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| **Title:** | Effects of Physician Social Networks on Surgical Quality, Safety, and Costs |
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| **Inclusive Dates of the Project:** | 09/30/2012 – 09/29/2016 |
| **Federal Project Officer:** | Tamara Willis, PhD, MPH |
| **Acknowledgment of Agency Support:** | The project described was supported by a grant from the Agency for Healthcare Research and Quality, and its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Agency. |
| **Grant Number:** | K08 HS20927 |

# I. Structured Abstract

**Purpose:** To test whether "teamwork" among physicians who provide care during a surgical episode is a determinant of surgical quality and costs

**Scope:** Wide variation in the quality and costs of surgical care suggests opportunities for improvement.

**Methods:** Among Medicare beneficiaries who underwent coronary artery bypass grafting between 2008 and 2011, we mapped relationships between all physicians who treated them during their surgical episodes. After aggregating across episodes to construct the physician social networks serving each health system, we then assessed the level of physician teamwork in these networks (with the bipartite clustering and assortativity coefficients). Finally, we fit multivariable regression models to evaluate associations between a health system's teamwork level and its 60-day surgical outcomes and episode costs.

**Results:** We observed substantial variation in the level of teamwork between health systems. While health systems with high and low teamwork levels treated beneficiaries with comparable comorbidity scores, these health systems differed over several sociocultural and healthcare capacity factors. After controlling for these differences, health systems with higher teamwork levels had significantly lower rates of emergency department visit, readmission, and mortality as well as lower episode costs.

**Key Words:** coronary artery bypass graft surgery; health outcomes; team-based care

## II. Purpose

To test whether "teamwork" (assessed with social network analytical tools) among physicians who deliver care to surgical patients is a determinant of surgical quality and spending

## III. Scope

*Variation in surgical quality and spending*

Surgical outcomes and spending vary significantly across hospitals in the United States, even after adjusting for case-mix differences. To reduce this variability, numerous quality improvement initiatives have been launched, including national and regional collaboratives, clinical pathways, and pay-for-performance programs. Despite some encouraging results, unwarranted variation in surgical outcomes and spending persists. Critics suggest that part of the problem relates to the one-dimensional nature of these initiatives, which primarily target surgeons' activities in the operating room and immediately following surgery.

*Surgery as a team sport*

However, there is growing recognition that surgery is not an "individual game" but rather a "team sport," involving multiple physicians who work together before, during, and after the surgical procedure. Frequent interactions between these physician teammates around shared patients may influence their collective performance. Specifically, as the number of their interactions increases, physician teammates will build trust and familiarity, be more likely to anticipate each other's practice patterns, and establish preferred ways of communication. Such enhanced teamwork could have salutary effects on surgical quality and spending, particularly for downstream events beyond the early perioperative period.

*Assessing physician teamwork with social network analysis*

Assessing teamwork requires the ability to measure and monitor the care delivered by all physicians involved in the surgical episode and their interactions. Social network analysis offers an elegant means of achieving this end. Networks are collections of points (or nodes) connected together in series of lines (called ties). In social networks, the nodes represent individuals within a particular social environment, and each tie connecting them denotes an interaction. The network perspective has provided valuable insight into an assortment of social and economic behaviors. More recently, it has been applied to the study of healthcare delivery.

## IV. Methods

*Subjects and databases*

For our study, we used Medicare claims from all beneficiaries age 66 and older who underwent coronary artery bypass grafting (CABG) in U.S. hospitals between January 2008 and December 2011. Several considerations make CABG attractive for the purposes of our study. First, CABG is commonly performed on older adults, and the procedure always requires inpatient admission, helping to ensure its reliable identification in Medicare claims. Second, outcomes for CABG vary widely across health systems for reasons not attributable to differences in clinical risk. Third, the complexity of CABG typically demands the attention of multiple providers. As a result, relationships between primary care physicians (PCPs), cardiologists, and cardiac surgeons may be especially important for shaping outcomes and spending.

To ensure complete data, we required for inclusion that beneficiaries had continuous enrollment in fee-for-service Medicare Parts A and B for 6 months prior to and extending 60 days after their admission for surgery. After identifying all beneficiaries who met these criteria, we then used the Medicare Provider Analysis and Review (MedPAR) file to determine the hospitals where the CABG was performed. These hospitals serve formally and informally as anchors for outpatient clinics and other facilities that constitute local health systems.

*Mapping the physician teams that serve the health systems where beneficiaries are treated*

Next, we identified all physicians who participated in the care of these beneficiaries during their surgical episodes through paid claims in the carrier, MedPAR, and outpatient files. We designated each beneficiary's treating surgeon as the surgeon who billed for cardiac surgery services closest to the surgery date. To determine each beneficiary's PCP, we used the plurality algorithm described by Pham and colleagues. To find care provided by other medical and surgical specialists, we constructed a time window that began 30 days prior to and extended 60 days after the index admission. We excluded claims submitted by physicians who do not participate in direct patient care and those who have limited roles in perioperative management.

We then aggregated across all CABG episodes at a given anchor hospital by calendar year to construct CABG-specific, bipartite physician social networks. For these networks, there were two sets of nodes (physicians and beneficiaries), and the ties connected one set of nodes to the other. We used these networks to represent the physician teams that serve each health system where beneficiaries are treated.

*Characterizing the level of physician teamwork in a health system*

To characterize the level of physician teamwork in a given health system, we calculated two network measures. The first is the bipartite clustering coefficient. Mathematically, the coefficient was measured as 4 * ($M/S$), in which $S$ is the number of physician pairs sharing a single patient (or more) in common and $M$ is the number of physician pairs sharing multiple patients in common. We multiplied the ratio of $M/S$ by four, because each $M$ contains four $S$ configurations. The number of $M$ relationships indicates the extent to which physicians re-partner with one another in the care of multiple patients.

The bipartite clustering coefficient summarizes the tendency for physicians in the network to assemble into dense, tightly interconnected groups (or cliques) around shared patients. In bipartite networks like ours, if the bipartite clustering coefficient is high, then many of the $L$ relationships—connections formed when physicians share in the care of only one patient—are redundant; therefore, they reinforce existing relationships between physicians. The measure ranges from 0 to 1. Values closer to 1 indicate higher levels of clustering in the network.

The second measure is known as assortativity. It captures the degree to which ties occur between nodes with similar properties (i.e., physicians of the same specialty). The coefficient ranges from -1 to 1. For our analysis, we used the reverse of assortativity, so higher values indicated deeper integration. A network will have negative index values if physicians share more patients with colleagues in their own specialty; a network will have positive values if physicians share more patients with colleagues in specialties different from their own. Lower connectivity across specialties may mean that communication among physicians overseeing different aspects of surgical care is weaker.

*Assessing surgical quality*

Our primary quality measures were 60-day rates of emergency department (ED) visit, readmission, and mortality—all three of which are plausibly influenced by physician teamwork. We considered an ED visit, readmission, or death to have occurred if a patient was discharged alive from the acute care hospital where he underwent surgery and was subsequently seen in the ED, was readmitted at any acute care hospital, or died within 60 days from the date of discharge. We excluded from the readmission definition patients who were transferred to another hospital or to a rehabilitation facility at the time of discharge. We aggregated all outcomes for individuals to the health system level to calculate rates per 1,000 discharges.

*Measuring surgical spending*

To examine whether differences in informal integration help explain surgical cost variation, we extracted data on 60-day episode payments for beneficiaries' surgical care using the MedPAR, carrier, and outpatient files. Following earlier studies, we decomposed payments into physician services, index hospitalization, readmission, and post-acute care components. We standardized payment values to account for regional price differences.

*Statistical analysis*
For analyses on surgical quality, our unit of analysis was the health system-year. In our initial analytic step, we used one-way analysis of variance to make comparisons between health systems stratified by their bipartite coefficient. For these comparisons, we broke our observations (hospital x years) into three equal groups. Specifically, we compared the communities (defined using hospital service area [HSA] boundaries) served by each health system over a range of sociocultural (total resident population, total black population, total Hispanic population, proportion of residents living below federal poverty line, proportion of residents with a bachelor's degree, proportion of residents living in a rural area) and healthcare capacity (number of acute care hospital beds per 1,000 residents, number of PCPs per 100,000 residents, number of medical specialists per 100,000 residents, number of surgeons per 100,000 residents) factors.

In addition, we evaluated differences between anchor hospitals where CABG was performed in health systems with low versus high teamwork levels. Specific hospital factors examined included the number of CABG patients treated, the number of physicians providing care around the CABG episode, the proportion of CABG patients from outside the core-based statistical area in which the hospital was located, and the mean Charlson score for the hospital's CABG patients. We also used data from the American Hospital Association Annual Survey to compare anchor hospitals with regard to their academic status.

We then estimated a series of multivariable regression models to assess whether surgical outcomes (60-day ED visit, readmission, and mortality) varied significantly by a health system's bipartite clustering coefficient. We used a random-effects negative binomial specification, treating the health system's bipartite clustering coefficient as a continuous predictor. In our random intercept models, we included random effects for health system. We adjusted our models for the hospital- and HSA-level factors described above as well as for the number of physicians in the network. All models had year fixed effects (i.e., a categorical variable for year was included in each model; the reference year was 2008).
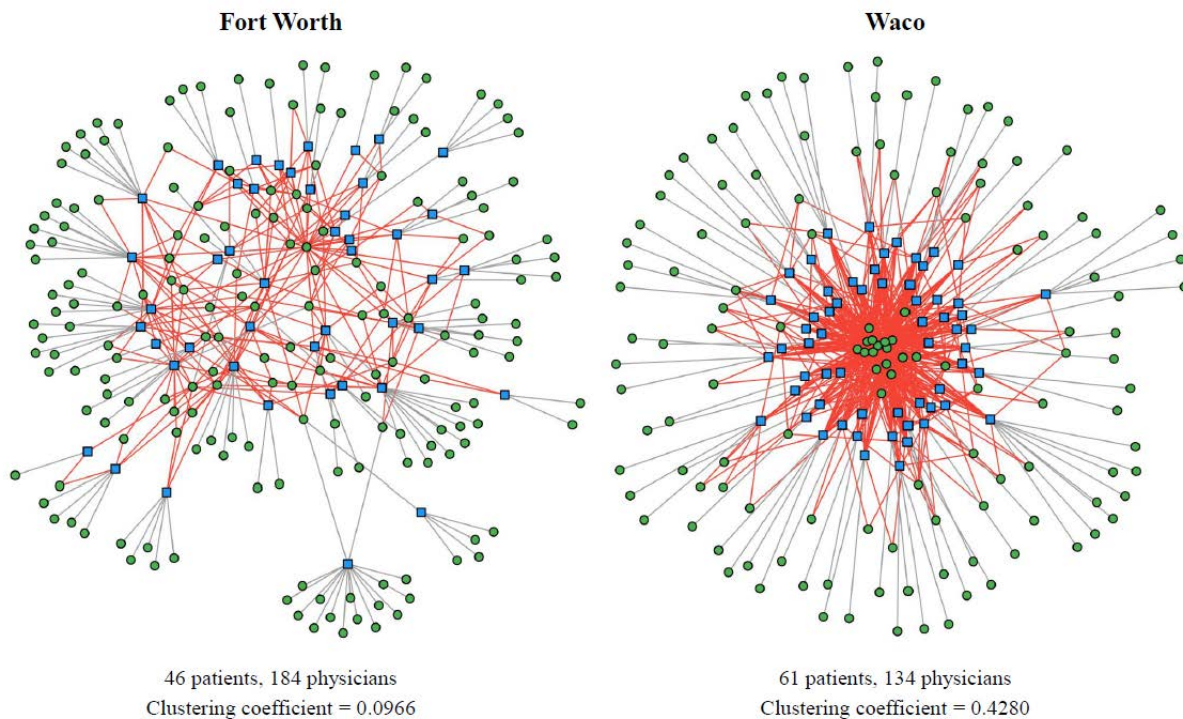
To assess whether surgical spending varied with a network's assortativity, we again used multivariable regression. The analytic unit in these regressions was the patient, but we measured networks at the health system level. Thus, we estimated multilevel models with health system random effects and clustered errors. Our models included year fixed effects. Our outcomes were price-adjusted episode payment components, and our predictor was assortativity. We controlled for confounders at the patient, health system, and community levels.

## V. Results

In total, we examined 251,630 Medicare beneficiaries who underwent CABG during the study period. Over the course of their surgical episodes, these beneficiaries were cared for by 466,243 physicians practicing in 1,186 health systems. The levels of clustering and assortativity for CABG varied substantially across these health systems.

As an example, Figure 1 shows two physician referral networks at health systems in Texas with higher and lower levels of clustering for CABG based on 2011 data. Despite being only 90 miles apart and having similar patient and physician counts, there are visually striking differences between the two with regard to their patterns of ties and, hence, clustering. For example, physicians in Fort Worth share relatively few patients with their colleagues, as indicated by the large number of gray-colored ties in the corresponding network diagram (Figure 1, left panel). With a bipartite clustering coefficient of 0.097, the Fort Worth health system has a relatively low level of teamwork for CABG, and the network appears to be fragmented with a highly decentralized structure. By contrast, the network diagram for Waco (Figure 1, right panel) is highly interconnected around a dense core of physicians who share many patients (as indicated by the many red colored ties). A bipartite clustering coefficient of 0.428 suggests a high level of teamwork through referral relationships around patients undergoing CABG in this health system.

**Figure 1.** Illustrative example of two health systems in Texas where CABG procedures were performed, based on 2011 data



**Fort Worth** — 46 patients, 184 physicians — Clustering coefficient = 0.0966

**Waco** — 61 patients, 134 physicians — Clustering coefficient = 0.4280

Compared with health systems with high clustering levels for CABG, those with low levels served communities with higher proportions of Black and Hispanic residents (Table 1, $P<0.001$ for each comparison). Their communities were less rural, and they had a higher proportion of college-educated residents ($P<0.001$ for each comparison). With regard to healthcare capacity, health systems with low clustering levels for CABG tended to have more PCPs and medical specialists but fewer acute care beds and surgeons per capita ($P<0.001$ for each comparison).

**Table 1.** Comparisons between communities served by health systems with low, moderate, and high levels of clustering (2011 data)

| | Low | | Moderate | | High | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Mean | SE | Mean | SE | Mean | SE | *P* Value |
| **Regional sociocultural factors** | | | | | | | |
| Total resident population (in thousands, log) | 13.65 | 1.08 | 13.16 | 1.11 | 12.75 | 1.05 | 0.00 |
| Proportion of residents living below federal poverty line (mean)* | 0.13 | 0.05 | 0.14 | 0.04 | 0.14 | 0.05 | 0.06 |
| Proportion of residents with a bachelor's degree (mean)* | 0.18 | 0.05 | 0.17 | 0.05 | 0.16 | 0.05 | 0.00 |
| Proportion of residents living in a rural area (mean)* | 0.24 | 0.19 | 0.26 | 0.20 | 0.31 | 0.23 | 0.00 |
| Total black population (in thousands, log) | 11.26 | 1.86 | 10.62 | 1.88 | 10.09 | 1.91 | 0.00 |
| Total Hispanic population (in thousands, log) | 11.45 | 1.73 | 10.76 | 1.79 | 10.16 | 1.74 | 0.00 |
| **Regional healthcare capacity factors** | | | | | | | |
| No. of acute care hospital beds per 1,000 residents (mean) | 2.29 | 0.58 | 2.39 | 0.63 | 2.44 | 0.70 | 0.00 |
| No. of PCPs per 100,000 residents (mean) | 69.41 | 17.03 | 67.20 | 16.38 | 66.16 | 15.16 | 0.02 |
| No. of medical specialists per 100,000 residents (mean) | 48.74 | 14.76 | 45.79 | 13.83 | 42.69 | 11.62 | 0.00 |
| No. of surgeons per 100,000 residents (mean) | 37.60 | 9.03 | 37.73 | 9.23 | 38.52 | 8.46 | 0.31 |

* Estimated using levels found in patients' home ZIP codes

Abbreviations: CBSA, core-based statistical area; No., number; PCP, primary care physician; SE, standard error

Characteristics of the hospitals within these local health systems where CABG procedures were performed are displayed in Table 2. Generally speaking, the level of comorbid illness for patients undergoing CABG was comparable between hospitals. However, hospitals in health systems with low levels of clustering for CABG were more likely to have an academic affiliation (*P*<0.001). In addition, they had larger physician staffs, treated more cardiac patients, and received more surgical referrals from outside their immediate geographic area (*P*<0.001 for each comparison) than those hospitals in health systems with high clustering levels for CABG.

**Table 2.** Comparisons between anchor hospitals of health systems with low, moderate, and high levels of clustering (2011 data)

| | Low | | Moderate | | High | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Mean | SE | Mean | SE | Mean | SE | *P* Value |
| **Anchor hospital characteristics** | | | | | | | |
| No. of CABG patients (mean) | 63.65 | 57.30 | 42.28 | 31.00 | 27.23 | 22.38 | 0.00 |
| No. of physicians caring for CABG (mean) | 238.77 | 224.94 | 151.34 | 95.10 | 90.16 | 58.54 | 0.00 |
| Proportion of CABG patients from outside the CBSA (mean) | 0.55 | 0.26 | 0.52 | 0.23 | 0.44 | 0.24 | 0.00 |
| Mean Charlson score for CABG patients | 2.31 | 0.61 | 2.39 | 0.56 | 2.36 | 0.65 | 0.22 |
| Academic status | 0.63 | 0.48 | 0.53 | 0.50 | 0.44 | 0.50 | 0.00 |

Abbreviations: CABG, coronary artery bypass grafting; CBSA, core-based statistical area; SE, standard error

After accounting for these differences between health systems, we found that higher clustering was associated with significantly improved CABG outcomes. Adjusted rates of ED visit, readmission, and mortality, stratified by a health system's teamwork level for CABG, are displayed in Figure 2. Health systems with physician teams that worked together frequently around CABG episodes achieved ED visit, readmission, and mortality rates that were 24.6%, 24.4%, and 28.4% lower, respectively, than those of health systems with low clustering levels. Put differently, initiatives seeking to foster physician teamwork in health systems with low to moderate levels at baseline could reduce the number of ED visits, readmissions, and deaths after CABG by 71.4, 53.7, and 16.8 per 1,000 discharges each year, respectively.

**Figure 2.** Adjusted rates (per 1,000) of ED visit (A), readmission (B), and mortality (C) stratified by the level of teamwork for CABG in a health system
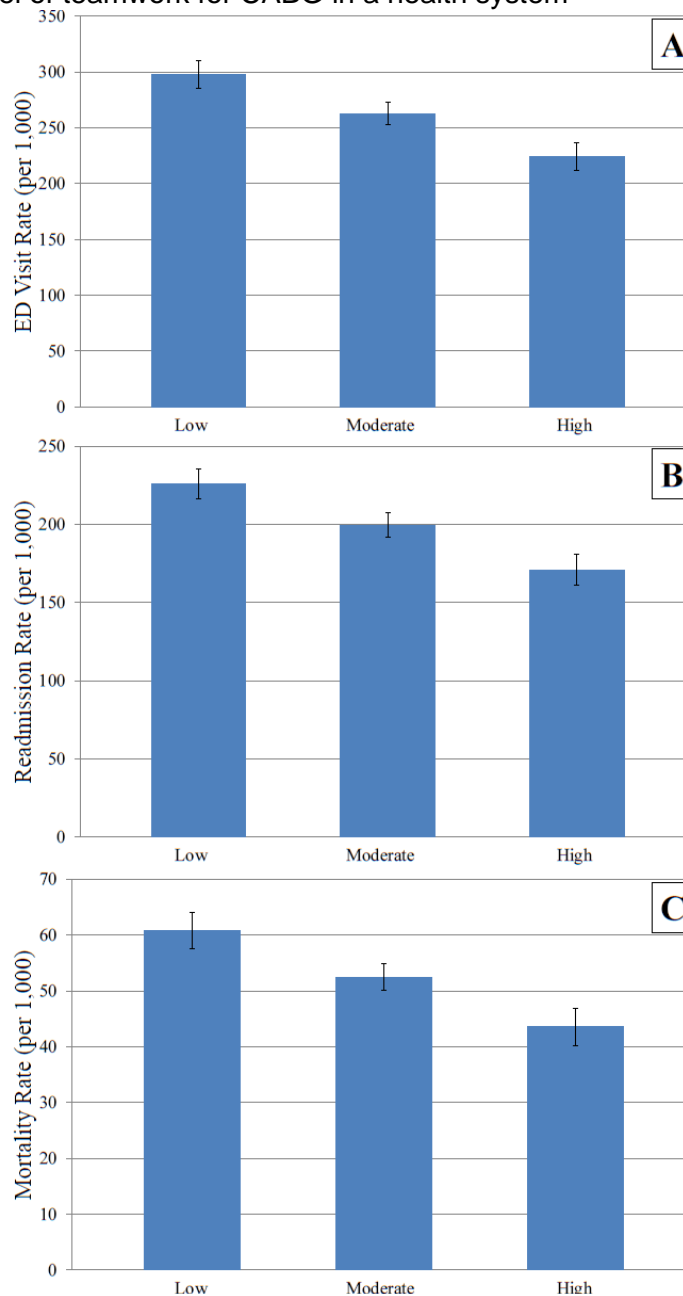


Our next analyses examined associations between network assortativity and episode payments for CABG. After adjusting for patient, health system, and community factors, we found significant associations. Our results are shown in Figure 3 by the assortativity tercile groups. Figure 4 compares predicted costs for the four payment components among health systems with high assortativity relative to those with low levels. Although health systems with higher teamwork have better performance on all four components, savings are most pronounced for readmission and post-acute care. Here, we observe that health systems in the high-integration group have predicted costs that are 13.03% and 5.82% lower, respectively, than in the low group.

To put these numbers in perspective, consider that roughly 250,000 CABG procedures are performed annually in the United States. Assuming these procedures were done by health systems with high teamwork, we would expect savings of $130,500,000 on readmissions relative to what we would expect if the procedures were done by health systems with low teamwork. The corresponding expected savings on post-acute care is $108,500,000. For *total* episode payments, the expected savings are $640,277,500 annually.

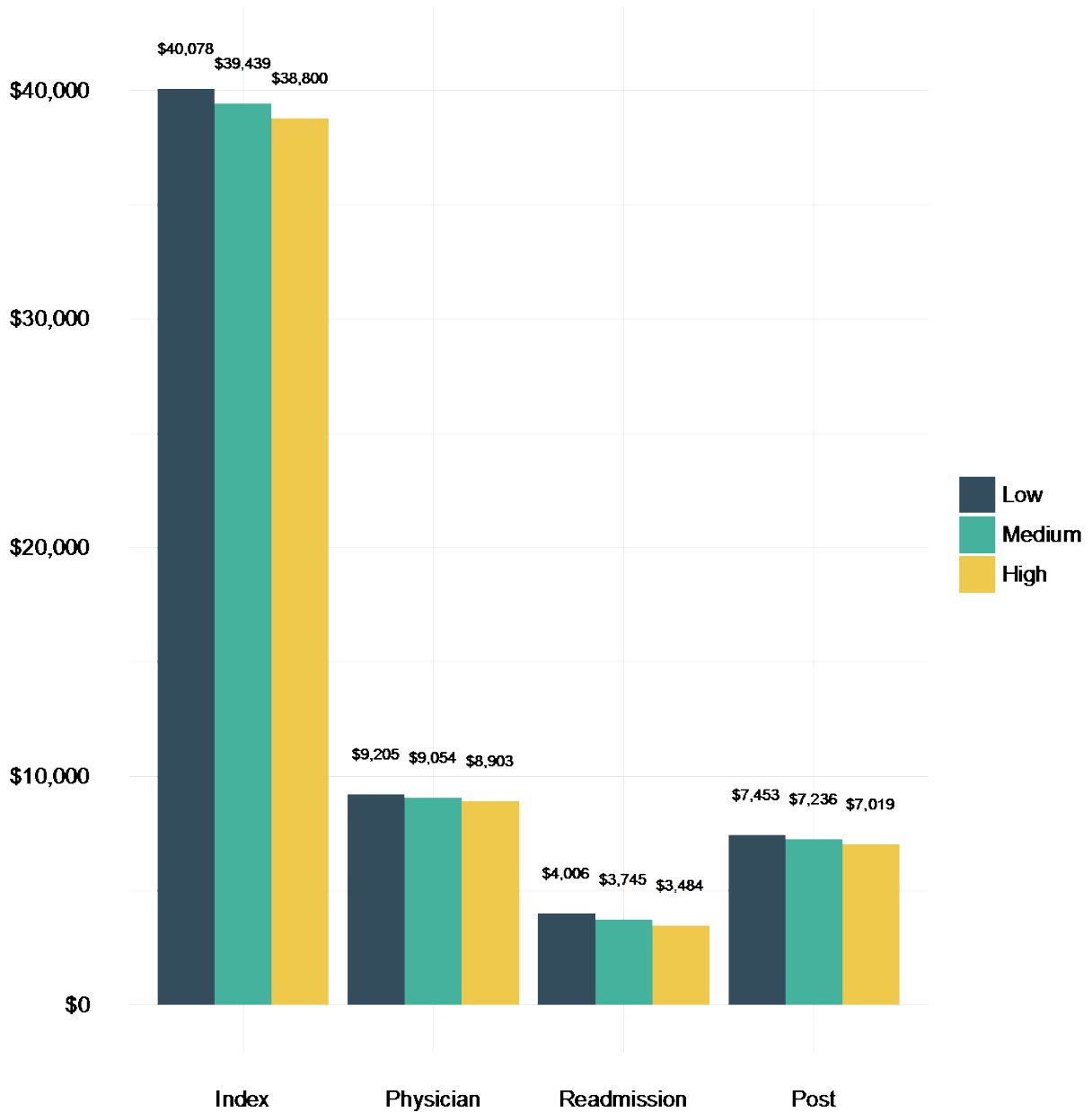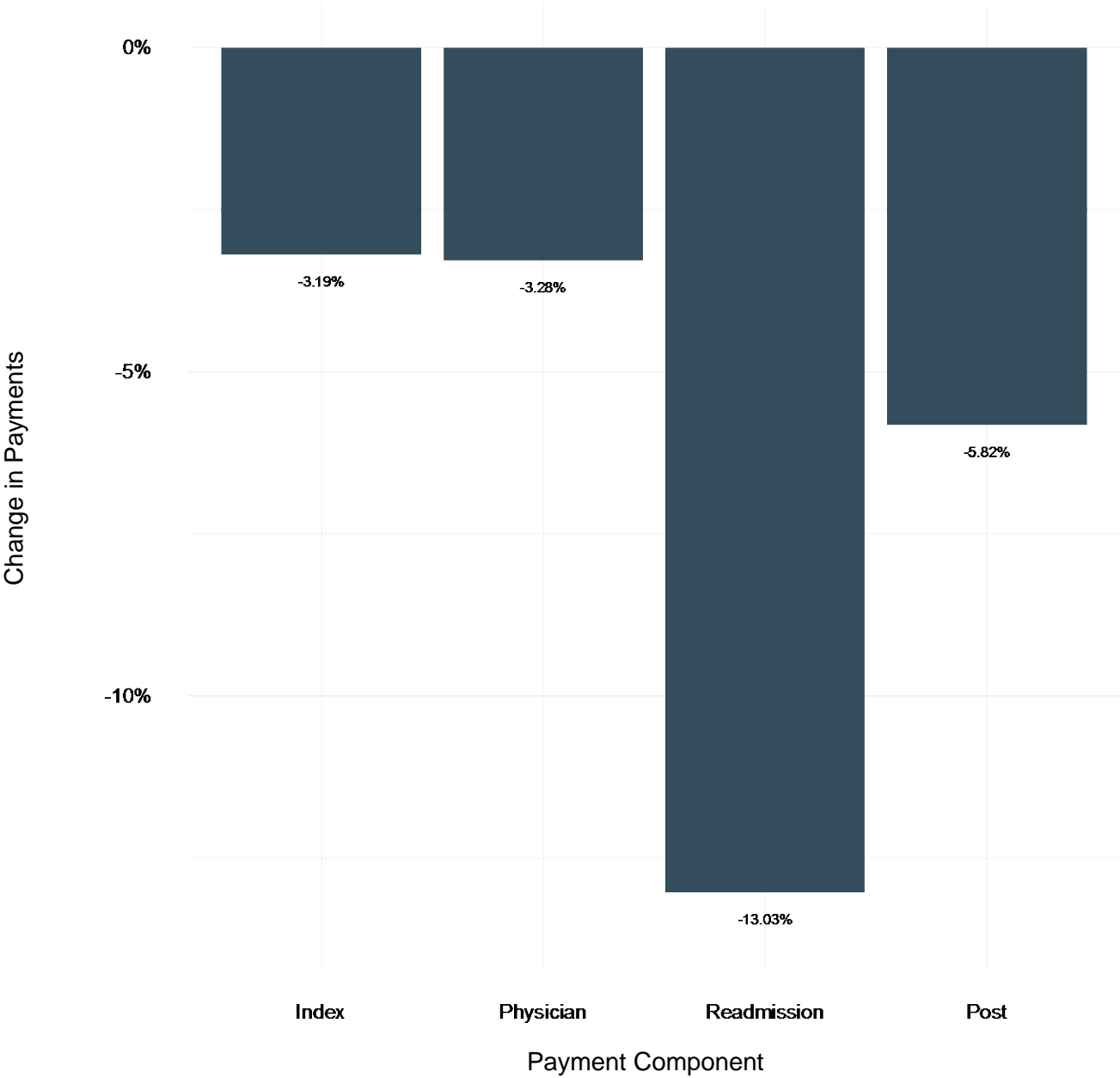**Figure 3.** Adjusted component payments for CABG across three levels of assortativity

**Figure 4.** Relative change in component payments for CABG moving from low to high teamwork

## VI. List of Publications

Hollingsworth JM, Saigal CS, Lai JC, Dunn RL, Strope SA, Hollenbeck BK, Urologic Diseases in America Project: Surgical quality among Medicare beneficiaries undergoing outpatient urological surgery. J Urol 188(4): 1274-1278, 2012.

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Funk RJ, Owen-Smith J, Landon BE, Birkmeyer JD, Hollingsworth JM: Identifying natural alignments between ambulatory surgery centers and local health systems: Building broader communities of surgical care. Med Care [Epub ahead of print]: Aug 20, 2015.

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