amputation rates ($ = 0.10, $ = .06). The regions that were most aggressive in the use of endovascular interventions were the regions that were most likely to have high spending ($ = 0.42, $ = .002) and high amputation rates ($ = 0.40, $ = .004).

**CONCLUSIONS AND RELEVANCE** Regions that spend the most on vascular care perform the most procedures, especially endovascular interventions, in the year before amputation. However, there is little evidence that higher regional spending is associated with lower amputation rates. This suggests an opportunity to limit costs in vascular care without compromising quality.
health care costs attributable to critical limb ischemia, the most severe form of peripheral arterial disease (PAD), have been estimated at nearly 5 billion dollars annually for Medicare patients. Moreover, with the advent of less invasive endovascular techniques, the use of revascularization procedures for critical limb ischemia has increased 4-fold since 2003. Therefore, many believe that, in recent years, vascular care aimed at preventing amputation has become increasingly intensive and expensive.

However, the costs of revascularization for patients who are at risk for amputation, as well as the costs of the amputation procedure itself, remain uncertain. These costs vary significantly according to the type of treatments patients receive. For example, a “plain old” balloon angioplasty requires catheters that cost a few hundred dollars each, whereas the newer atherectomy devices, drug-coated balloons, and other endovascular adjuncts can exceed several thousand dollars for each artery treated. Second, although leg bypass surgery is spared the device-related costs of endovascular interventions, the resultant hospital stay nearly always spans several days and is a significant expense. And third, the costs related to the amputation procedure itself remain uncertain, and patients undergoing amputation commonly have postoperative complications and a prolonged hospital stay. A description of spending patterns for patients at risk for amputation, as well as a delineation of relationships between spending on vascular care and amputation risk, may help to guide physicians and policy makers toward establishing value-based guidelines for the treatment of severe PAD.

Therefore, we characterized Medicare spending related to severe PAD in the year prior to amputation, including costs related to the amputation procedure itself. To ensure that we studied vascular care provided to patients with the most severe form of PAD, rather than the discretionary treatment of claudication, we studied the care provided to patients in the year prior to major limb amputation as a result of PAD. Using data from across hospital referral regions as our unit of analysis, we examined risk-adjusted relationships between spending and amputation risk.

Methods

Database

We used Medicare claims (2003-2010) to identify patients with severe PAD, and then we examined the costs associated with vascular care in the year prior to amputation. We used Current Procedural Terminology codes to define both revascularization procedures and leg amputation procedures (above and below knee only) commonly utilized in the care of patients with severe PAD (eAppendix in Supplement). As in prior work, we also ensured that all patients had International Classification of Diseases, Ninth Revision diagnosis codes for PAD and underwent a major above- or below-knee amputation—an indicator of critical limb ischemia. We recorded the procedure and the age, sex, and race of the beneficiary receiving the procedure. Vital status was determined using the Denominator file, which contains information about eligibility by year for Part B and information about age, sex, and race of eligible beneficiaries (Figure 1).

We excluded patients younger than 66 years of age, to allow a 1-year “look-back” for comorbidity assessment. Similarly, records with missing values for sex, age, and race strata were also removed from the analysis. We recorded comorbidities, including hypertension, diabetes mellitus, coronary disease, renal insufficiency, cerebrovascular disease, congestive heart failure, and malignancy, measured both individually and in aggregate using the Charlson comorbidity score. We identified each patient’s zip code of residence and hospital referral region, as described by the Dartmouth Atlas of Health Care. Among the 20,058 patients in our data set, cost data were unavailable in Medicare claims for 1,959 patients (8%). These patients were excluded from our analysis; however, they had characteristics similar to those patients who remained in our cohort.

Studying Cost in the Year Prior to Amputation

The severity of PAD can vary significantly, from claudication to limb-threatening ischemia and gangrene. To study a population of patients whose extent of PAD was as similar as
possible, we examined vascular care during the year prior to amputation. By intent, the extent of PAD is similar across patients studied in this manner because the risk of 1-year limb loss for the entire cohort is 100%. As reported in prior work, the use of this exposure variable (vascular care in the year prior to amputation) allows us to study care aimed specifically at the treatment of severe PAD, rather than the discretionary treatment of claudication.

Calculating Price-Adjusted Medicare Spending in the Year Prior to Amputation

We studied inpatient costs during the year prior to amputation, including costs related to revascularization, wound debridement, and management of cellulitis. This encompassed both diagnostic (such as a diagnostic angiogram) and therapeutic invasive vascular procedures. We also studied costs incurred during the amputation procedure itself. Spending was aggregated at the level of the hospital referral region, as defined in the Dartmouth Atlas of Health Care. Costs were then adjusted for regional differences in Medicare payments, adjusted for inflation given the year of the procedure, and reported as “price-adjusted” Medicare spending.

Calculating Population-Based Regional Major Leg Amputation Rate

The population-based regional amputation rate was calculated across hospital referral regions, using the total number of major amputations as the numerator and the total number of patients in the region (determined from the midyear census estimate) as the denominator. Toe amputations and foot amputations were not considered in this analysis.

Examining Relationships Between Regional Spending and Rates of Amputation

After defining regional spending in the year prior to amputation and calculating population-based regional rates of major amputation, we examined the associations between these 2 variables. These associations were displayed using scatterplots between the exposure variable and the outcome variable, at the regional level. Correlation coefficients were calculated between the exposure and the outcome.

To adjust for differences in patient characteristics across regions, we generated quintiles of spending and population-based amputation rates, and we adjusted for differences in comorbidities and Charlson comorbidity scores across quintiles of spending using backward stepwise logistic regression models. Models were adjusted for patient-level comorbidities as outlined in Table 1, and a cutoff of \( P < .20 \) was established for model inclusion. We censored regions where fewer than 11 amputations occurred, in accordance with guidelines regarding preservation of patient confidentiality from the Centers for Medicare and Medicaid Services. All calculations were performed using SAS (SAS Institute) and Stata (StataCorp). Institutional review board approval was obtained from the Committee for Protection of Human Subjects from the Geisel School of Medicine at Dartmouth in Hanover, New Hampshire.

Results

Patient Characteristics, Revascularization, and Hospitalization Rates

We identified 18463 patients who underwent a major PAD-related amputation between 2003 and 2010. Overall, patients had a mean age of 78 years, and 51% of the patients were male. Patients commonly had a history of diabetes (49%), heart failure (35%), and coronary disease (14%) (Table 1).

Within this cohort, 11785 patients (64%) were hospitalized during the year prior to amputation, while the remaining 36% were not admitted for a PAD-related reason during this same period. Of the 11785 patients admitted to the hospital, 2762 (23%) underwent an inpatient revascularization procedure, and 2491 (21%) had a debridement procedure performed during a hospital admission in the year prior to amputation.

### Table 1. Characteristics of Vascular Amputees in 2007-2009 Medicare Claims, by Quintile of Spending in Year Prior to Amputation on Revascularization/Hospitalization

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n = 18 463)</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
<th>Ratio</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean cost, $</td>
<td>22 405</td>
<td>17 134</td>
<td>20 138</td>
<td>21 612</td>
<td>23 107</td>
<td>27 395</td>
<td>1.60</td>
<td>.001</td>
</tr>
<tr>
<td>Age, mean, y</td>
<td>78.4</td>
<td>78.6</td>
<td>78.0</td>
<td>78.3</td>
<td>78.2</td>
<td>78.3</td>
<td>1.00</td>
<td>.51</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>50.7</td>
<td>52</td>
<td>52</td>
<td>53</td>
<td>53</td>
<td>53</td>
<td>1.03</td>
<td>.84</td>
</tr>
<tr>
<td>African American, %</td>
<td>28</td>
<td>14</td>
<td>18</td>
<td>22</td>
<td>22</td>
<td>20</td>
<td>1.45</td>
<td>.001</td>
</tr>
<tr>
<td>Comorbid condition, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>49.1</td>
<td>48</td>
<td>46</td>
<td>50</td>
<td>49</td>
<td>49</td>
<td>1.03</td>
<td>.007</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>35.8</td>
<td>32</td>
<td>35</td>
<td>36</td>
<td>35</td>
<td>37</td>
<td>1.14</td>
<td>.001</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>13.6</td>
<td>13</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>15</td>
<td>1.18</td>
<td>.001</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>17.7</td>
<td>14</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>19</td>
<td>1.29</td>
<td>.001</td>
</tr>
<tr>
<td>Mean Charlson comorbidity score</td>
<td>3.5</td>
<td>3.0</td>
<td>3.3</td>
<td>3.5</td>
<td>3.5</td>
<td>3.6</td>
<td>1.18</td>
<td>.001</td>
</tr>
<tr>
<td>Underwent invasive diagnostic or therapeutic vascular procedure, %</td>
<td>46.8</td>
<td>39.4</td>
<td>46.6</td>
<td>46.2</td>
<td>48.0</td>
<td>54.1</td>
<td>1.37</td>
<td>.001</td>
</tr>
<tr>
<td>Per capita income, $</td>
<td>18 867</td>
<td>18 707</td>
<td>19 226</td>
<td>18 721</td>
<td>18 822</td>
<td>18 857</td>
<td>1.01</td>
<td>.001</td>
</tr>
</tbody>
</table>
Overall, Amputation-Specific, and Revascularization-Based Spending

The mean total cost of inpatient vascular care in the year prior to amputation, including costs related to the amputation procedure itself, was $22,405 (95% CI, $22,145-$22,666) per patient. The hospital referral regions with the lowest mean spending on overall inpatient care in the year prior to amputation were Bismarck, North Dakota ($11,077 [95% CI, $7,799-$14,754]); Lebanon, New Hampshire ($13,206 [95% CI, $8,870-$17,541]); and Meridian, Mississippi ($14,120 [95% CI, $10,320-$17,921]). Costs in the year prior to amputation were highest in Paterson, New Jersey ($35,040 [95% CI, $23,658-$46,421]); Ridgewood, New Jersey ($38,070 [95% CI, $7,123-$69,017]); and Salinas, California ($42,613 [95% CI, $14,041-$71,185]) (Figure 2).

The mean regional spending on revascularization or debridement (exclusive of the amputation) in the year prior to amputation was $8316 (95% CI, $8,150-$8483) per patient. The regions with the lowest mean spending on revascularization or debridement were Muncie, Indiana ($12,777 [95% CI, $6,050-$5,582]); Duluth, Minnesota ($3,342 [95% CI, $1,141-$5,542]); and Topeka, Kansas ($4,199 [95% CI, $1,445-$6,993]). The regions with the highest mean spending were St Paul, Minnesota ($14,063 [95% CI, $4,698-$23,427]); Toledo, Ohio ($14,107 [95% CI, $9,763-$18,450]); and Harlingen, Texas ($14,120 [95% CI, $10,553-$17,686]).

The mean spending for the amputation procedure itself was $14,088 (95% CI, $13,898-$14,278) per patient. The regions with the lowest mean spending on amputation-related hospitalization were Lebanon, New Hampshire ($8,368 [95% CI, $6,076-$10,659]); Meridian, Mississippi ($9,408 [95% CI, $7,233-$11,484]); and Bismarck, North Dakota ($9,451 [95% CI, $6,382-$12,700]). The hospital referral regions with the highest mean spending on the amputation procedure itself were Paterson, New Jersey ($22,725 [95% CI, $12,859-$32,590]); Rapid City, South Dakota ($25,448 [95% CI, $3,605-$47,292]); and Salinas, California ($30,039 [95% CI, $12,195-$47,884]).

Variation in the Proportion of All Costs Related to Revascularization

The proportion of all costs related to hospitalizations for revascularization, cellulitis, or debridement represented less than 10% of all costs in many regions, such as Pueblo, Colorado (7%); Grand Junction, Colorado (6%); and Redding, California (10%). However, revascularization and other procedural care represented more than 50% of all costs in Waterloo, Iowa (51%); Burlington, Vermont (52%); and Sun City, Arizona (53%). In 90 of the 307 hospital referral regions, more than 40% of spending in the year prior to amputation was attributable to revascularization, rather than wound care or the amputation procedure itself. There was a positive correlation between the proportion of patients treated with revascularization and the costs incurred in the year prior to amputation (R = 0.38, P < .001) (Figure 3).

Differences in Patient Characteristics, by Quintile of Spending

We examined differences in patient characteristics between high- and low-spending regions, across quintiles of spending (Table 1). In regions where spending was highest (mean spending of $27,395), patients undergoing an amputation were more likely to be African American (14% in very slow spending regions and 20% in very high spending regions) and were slightly more likely to have coronary artery disease (13% in very slow spending regions and 15% in very high spending regions). Charlson comorbidity scores were slightly higher in regions where spending was highest (2.0 in very slow spending regions and 3.6 in very high spending regions). As shown in Table 1, although many of these differences were statistically significant given our large sample, clinical differences in patients across quintiles of spending were small.

Use of Invasive Vascular Care, by Quintile of Spending

In regions with higher spending, patients were more likely to be treated with invasive vascular care. For example, patients in higher spending regions were more likely to undergo a vascular procedure, such as a diagnostic or therapeutic angiogram, or an open surgical procedure (12.0 procedures per 10,000 patients in the lowest quintile of spending and 20.4 procedures per 10,000 patients in the highest quintile of spending; P < .001 (Figure 4)).

Adjustment for age, sex, race, diabetes, cardiac, and renal disease across quintiles of spending on vascular care accentuated these differences. Overall, patients living in regions in the highest quintile of spending were more than 3 times as likely to undergo a vascular procedure compared with patients in regions in the lowest quintile of spending (adjusted odds ratio for receiving a vascular procedure, 3.5 [95% CI, 3.2-3.8]; P < .001 (Table 2)). Similar trends were seen in both crude and adjusted analyses when individually examining open surgical revascularizations, therapeutic endovascular interventions, and diagnostic angiograms (crude rates are shown in Figure 4, and adjusted odds ratios are demonstrated in Table 2). We also found that regions where spending on vascular procedures was high also had high spending on the amputation procedure itself (R = 0.82, P < .001).

Correlation Between Spending and Amputation Rate, by Region

Despite the direct correlation between procedural care and overall spending, we did not find a direct relationship between overall spending in the year prior to amputation and regional amputation rate (R = 0.10, P = .06) (Figure 5). Even in risk-adjusted comparisons, there was no significant relationship between the likelihood of being in the highest quintile of the amputation rate and the overall spending rate (adjusted odds ratio, 0.95 [95% CI, 0.9-1.1]; P = .38) (Table 2).

Across practice patterns, the regions that were most aggressive in the use of endovascular interventions (in the highest 20th percentile) were likely to have a high-spending rate (R = 0.42, P = .002) and a high amputation rate (R = 0.40, P = .004). Conversely, regions that were not aggressive in the use of endovascular interventions (in the lowest 20th percentile) were not likely to be in the highest quintile of the amputation rate (R = 0.10, P = .36).
Discussion

In this descriptive analysis, we demonstrate that the costs of inpatient care in the year prior to amputation for patients with critical limb ischemia are more than $20,000 per patient for inpatient care alone. Furthermore, these costs vary more than 2-fold across hospital referral regions in the United States. Much of this variation is driven by differences in the use of revascularization treatments, rather than differences in patient char-
acteristics or costs related to the amputation itself. Moreover, there is little evidence to suggest that higher spending on invasive vascular care, especially endovascular care, in the year prior to amputation is associated with lower regional rates of amputation.

An accurate measurement of the true cost of critical limb ischemia is difficult. Nonetheless, prior studies have examined the inpatient costs of vascular care. For example, the Reduction of Atherothrombosis for Continued Health (REACH) Registry investigators studied the 2-year costs of 25,763 patients with systemic atherosclerosis. For patients who underwent revascularization or amputation, the costs easily averaged more than $10,000 per patient during the 2 years following enrollment in the registry—a cost much higher than the cost for those patients with mild coronary disease. European patients enrolled in the REACH Registry also demonstrated high costs when they required revascularization or amputation, but the magnitude of these costs was much less than in the United States. Finally, investigators from Minnesota extrapolated costs from statewide data to estimate that vascular care in the United States exceeds several billion dollars annually. Therefore, although our study is limited to only patients in Medicare, it provides estimates that are consistent with prior work and provides national-level detail for each individual region of the United States.

In our study, some regions spent less than $13,000, on average, in the year prior to amputation, whereas other regions spent $30,000 or more in the year prior to amputation. Using these “natural experiments,” we found little evidence to suggest that the most expensive strategies are associated with better outcomes. Although we acknowledge the well-known weaknesses of administrative claims, the patients were roughly similar in many important demographic and comorbidity variables across strata of spending, and adjustment for any statistical differences had little impact on our findings. Therefore, it appears unlikely that these large differences in spending can be explained simply by differences in patient characteristics.

This suggests that an important opportunity exists, given the right kind of evidence, to save money while still provid-
Prior work by our group and others has suggested that more vascular care—as measured by any type of diagnostic or therapeutic vascular procedure in the year prior to amputation—is related to lower risks of amputation. Are these findings discordant with those reported herein? We believe not. Dramatic differences in cost can exist and are related to the manner in which patients with critical limb ischemia are treated. For example, patients treated with a plain old balloon angioplasty or a single surgical revascularization will incur much lower costs than patients receiving multiple rounds of atherectomy, drug-eluting balloons, or other more expensive endovascular adjuncts. And, moreover, other strategies—such as primary amputation—may be the most cost-effective for patients with little chance of success with those kinds of treatment. Overall, however, our current analyses found that the highest spending rates—and the highest amputation rates—occurred in regions where multiple endovascular interventions were commonly used.

Different interpretations of the spending patterns described in our study are plausible as well. For example, one might argue that a region could provide high-quality preventive and invasive vascular care, and thereby prevent many patients from ever requiring amputation. Within a region like this, overall spending on vascular care would be high, and amputation rates would be low. However, we found few regions where spending and the overall intensity (measured by the number of procedures) of vascular care were high and where the amputation rates were low. In fact, only 3 of 307 regions (Fort Lauderdale and Fort Myers, Florida, and Madison, Wisconsin) fit this description. There-
Spending on Vascular Care and Amputation Rate

Our study has several important limitations. First, our work considered only inpatient costs and did not directly capture outpatient care. This outpatient care includes care that may be provided in wound care centers, outpatient angiography suites, and ambulatory imaging centers, and complexities exist in differentiating and categorizing these different types of outpatient treatment centers. Even though the significant burden of comorbidities carried by patients with critical limb ischemia most commonly necessitates hospital-based care, vascular care is increasingly provided in outpatient settings. Our future work will consider not only hospital-based care but also care that is provided in ambulatory environments.

Second, our observational data set derives from administrative claims, and therefore it cannot provide patient-level clinical detail as to the extent of PAD or surgical-level specifics at the time of revascularization, such as the absolute number of patients in each region with any symptoms of PAD. However, our cohort was purposefully designed to consider only those patients with the most severe PAD, such that all patients studied had a limb-loss rate of 100%, an algorithm reflected in our prior publications. A further understanding of these mechanisms in patients who do not ultimately undergo amputation requires examination in clinically detailed cohorts, such as those from national registries. Third, because sidedness is not indicated on Medicare claims, we cannot be sure that revascularization procedures and amputations all occurred on the same limb. However, prior work by our group suggested that differential sides occur in fewer than 10% of procedures.

Conclusions

Medicare spending on patients with severe PAD varies more than 2-fold across the United States, and the regions where spending is the highest perform the most revascularization procedures in the year prior to amputation. And although our prior work suggests that access to revascularization is a key component in preventing amputation, our current analysis offers little evidence to suggest that more expensive vascular care offers a marginal advantage over less expensive vascular interventions. In the current era of accountable care organizations, in which quality and cost must be equally considered, saving money and preventing amputation appear to be 2 achievable and complementary goals.


