NBER WORKING PAPER SERIES

COMPARATIVE EFFECTIVENESS RESEARCH, COURAGE, AND TECHNOLOGICAL ABANDONMENT

David H. Howard
Yu-Chu Shen

Working Paper 17371
http://www.nber.org/papers/w17371

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2011

Comparative Effectiveness Research, COURAGE, and Technological Abandonment
David H. Howard and Yu-Chu Shen
NBER Working Paper No. 17371
August 2011
JEL No. I11,O33

ABSTRACT

When a major study finds that a widely used medical treatment is no better than a less expensive alternative, do physicians stop using it? Policymakers hope that comparative effectiveness research will identify less expensive substitutes for widely-used treatments, but physicians may be reluctant to abandon profitable therapies. We examine the impact of the COURAGE trial, which found that medical therapy is as effective as percutaneous coronary intervention (PCI) for patients with stable angina, on practice patterns. Using hospital discharge data from US community, Veterans Administration, and English hospitals, we detect a moderate decline in PCI volume post-COURAGE. However, many patients with stable angina continue to receive PCI. We do not find differences in PCI volume trends by reimbursement scheme or hospitals' teaching status, ownership, or degree of vertical integration.

David H. Howard
Department of Health Policy and Management
Emory University
1518 Clifton Road NE
Atlanta, GA 30322
dhhowar@emory.edu

Yu-Chu Shen
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road
Monterey, CA 93943
and NBER
yshen@nps.edu

When a major study finds that a widely used medical treatment is no better than a less expensive alternative, do physicians stop using it? The Patient Protection and Affordable Care Act (i.e., the health reform bill) includes a dedicated funding stream for comparative effectiveness research, which subjects competing treatments to head-to-head trials, of approximately $500 million annually. The premise behind comparative effectiveness research is that expensive treatments often diffuse into clinical practice without evidence that they are better than existing therapies (Chandra et al. 2011). Policymakers hope that comparative effectiveness studies will identify ineffective but costly treatments, leading to cost savings. However, it is unclear how evidence from comparative effectiveness research studies, and studies that report "negative" results in particular, influence medical treatment patterns. The same factors that promote rapid adoption of new medical technologies – fee for service reimbusement, third party payment, etc. (Emanuel and Fuchs 2008) – may retard the abandonment of widely-used technologies found to be ineffective.

Percutaneous coronary intervention (PCI) is an invasive procedure to open clogged coronary arteries. Medicare spent over $5 billion on PCIs in 2005 (Committee on Finance 2010). In 1999 the Department of Veterans Affairs initiated a multi-million dollar study, the COURAGE trial, to compare PCI and medical therapy versus an inexpensive regimen of medical therapy alone in patients with stable angina. The study, which was published in April 2007 in the *New England Journal of Medicine* (Boden et al. 2007), found that the treatments were equivalent in terms of survival time and heart attack risk. In this paper, we assess the impact of the widely-publicized COURAGE trial on the abandonment of PCI as a treatment for stable angina. We also compare trends in PCI volume between 1) health systems where cardiologists are compensated via fee-for-service and systems where cardiologists are salaried and 2) hospital organizational environments that may affect physicians' responsiveness to negative evidence. While it is difficult to

precisely identify the impact of the COURAGE trial in light of pre-existing trends, our results suggest that 1) COURAGE had a small-to-moderate impact on practice patterns and 2) many patients with stable coronary disease continue to receive PCI as primary therapy.

2. Technological abandonment

2.1 Adoption and abandonment

New medical technology is responsible for most of the growth in health care spending (Newhouse 1992). Naturally, there is an extensive literature on technology diffusion in health care. Few papers address technological abandonment, either in health care or non-health care settings.[1] Abandonment may be uncommon outside of health care settings because unsuccessful innovations are quickly jettisoned and only successful innovations are widely adopted. In health care, by contrast, many technologies diffuse into clinical practice without evidence of benefit (Fuchs 1968; 1986). Given that randomized controlled trials are costly and the knowledge they produce is a public good, production of evidence will be suboptimal (Murphy and Topel 2006), a market failure that federally- sponsored comparative effectiveness research is designed to address.

A number of factors may push physicians to adopt untested therapies, including reimbursement incentives, manufacturer's marketing efforts, a desire to achieve prestige through technology acquisition, and a cultural faith in technological progress (Emanuel and Fuchs 2008; Teplensky et al. 1995).[2]

Once adopted, unproven technologies often remain in use. Most models of adoption under uncertainty assume that producers eventually learn whether the

[1] Technological abandonment refers to instances where a technology is replaced by an older, pre-existing treatment alternative or technology.
[2] David Eddy (1984), an early advocate of comparative effectiveness research, has described the prevaling mindset as "When in doubt, do it".

new technology is better than the old one (Young 2009), but physicians may never learn about the effectiveness of new treatments absent large randomized controlled trials. Patient outcomes are variable, making it difficult to draw inferences about effectiveness based on the patient panel of a single physician or hospital. In situations where patients receive treatment in one setting but follow-up care in another, physicians may not even observe outcomes in their own patient populations.

2.2 Reimbursement incentives

Comparative effectiveness studies that pool patients from multiple providers can overcome the inherent limitations of inferring treatment effects based on the historical experience of a single physician or hospital. Physicians' incentives to act on new information vary based on how they are compensated. Barros and Martínez-Giralt (2010) model adoption of a new technology under different reimbursement arrangements assuming that providers value their own financial performance and patient health. They show that when providers earn higher margins on the new technology, they may adopt the treatment even if it provides no benefit to patients.

Under Medicare's resource based relative value scale, which is widely used by private payers in the US, payments for PCI are higher than payments for medical management. Medicare's 2011 payment to a physician for insertion of a stent is $873 (Current Procedural Terminology code 92980). The payment for an office visit for medical management is about $54 (code 90862). Comparing these payments does not precisely represent the incentives facing physicians – physicians may bill for multiple services during a PCI and patients on medication may require multiple

visits – but it does give a sense of the magnitude of the difference in reimbursement levels.[3,4]

The market for PCI is particularly prone to physician-induced demand. Cardiologists often act as both diagnosticians and proceduralists. Patients with stable angina are referred for diagnostic imaging to define both the extent and severity of obstructive coronary artery disease. The imaging process requires that patients undergo cardiac catheterization. Once the patient has been prepped, anesthetized, and the cardiologist has established arterial access, it is relatively straightforward to perform PCI. Some observers argue that this process leads to a "diagnostic-therapeutic cascade" where patients initially brought in for evaluation end up undergoing PCI.[5] Because PCI often immediately follows diagnosis, patients and insurers have relatively little input into the care process.

Most empirical analyses find evidence consistent with the prediction that low powered reimbursement schemes (e.g. fee-for-service) are associated with greater use of technology. A study of the diffusion of PCI and bypass surgery for heart attack patients in industrialized countries found that diffusion tended to be more rapid in countries where reimbursement systems favor adoption (Bech et al. 2009; TECH Research Network 2001).[6] Baker and Phibbs (2002), Baker and Wheeler

---

[3] Medicare and other insurers make payments to physician groups, not individual physicians. However, most cardiology groups closely link physician compensation with procedure volume.

[4] PCI is performed in hospitals while medical therapy is administered in physicians' offices, and so, hospitals benefit when physicians recommend PCI. Medicare hospital payments for PCI range from $10,000 to $18,000. Federal law prohibits hospitals from providing monetary incentives to non-employed physicians for referring patients, but they can offer marketing and support services that serve as subtler inducements to recommend hospital-based care.

[5] Cardiologists jokingly refer to the "oculostenotic reflex" that causes them to automatically perform PCI once the see evidence of a blockage (i.e. stenosis).

[6] Baker and Wheeler (1998) find that the number of MRI machines per capita was negatively associated with the market share of health maintenance organizations in the mid 1990s. It is unclear if the correlation is driven by reimbursement policies,

(1998), and Mas and Seinfeld (2008) report that managed care slowed the adoption of cost-increasing medical technologies, though Baker and Spetz (1999) find no evidence of a managed care effect. Studies of the impact of the Medicare prospective payment system on technology adoption and use report mixed effects (Acemoglu and Finkelstein 2008; Kane and Manoukian 1989; Sloan et al. 1988), possibly reflecting the complex set of incentives inherent in the payment scheme (McClellan 1997).

2.3 Organizational form

Another factor that may retard abandonment of ineffective technologies is organizational fragmentation in the health system. Physician practice is organized around single specialty groups. Many observers have remarked that under this arrangement, physicians do not focus on the "whole patient". Rather, organizations in health care are organized around delivering specific medical technologies (Enthoven and Tollen 2005; Schroeder and Showstack 1977). For example, cardiologists deliver PCI. Specialists may be reluctant to abandon the technologies that help to define their specialty.

Integrated health systems that are able to provide multiple treatments may display more flexibility in responding to comparative effectiveness research, especially in cases where patients in non-integrated systems must cross organizational boundaries to access alternative treatments.

Counteracting this effect, integrated delivery systems that are subject to fee-for-service reimbursement may encourage its physicians to engage in "self referral". In the case of stable angina, an integrated system could increase its revenues by promoting referrals from primary care physicians and non-interventional cardiologists to interventional cardiologists. Studies of the entry of physician-owned cardiac specialty hospitals (Barro et al. 2006; Mitchell 2007; Nallamothu et al. 2007;

---

other forms of cost control (e.g., utilization review), or unobserved market characteristics.

MedPAC 2006) and 1990s-era physician-hospital alignment (Madison 2004; Cuellar and Gertler 2006) find that integration is associated with increased volume and treatment intensity. For this reason, the Patient Protection and Affordable Care Act severely limits entry of new physician-owned specialty hospitals.

Other characteristics of providers may influence their receptivity to negative results. Private hospitals (especially for-profits), for example, have a strong incentive to invest in innovation that might be difficult to relinquish because of sunk costs (Grossman and Hart 1986; Hart 1995; Hart, Shleifer and Vishny 1997). Physicians practicing in for-profit hospitals may be less willing to abandon lucrative treatments. Hospitals whose mission involves educating the next generation of physicians, i.e. teaching hospitals, or those that specialize in cardiac care might be more receptive to studies that demonstrate "best practice" treatment options.

2.4 Empirical evidence

Few studies have examined the impact of comparative effectiveness research studies reporting negative results.[7] Duffy and Farley (1992) describe the impact of negative trial results on use of intermittent positive pressure breathing therapy as a treatment for chronic obstructive pulmonary disease. They found that use was slow to decline, and many patients continued to receive the therapy four years after the results were published. Stafford et al. (2006) studied abandonment of costly calcium channel blockers and angiotensin-converting enzyme inhibitors for patients with hypertension following negative trial results. They found that evidence had a "modest" effect on use but many patients continued to receive these drugs as first-line therapy. A high profile 2002 study failed to find evidence of a benefit of arthroscopy for osteoarthritis of the knee (Moseley et al. 2002). There was a slight

[7] The impact of disclosure of previously unknown side effects on abandonment has been widely studied. Here, we restrict attention to the impact of trials that report equivalence results.

decline in use in England and Ontario between 2002 and 2004 in patients with a diagnosis of osteoarthritis, though there were increases in the use of the procedure for other diagnoses (Hawker et al. 2008). Howard et al. (forthcoming) report that use of high dose chemotherapy followed by autologous hematopoietic stem cell transplantation declined rapidly following the release of negative clinical trial results.

3. The COURAGE trial

Chronic stable angina is characterized by chest pain during exertion caused by a narrowing of the coronary arteries. Treatment options include revascularization via PCI or a low cost regimen of medical therapy and lifestyle modification. PCI entails cardiac catheterization, use of balloon angioplasty to mechanically open the artery, and, in most cases, placement of a stent to maintain blood flow. The Department of Veterans Affairs-sponsored Clinical Outcomes Using Revascularization and Aggressive Drug Evaluation (COURAGE) trial randomized 2,287 patients with stable angina to receive optimal medical therapy alone or PCI plus medical therapy between 1999 and 2004.

The main finding from COURAGE was that there was no difference between treatment arms in all-cause mortality or acute myocardial infarction (AMI). The results, which were published in the *New England Journal of Medicine* in April 2007, were widely publicized and "shook the world of cardiology" (Winstein 2010).[8]

A subsequent analysis found that while patients in the PCI arm experienced earlier resolution of symptoms, quality of life was no different after 3 years (Weintraub 2008). Based on COURAGE results, Weintraub et al. (2008) calculate

[8] Some cardiologists have questioned the external generalizability of the COURAGE trial and its relevance to current cardiology practice (Curzen 2010).We do not wish to weigh in on this debate, except to note that specialists may be more likely to scrutinze studies that will potentially result in revenue-reducing practice changes.

that lifetime costs for stable ischemic heart disease patients treated with PCI are over $9,000 higher than for patients treated with optimal medical therapy alone.

Prominent cardiologists perceive that fee-for-service reimbursement is a major obstacle to implementing the COURAGE results. Peterson and Rumsfeld (2008) write: "[The COURAGE trial] underscores a major challenge to clinicians — how to successfully execute a strategy of optimal medical therapy in a health care system that provides strong financial incentives for PCI but few rewards for careful management of medications." The principal investigator of the COURAGE trial, Dr. William Boden, echoed these sentiments: "What's going to continue to drive practice is reimbursement," (Winstein 2010).

A handful of studies have examined the impact of the COURAGE trial and the appropriateness of care for patients with stable angina. An analysis of data from 10 hospitals in Maine, New Hampshire, and Vermont found that there was a 16% decline in PCI volume post-COURAGE (Ahmed et al. 2011). The proportion of patients receiving PCI who had a diagnosis of stable angina (i.e. the target population of the COURAGE trial) declined from 21% to 16%. Borden et al. (2011) analyzed changes in the use of optimal medical therapy in patients undergoing PCI before and after publication of the COURAGE trial. He found that there was a 1 percentage point increase in receipt of medical therapy post-COURAGE. The study restricted attention to patients receiving PCI and did not report trends in PCI volume. Chan et al. (2011) used a rating system to assess the appropriateness of PCIs performed at 1,091 US hospitals between July 1, 2009, and September 30, 2010. Of the 500,154 procedures they examined, 144,737 (29%) were for stable angina. Of these, 72,911 (50%) were rated as "appropriate", 54,988 (38%) were rated as "uncertain", and 16,838 (12%) were rated as inappropriate. Only the Ahmed et al. paper tracks trends in PCI volume over time, but the sample of hospitals is small and self-selected. Whether COURAGE affected practice patterns in the US and other health systems remains an open question.

4. Aggregate Trends

4.1 Overview

Using data capturing discharges from US community hospitals, US Veterans Administration hospitals, and English National Health Service hospitals, we analyze trends in PCI volume by indication. In each case, we report the number of discharges per quarter. The data include records for inpatient PCIs and so-called "23-hour admissions" for PCI. We identified patients undergoing PCI using procedure codes.[9] We do not have data on receipt of medical therapy. Medical therapy is administered on an outpatient basis. It is difficult to identify patients with stable angina who are receiving medical therapy as an alternative to PCI in standard claims databases.

4.2 US Community Hospitals

Figure 1 presents long-run trends in quarterly PCI volume from the National Hospital Discharge Survey (NHDS), a random sample of hospital discharges in US community hospitals. The sample size is over 300,000 in most years but, because of budget cuts, is only 120,000 in 2008. NHDS includes sample weights for producing national estimates of procedure volume.

We group patients into two mutually exclusive categories. The "Other diagnoses, Elective" group includes patients without a diagnosis of AMI where the admission type was recorded as "Elective". The "AMI and Other diagnoses, Non-Elective" group includes all patients with a diagnosis of AMI and patients with other diagnoses with an "urgent" or "emergency" admission. The first group

[9] The codes for PCI are 36.01, 36.02, 36.05, 36.06, 36.07, and 36.09. These are often preceded by code 00.66.

includes many patients who would have met the COURAGE inclusion criteria, though there may be some patients who would have been excluded.

The data show that PCI volume in the "Other diagnoses, Elective" group plateaued between 2003 and 2006 but declined rapidly following publication of the COURAGE trial. There was also a decrease in PCI volume in late 2007 among patients in the "AMI and Other diagnosis, Non-elective" group (note that the y-axis for this group is compressed). A paper presented at a September 2006 cardiology meeting raised concerns about the safety of drug-eluting stents, a device used in a large share of PCIs.[10] Although cardiologists could have substituted bare metal stents, the findings, which have been contradicted by subsequent research, temporarily depressed demand for PCI among patients regardless of diagnosis.

Figure 2 presents PCI volume trends in Arizona, California, Florida, Massachusetts, Maryland, New Jersey, and New York using the State Inpatient Discharge databases. These databases capture 100% or close to 100% of hospital discharges, depending on the state.[11]

Arizona, California, Florida, Massachusetts, Maryland, New Jersey, and New York represent about 35 percent of US population. The average PCI rate per 1,000 fee-for-service Medicare enrollees in these states in 2007, as reported by The Dartmouth Atlas of Health Care (2011), is 9.8, with a range of 7 (Massachusetts) to 11.9 (Arizona). Nationally, the rate is 10 with a range of 3 (Hawaii) to 14.3 (Arkansas).

We grouped patients into two categories 1) Stable Angina/Other and 2) AMI/Unstable angina.[12] Patients in the first group include those with a diagnosis of

---

[10] Camenzind E, Steg PG, Wijns W. A metaanalysis of first generation drug eluting stent
programs. Presented at Hotline Session I, World Congress of Cardiology 2006, Barcelona, September 2–5, 2006. abstract.

[11] The advantage of using these data, as opposed to databases that randomly sample hospitals, is that trends in procedure volume are not affected by year-to-year changes in the sample of hospitals.

[12] The ICD-9 codes are AMI: 410.X, and unstable angina: 411.1.

stable angina or with a general ischemic heart disease diagnosis code but no diagnosis of AMI or unstable angina. Stable angina is rarely recorded as a diagnosis, and so it is not possible to specifically identify these patients. The second category includes patients with a diagnosis of heart attack (i.e. acute myocardial infarction [AMI]) or unstable angina. These patients have serious, acute symptoms that require immediate medical attention.

Pre-COURAGE, patients with stable angina accounted for one-third of PCI procedures (Peterson and Rumsfeld 2008), so it likely that a large share of patients in the Stable Angina/Other group would have satisfied the COURAGE inclusion criteria. None of the patients in the AMI/Unstable angina would have been considered candidates for COURAGE.

Figure 2 shows that PCI volume in the Stable Angina/Other group declined following publication of the COURAGE trial. For reasons that are unclear, PCI volume declined between the second and third quarters of 2006. However, based on the results presented in Figure 1, it does not appear that this was a continuation of a pre-existing trend.

PCI volume also declined among patients with a diagnosis of AMI or unstable angina between the first and second quarters of 2007. The decline may reflect concerns about the safety of drug-eluting stents or an informational spillover of the COURAGE trial to excluded patient groups.

Our reading of the data in Figures 1 and 2 is that publication of the COURAGE trial led to a decrease in PCI volume. However, many patients with stable coronary syndrome continue to receive PCI.

4.3 Veterans Administration hospitals

Figure 3 displays PCI volume trends in Veterans Administration medical centers. We calculated trends using the Patient Treatment File, a census of discharges from US Veterans Administration Medical Centers. Like the State

Inpatient Discharge databases, the Patient Treatment File includes diagnoses codes but does not allow us to specifically identify patients meeting the COURAGE trial inclusion criteria.

Veterans Administration hospitals are notable in several respects. First, many Veterans Administration hospitals enrolled patients in the COURAGE trial. Second, cardiologists in the Veterans Administration are salaried and hospitals are subject to a global budget. Some cardiologists split their time between Veterans Administration hospitals and academic medical centers. Their practice styles may fall in-between the practice patterns of physicians subject to salary or fee-for-service reimbursement alone.

The data show that PCI volume declined post-COURAGE in the Stable angina/Other group but was steady in the AMI/Unstable angina group.

4.4 English hospitals

Figure 4 displays trends in PCI volume in English hospitals. We calculated PCI volume using the Hospital Episode Statistics database, a census of discharges from English National Health Service hospitals. The data include diagnosis codes, but not other clinical indicators, and capture admissions by private pay patients.

English cardiologists are salaried. Prior to 2002, hospitals were subject to budgets. In 2002 the National Health Service adopted a fee-for-service-like reimbursement scheme, "Payment by Results" that pays hospitals for each admission, similar to Medicare's prospective payment system. Based on the trends depicted in the Figure, it does not appear that the COURAGE trial had an impact on PCI volume. We discuss this result below.

4.5 US-VA-England comparison

Aggregate trends in PCI volume are summarized in Table 1. The table also displays PCIs per 100,000 persons age 45 and older in the US and UK populations and the number of patients admitted with a diagnosis of AMI, a rough measure of trends and cross-sectional differences in the underlying prevalence of heart disease.

According to the SID and NHDS, PCI volumes declined between 2006 and 2008 in US community hospitals. The magnitude of the decline in percentage terms was much larger in the Stable angina/Other and Elective groups.

PCI rates in the US are much higher than those in England, possibly reflecting differences in disease prevalence. Banks et al. (2006) report that the prevalence of heart disease is anywhere from 20% to 50% higher in the US versus the UK. However, we find that the AMI rate (column 3 of the table) is similar. Differences in PCI rates may also reflect differences in practice patterns. Heart attack patients in Canada and the UK are substantially more likely to receive PCI or surgery compared to patients in the US (Adams et al. 1998; Kaul et al. 2005; Mark et al. 1994; Rouleau et al. 1993; TECH Research Network 200; Yusef et al. 1998.)

PCI rates did not decline in England following COURAGE. Pre-COURAGE PCI rates were lower in England, and so there may have been fewer opportunities to substitute medical therapy for PCI. Yet, over half the patients undergoing PCI in the UK receive the procedure for stable angina and other forms of stable coronary disease (NHS Information Center 2007), and so there are probably many patients receiving PCI who could be safely treated using medical therapy.

The impact of COURAGE on PCI volume in England may have been dampened by capacity constraints. Historically the demand for PCI has exceeded PCI capacity, resulting in waiting lists. Capacity constraints have a smoothing effect on realized procedure volume. Not surprisingly, we find that there is little

quarter-to-quarter variation in PCI volume in England (Figure 4) compared to the US (Figure 3).

If demand exceeds capacity, then a shift from PCI to medical therapy would show up as a decline in waiting times rather than a change in observed procedure volume. In our sample, waiting time among patients in the Stable angina/Other group declined from 53 days in 2006 to 37 days in 2008. Waiting time among patients with AMI/Unstable angina declined from 49 days to 32 days.

5. Organizational environment

Hospitals' organizational environment may affect how physicians responded to the COURAGE trial. We assess the impact of hospitals' organizational environment within the US by linking the State Inpatient Discharge data with hospital characteristics from the American Hospital Association (AHA) annual survey from 2006 to 2009. The estimation sample consists of hospital-quarter of year observations.

We estimated regression models of the following form:

$$\left(PCI_{it}^{SA/O} - PCI_{it}^{AMI/UA}\right) = \sum_j \beta^j \times CRG_t \times x_i^j + \sum_k \beta^k \times w_{it}^k + \mu_i + \gamma_t + \varepsilon_{it}$$

Where $PCI_{it}^{SA/O}$ and $PCI_{it}^{AMI/UA}$ are the number of PCIs performed in hospital i at time t in patients with stable angina/other diagnoses and AMI/unstable angina, respectively. CRG_t is an indicator equal to one following publication of the COURAGE trial, x_i^j are a set of time-invariant hospital characteristics, w_{it}^k are a set of time-variant hospital characteristics, μ_i are hospital-specific fixed effects, γ_t are year and quarter fixed effects, and ε_{it} is an i.i.d. error term.

Hospital-level PCI volume is highly skewed, and so we chose to specify the dependent model as a difference, rather than controlling for $PCI_{it}^{AMI/UA}$ on the right

hand side of the regression, to "normalize" the residuals. Hereafter, we refer to the dependent variable as "relative PCI volume." Standard errors were adjusted for clustering using the approach described by Stock and Watson (2008).

We estimated specifications where observations were weighted by hospital's average PCI volume, but results were similar to those from the unweighted specification, and so we report the unweighted results.

In this model, the year and quarter indicators capture the macro and seasonal trends of the PCI volume between 2004 and 2009. The hospital fixed effects control for any unobserved time-invariant heterogeneity across hospitals. Table 2 displays summary statistics of the sample, and annual PCI volume by indication for each type of hospital (pooled across all years).

The variables of interest are the interaction terms between the COURAGE indicator and the hospital time-invariant characteristics. As discussed previously, we expect that physicians in for-profit hospitals may be less likely to abandon profitable treatments and physicians in teaching hospitals ought to be more responsive to new evidence. We include indicators for ownership (for-profit, not-for-profit, government) and for whether the hospital is a teaching hospital, as indicated by membership in the Council of Teaching Hospitals.[13] Physicians practicing in integrated delivery systems may be better able to switch between alternative treatments, but may face added pressure to refer patients for profitable treatments. We include the following indicators to capture this dimension: 1) whether a hospital is in a joint venture with physicians or physician groups and 2) whether a hospital is part of a health delivery system with highly centralized physician arrangements. We also examine whether hospitals that offer cardiac surgery were more or less responsive to the results of the COURAGE trial. We use this measure, along with the number of AMI admissions, as proxy for the size of the cardiac care program in

[13] We also estimate the model with different definition of teaching hospitals, such as if the hospital has a resident program, if the hospital is affiliated with a medical school, and our results are similar using various teaching hospital definition.

a given hospital.

Table 3 displays results. Models 1 through 4 include different hospital characteristics. Model 5 includes all characteristics. All models include a constant term, a post-COURAGE indicator, which takes the value of 1 from the 2nd quarter of 2007 onward, and year-specific indicators. The post-COURAGE indicator and the year-specific indicators combined capture the average impact of the COURAGE trial. The interactions of the post-COURAGE indicator and hospital characteristics, which are of primary interest, capture the differential effect of the COURAGE trial on different types of hospitals.

We do not find that COURAGE had a differential impact on relative PCI volume by hospital ownership, teaching status, whether there is a joint venture with physician groups, and whether the hospital is part of a centralized health system. On the whole, these results are consistent with previous studies of abandonment that have failed to identify differential effects of hospital ownership or teaching status on abandonment rates (Howard et al., forthcoming, Duffy and Farley 1992), though Duffy and Farley found that hospitals that were part of multi-hospital systems were quicker to relinquish intermittent positive pressure breathing therapy.

Model 4 indicates that there was a larger decline in relative PCI volume in hospitals that offer cardiac surgery. In addition, there were steeper declines in relative PCI volume over the study period in hospitals with greater numbers of AMI admissions. These trends may reflect increases in the number of hospitals offering PCI and the greater acceptability of performing PCI without having bypass surgery as a backup. We would expect that new entrants and hospitals that offer PCI without performing bypass surgery would draw away patients with less serious forms of cardiac disease from the larger, more established programs. We assessed this hypothesis by estimating a version of the model with a control variable for the number of hospitals offering PCI within a given hospital's market area (defined as within a 15-mile radius) in each year. The inclusion of this variable did not change

the original results. It is also possible that larger cardiac program might have more resources and a wider variety of care management options to substitute non-invasive for invasive care.

We estimated a number of alternative specifications, weighting the regression by average PCI volume, limiting the sample to hospitals that performed more than 25 PCIs in 2006, and using the percent of PCIs performed in patients with stable angina/other indications as the dependent variable. In all cases, results were similar to those from the baseline model.

6. Conclusion

If medical practice patterns respond asymetrically to postive and negative evidence – physicians adopt new treatments based on "positive" results but do not abandon existing ones following "negative" studies – then comparative effectiveness research is unlikely to reduce spending and may very well lead to increased costs. We find, encouragingly, that COURAGE had an impact on the use of PCI within the US. However, many patients with stable angina continue to receive PCI as primary therapy, a result confirmed in a recent audit of PCIs performed in 2009 (Chan et al. 2011). There are unexploited opportunities to reduce costs without adversely affecting outcomes by substituting medical therapy for PCI.

Prominent cardiologists were pessimistic about the potential impact of COURAGE in the US given the incentives facing cardiologists. However, we find that the post-COURAGE decline in PCI volume was larger in US community hospitals compared to Veterans Administration and English hospitals, where cardiologists are salaried. It is difficult to interpret differential trends in PCI volume in light of baseline differences in practice patterns, but the results suggest that changing reimbursement incentives may not be sufficient to increase the uptake of comparative effectiveness research studies that report negative results. At least in the short run, inertia and the preferences of specialists who are

professionally invested in use of a particular treatment may exert a larger influence on practice patterns.

References

Adams, P.C., Skinner, J.S., Cohen, M., McBride, R., Fuster, V., 1998. Acute coronary syndromes in the United States and United Kingdom: a comparison of approaches. Clinical Cardiology 21 (5), 348-352.

Acemoglu, D., Finkelstein, A., 2008. Input and technology choices in regulated industries: evidence from the health care sector. Journal of Political Economy 116 (5), 837-80.

Baker, L.C., Wheeler, S.K., 1998. Managed care and technology diffusion: the case of MRI. Health Affairs 17 (5), 195-207.

Baker L, Spetz, J., 1999. Managed Care and Medical Technology Growth. Frontiers in Health Policy Research. Garber, Alan M., ed., Cambridge: MIT Press, pp. 27-52.

Baker, L.C., Phibbs, C.S., 2002. Managed care, technology adoption and health care: the adoption of neonatal intensive care. Rand Journal of Economics 33 (3), 524-548.

Banks, J., Marmot, M., Oldfield, Z., Smith, JP., 2006. Disease and disadvantage in the United States and in England. Journal of the American Medical Association 295 (17), 2037-2045.

Barro, J.R., Huckman, R.S., Kessler, D.P., 2006. The effects of cardiac specialty hospitals on the cost and quality of medical care. Journal of Health Economics 25 (4), 702-721.

Barros, P, Martínez-Giralt, X, 2010. Technological Adoption in Health Care (February 1, 2010). FEUNL Working Paper Series No 545. Available at SSRN: http://ssrn.com/abstract=1589398.

Bech, M., Christiansen, T., Dunham, K., Lauridsen, J., Lyttkens, C.H., McDonald, K., McGuire, A., 2009. The influence of economic incentives and regulatory factors on the adoption of treatment technologies: a case study of technologies used to treat heart attacks. Health Economics 18 (10), 1114-1132.

Boden, WE., O'Rourke, RA., Teo, KK., Hartigan, PM., Maron, DJ., Kostuk, WJ., Knudtson, M., Dada, M., Casperson, P., Harris, C.L., Chaitman, B.R., Shaw, L.,

Gosselin, G., Nawaz, S., Title, L.M., Gau, G., Blaustein, A.S., Booth, D.C., Bates, E.R., Spertus, J.A., Berman, D.S., Mancini, G.B., Weintraub, W.S., 2007. Optimal medical therapy with or without PCI for stable coronary disease. New England Journal of Medicine 356 (15), 1503-1516.

Chan, P.S., Patel, M.R., Klein, L.W., Krone, R.J., Dehmer, G.J., Kennedy, K., Nallamothu, B.K., Weaver, W.D., Masoudi, FA, Rumsfeld, JS, Brindis, RG, Spertus, JA, 2011. Appropriateness of percutaneous coronary intervention. Journal of the American Medical Association 306 (1), 53-61.

Chandra, A., Jena, A.B., Skinner, J.S., 2011. The pragmatist's guide to comparative effectiveness research. Journal of Economic Perspectives 25 (2), 27-46.

Committee on Finance, United States Senate, 2010. Staff Report on Cardiac Stent Usage at St. Joseph Medical Center.

Cuellar, A, Gertler, P., 2006. Strategic integration of hospitals and physicians. Journal of Health Economics 25, 1-28.

Curzen, N.P, 2010. Is there evidence for prognostic benefit following PCI in stable patients? COURAGE and its implications: an interventionalist's view. Heart 96, 103–105.

Duffy, S.Q., Farley, D.E., 1992. The protracted demise of medical technology: the case of intermittent positive pressure breathing. Medical Care 30 (8), 718-736.

Eddy, D.M., 1984. Variations in physician practice: the role of uncertainty. Health Affairs 3, 74-89.

Emanuel, E.J., Fuchs, V.R., 2008. The perfect storm of overutilization. Journal of the American Medical Association 299 (23), 2789-2791.

Fuchs, VR., 1968. The Growing Demand for Medical Care, , pages 1-8, 1968.

Victor R. Fuchs, 1968. "The Growing Demand for Medical Care," NBER Books, National Bureau of Economic Research, Inc,

Fuchs VR. The health economy. Cambridge: Harvard U Press 1986.

Hawker, G., Guan, J., Judge, A., Dieppe, P., 2008. Knee arthroscopy in England and Ontario: patterns of use, changes Over time, and relationship to total knee replacement. J Bone Joint Surg Am. 90 (11), 2337-2345.

Howard DH., Kenline, C., Hassebroek, A., Horowitz, MM., Parsons, SK., Rizzo, JD., Majhail, NS., Abandonment of high dose chemotherapy/hematopoietic cell transplants for breast cancer following negative trial results. In press.

Hospital Episode Statistics, Main procedures and interventions: 4 characters. Available at http://www.hesonline.nhs.uk/. [Accessed April 4, 2011].

Kane N.M,, Manoukian P.D., 1989. The effect of the Medicare prospective payment system on the adoption of new technology. The case of cochlear implants. New England Journal of Medicine 321 (20), 1378-83.

Newby, K.P., Fu Y, L.K., Mark, D.B., Goodman S.G., Wagner, G.S., Harrington, R.A., Granger, C.B. Van de Werf, F. Ohman, E.M. Armstrong, P.W., 2005. Relation between baseline risk and treatment decisions in non-ST elevation acute coronary syndromes: an examination of international practice patterns. Heart 91 (7), 876-881.

Mark, D.B., Naylo, C.D., Hlatky, M.A., Califf, R.M., Topol, E.J., Granger, C.B., Knight, J.D., Nelson, C.L., Lee, K.L., Clapp-Channing, N.E. et al, 1994. Use of medical resources and quality of life after acute myocardial infarction in Canada and the United States. New England Journal of Medicine 331 (17), 1130-1135.

Mas, N., Seinfeld, J., 2008. Is managed care restraining the adoption of technology by hospitals? Journal of Health Economics 27 (4), 1026-45.

McClellan M., 1997. Hospital reimbursement incentives: an empirical strategy. Journal of Economics and Management Strategy 6 (1), 91-128.

Moseley, J.B et al. 2002. A controlled trial of arthroscopic surgery for osteoarthritis of the knee. New England Journal of Medicine 347 (2), 8 -88.

Murphy, K.M.,Topel, R.H., 2006. The value of health and longevity. Journal of Political Economy 114 (4), 871-904.

Newhouse, JP., 1992. Medical care costs: how much welfare loss? Journal of Economic Perspectives 6 (3), 3-21.

MedPAC. Report to the Congress: physician-owned specialty hospitals revisited. Washington, DC: MedPAC; 2006.

Mitchell, J., 2007. Utilization changes following market entry by physician-owned specialty hospitals. Medical Care Research and Review 64 (4), 395-415.

Nallamothu, B.K., Rogers, M.A., Chernew, M.E., Krumholz, H.M., Eagle, K.A., Birkmeyer, J.D., 2007. Opening of specialty cardiac hospitals and use of coronary revascularization in Medicare beneficiaries. Journal of the American Medical Association 297 (9), 962-968.

NHS Information Center. National Coronary Angioplasty Audit 2007.

NHS Information Center. National Coronary Angioplasty Audit 2009.

Peterson, E.D., Rumsfeld, J.S., 2008. Finding the courage to reconsider medical therapy for stable angina. New England Journal of Medicine 359 (7), 751-753.

Rouleau, J.L., Moye, L.A,. Pfeffer, M.A., Arnold, J.M., Bernstein, V., Cuddy, T.E., Dagenais, G.R., Geltman, E.M., Goldman, S., Gordon, D., et al., 1993. A comparison of management patterns after acute myocardial infarction in Canada and the United States. The SAVE investigators. New England Journal of Medicine 328 (11), 779-784.

Sloan, F., Morrissey, M., Valvona, J., 1988. Medicare prospective payment and the use of medical technologies in hospitals. Medical Care 26 (9), 837-853.

Stock J.H., Watson, M.W., 2008. Heteroskedasticity-robust standard errors for fixed effect panel data regression. Econometrica 76, 155-174.

TECH Research Network, 2001.Technological change around the world: evidence from heart attack care. Health Affairs 20 (3), 25-42.

Teplensky, J.D., Pauly, M.V., Kimberly, J.R., Hillman, A.L., Schwartz, J.S., 1995. Hospital adoption of medical technology: an empirical test of alternative models. Health Serv Res. 30 (3), 437–465.

The Dartmouth Atlas of Health Care. Inpatient Percutaneous Coronary Interventions (PCI) per 1,000 Medicare Enrollees, by Gender. 2011 http://www.dartmouthatlas.org/data/table.aspx?ind=96

Weintraub, W.S., Boden, W.E., Zhang, Z., Kolm, P., Zhang, Z., Spertus, J.A., Hartigan, P., Veledar, E., Jurkovitz, C., Bowen, J., Maron, DJ., O'Rourke, R., Dada, M., Teo, K.K., Goeree, R., Barnett, P.G., 2008. Cost-effectiveness of percutaneous coronary intervention in optimally treated stable coronary patients. Circulation: Cardiovascular Quality and Outcomes 1,12-20.

Weintraub, W.S., Spertus, J.A., Kolm, P., Maron, D.J., Zhang, Z., Jurkovitz, C., Zhang, W., Hartigan, P.M., Lewis, C., Veledar, E., Bowen, J., Dunbar, S.B., Deaton,

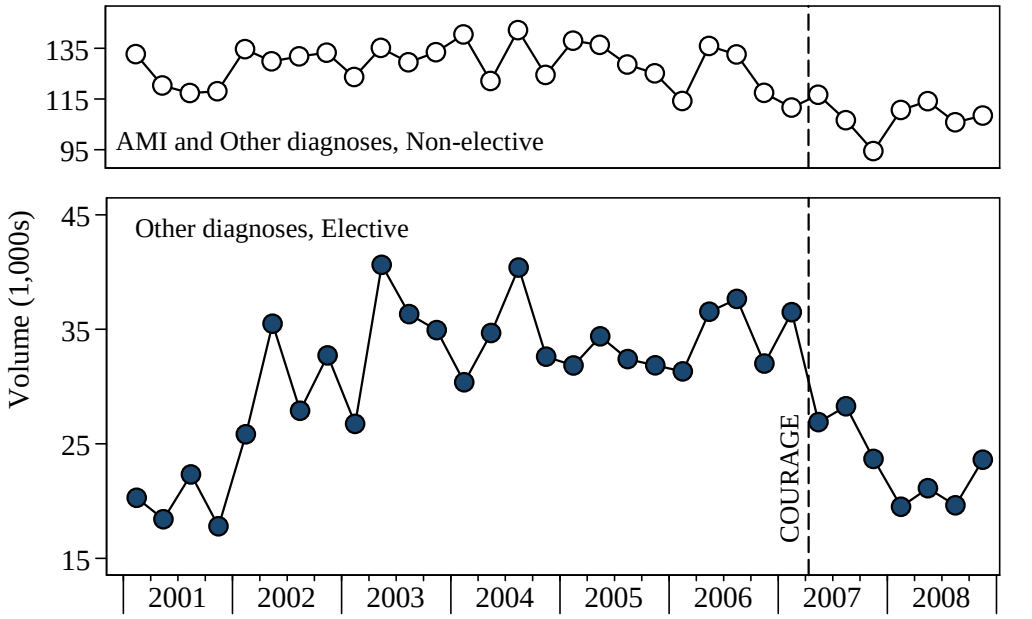
C., Kaufman, S., O'Rourke, R.A., Goeree, R., Barnett, P.G., Teo, K.K., Boden, W.E, Mancini, G.B., 2008. Effect of PCI on quality of life in patients with stable coronary disease. New England Journal of Medicine 359 (7), 677-687.

Weinstein, KJ., Simple Health-Care Fix Fizzles Out. Wall St. Journal February 11, 2010.

Young, H.P., 2009. Innovation diffusion in heterogeneous populations: contagion, social influence, and social learning. American Economic Review 99 (5),1899-1924.

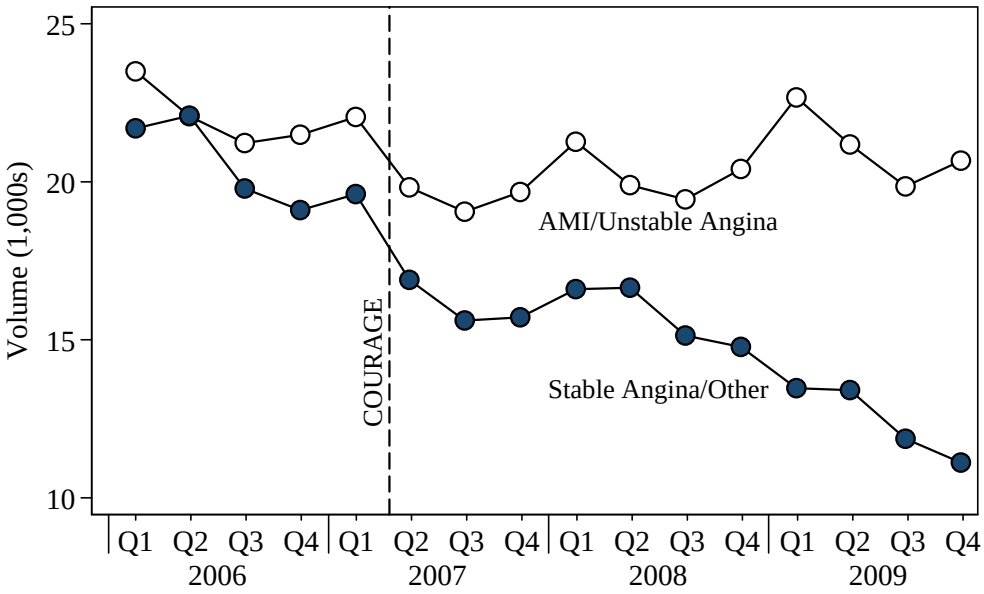
Yusuf, S., Flather, M., Pogue, J., Hunt, D., Varigos, J., et al., 1998. Variations between countries in invasive cardiac procedures and outcomes in patients with suspected unstable angina or myocardial infarction without initial ST elevation. The Lancet 352, 507-514.

Figure 1: Quarterly PCI volume by indication, US hospitals



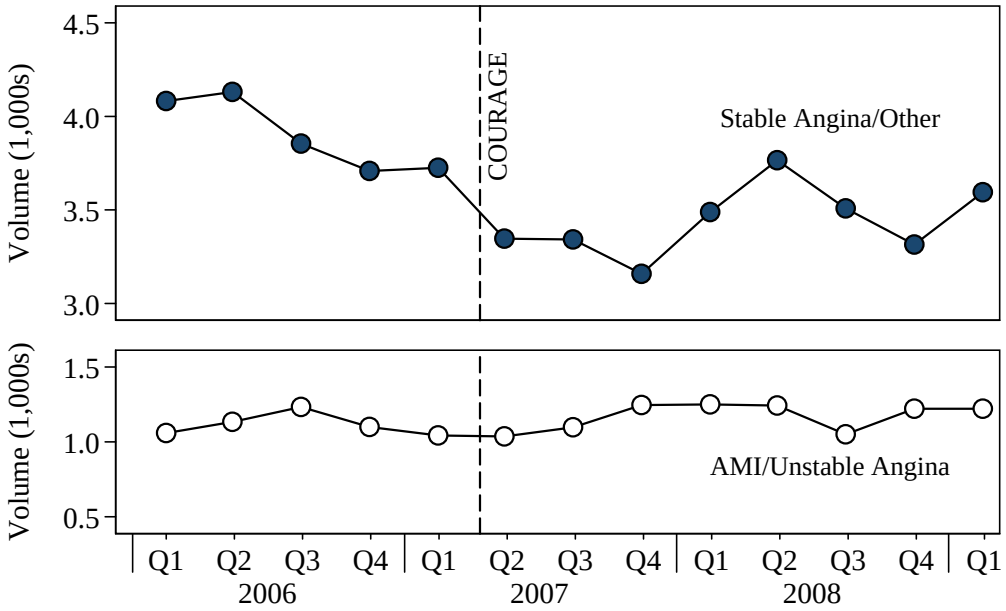
Source: Authors' analysis of the National Hospital Discharge Survey.
PCI: percutaneous coronary intervention

Figure 2: Quarterly PCI volume by indication, US (AZ, CA, FL, MA, MD, NJ, NY)



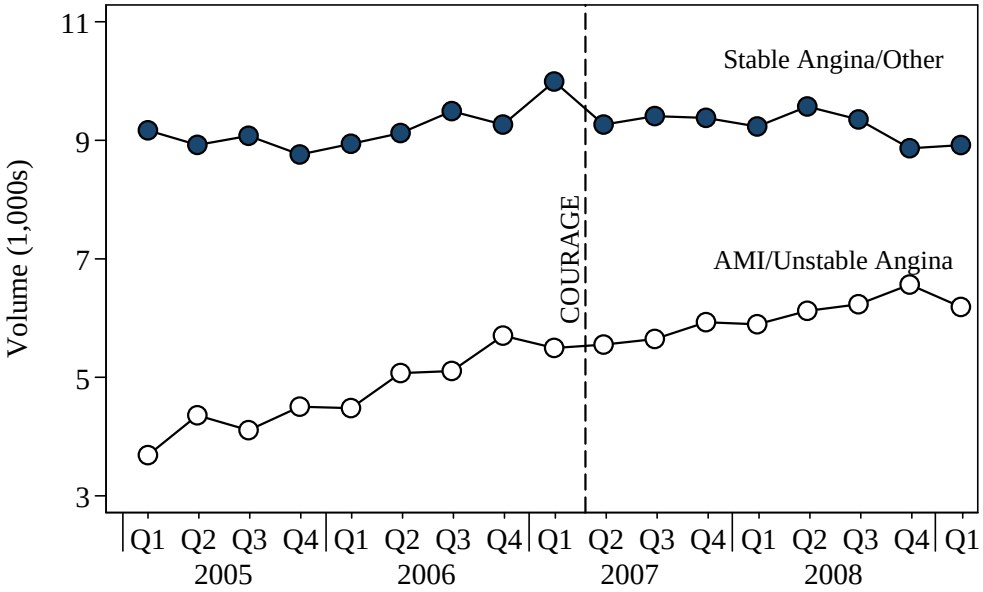
Source: Authors' analysis of State Inpatient Discharge data.
PCI: percutaneous coronary intervention

Figure 3: Quarterly PCI volume by indication in VA hospitals



Source: Authors' analysis of the Veterans Administration Patient Treatment File.
PCI: percutaneous coronary intervention

Figure 4: Quarterly PCI volume by indication, England



Source: Authors' analysis of Hospital Episode Statistics database.
PCI: percutaneous coronary intervention

Table 1: Change in PCIs and AMIs, 2006 to 2008

	PCIs		
	Stable angina/ Other	AMI/Unstable angina	AMI Admits[b]
	No. (1,000s) [Rate per 100K persons age≥45]		
	United States: SID		
2006	74 [274]	79 [292]	176 [653]
2008	57 [210]	72 [266]	172 [639]
Change	-17 (-30%)	-7 (-10%)	-4 (-2%)
	United States: Veterans Administration[b]		
2006	15.8	4.5	
2008	14.1	4.8	
Change	-1.7 (-12%)	0.2 (5%)	
	England: Hospital Episode Statistics		
2006	36 [169]	20 [94]	140 [650]
2008	36 [169]	24 [114]	140 [652]
Change	0 (0%)	4 (18%)	0.5 (0%)
	Elective	Non-elective	
	United States: NHDS		
2006	137 [116]	500 [420]	812 [682]
2008	84 [70]	439 [369]	825 [693]
Change	-54 (-64%)	-61 (-14%)	13 (2%)

[a]Total admissions for acute myocardial infarction.
[b]The total population for the VA is undefined. We do not have data on total AMI admissions.

PCI: Percutaneous coronary intervention.
AMI: Acute myocardial infarction (i.e. heart attack).
SID: State Inpatient Discharge data.
NHDS: National Hospital Discharge Survey.
SID: State Inpatient Discharge data from AZ, CA, FL, MA, MD, NJ, NY.

Table 2: Characteristics of the hospitals included in the sample

		Annual PCI volume		
	Mean	Stable angina/ Other	Unstable angina/AMI	Relative PCI volume
	N (%/SD)		N (SD)	
Not-for-profit	380 (70)	45 (74)	56 (73)	-11 (43)
For-profit	103 (19)	32 (41)	44 (49)	-12 (26)
Government	60 (11)	31 (41)	47 (53)	-16 (30)
Teaching	103 (19)	77 (103)	81 (86)	-4 (59)
Joint venture	168 (31)	50 (74)	65 (81)	-15 (44)
Centralized system	60 (11)	62 (85)	78 (83)	-15 (47)
Cardiac surgery	288 (53)	67 (78)	80 (75)	-13 (50)
All hospitals	543 (100)	41 (66)	53 (67)	-12 (39)
AMI admissions/year	99 (76)			
Bed size	385 (344)			
Number of hospitals	543			

Table 3: The impact of hospital characteristics on the difference in the number of PCIs in patients with stable angina/other indications versus unstable angina/AMI

	Model				
	(1)	(2)	(3)	(4)	(5)
	B (SE)				
Post-COURAGE					
×Constant	-3.4 (1.02) *	-2.0 (0.96) *	-2.7 (0.99) *	1.1 (1.18)	0.3 (1.52)
×For profit	2.0 (2.11)				0.6 (2.21)
×Government	3.0 (2.75)				3.4 (2.89)
×Teaching		-3.5 (3.13)			-1.3 (3.32)
×Joint venture			0.8 (1.71)		2.6 (1.85)
×Centralized system			-2.9 (3.83)		-2.1 (3.81)
×Cardiac surgery				-7.1 (1.90) *	-7.3 (2.01) *
AMI admissions/year	-0.2 (0.04) *	-0.2 (0.04) *	-0.2 (0.04) *	-0.2 (0.04) *	-0.2 (0.04) *
Bed size	0.6 (0.41)	0.8 (0.44)	0.6 (0.40)	0.9 (0.39) *	0.8 (0.44)
2007	-2.9 (1.07) *	-2.9 (1.07) *	-2.9 (1.07) *	-2.9 (1.08) *	-2.9 (1.07) *
2008	-4.1 (1.48) *	-4.1 (1.48) *	-4.1 (1.48) *	-4.0 (1.48) *	-4.0 (1.48) *
2009	-13.4 (1.63) *	-13.5 (1.64) *	-13.4 (1.63) *	-13.4 (1.64) *	-13.5 (1.64) *
2nd quarter	1.0 (0.62)	1.0 (0.61)	1.0 (0.61)	0.9 (0.61)	0.9 (0.61)
3rd quarter	-2.3 (0.87) *	-2.3 (0.87) *	-2.3 (0.87) *	-2.3 (0.87) *	-2.3 (0.87) *
4th quarter	-2.6 (0.61) *	-2.6 (0.60) *	-2.6 (0.61) *	-2.6 (0.61) *	-2.6 (0.61) *
Constant	13.8 (4.71) *	13.2 (4.72) *	13.7 (4.65) *	13.2 (4.67) *	13.4 (4.72) *

The unit of observations is the hospital-quarter. There are 8,176 observations.

All models include hospital fixed effects.

*p<0.05

AMI: Acute myocardial infarction