Changes in Physician Practice Patterns after Implementation of a Communication-and-Resolution Program

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Objective. To test if a 2006 communication-and-resolution program to address unexpected adverse outcomes was associated with changes in cost and use trajectories.

Data Source. Records of patients discharged with a principal diagnosis of chest pain from 44 nonfederal general hospitals in Cook County, Illinois, between January 2002 and December 2009.

Study Design. Propensity-score matched discharges from the intervention and comparison hospitals before computing difference-in-differences estimates of quarterly growth rates.

Data Collection Methods. We used discharge records submitted to a central state-wide repository.

Principal Findings. Relative to the comparison hospitals and to pre-implementation trends, and consistent with reduced testing at presentation, the intervention hospital recorded an increase in the number of patients with a principal diagnosis of chest pain. Among admitted patients, quarterly growth rates of clinical laboratory and radiology charges at the intervention hospital declined by 3.8 and 6.9 percentage points.

Conclusions. Among patients with chest pain, the implementation of a comprehensive communication-and-resolution program was associated with substantially reduced growth rates in the use of diagnostic testing and imaging services. Further research is needed to establish to what extent these changes were attributable to the program and clinically appropriate.

Key Words. Communication-and-resolution program, medical liability, chest pain, diagnostic radiology

Emerging communication-and-resolution programs (CRPs) aim to address adverse patient safety events proactively by recognizing the injury, fully disclosing to patients all information surrounding their care, and offering an apology and remediation if warranted (Boothman et al. 2009; McDonald et al. 2010).

By openly discussing adverse events with patients, physicians and administrators can contain the impulse to sue by patients wishing to learn why they were injured and whether their care was negligent (Vincent, Young, and Phillips 1994). When care was clearly inappropriate, providers may pair the error disclosure with an apology and an offer of additional medical care or financial compensation, thereby settling a meritorious claim faster and possibly without litigation (Mello, Studdert, and Kachalia 2014). At the same time, by building a reputation for vigorously defending appropriate care, providers can deter meritless claims more credibly. Consistent with these predictions, one early and well-known CRP at the University of Michigan Health System reported that after implementation in 2001, new claims and lawsuits decreased by 36 and 65 percent, respectively (Kachalia et al. 2010).

Although much attention has focused on their potential to curb the incidence of lawsuits, CRPs may arguably have a more immediate and widely felt impact on patients who are not injured insofar as they affect physicians' practice patterns (Frakes 2013). Specifically, the perceived reduction in the risk of a lawsuit may convince physicians to discharge patients sooner and order fewer imaging studies or laboratory tests of little medical value (Bishop, Federman, and Keyhani 2010; Nahed et al. 2012; Carrier et al. 2013; Chen and Yang 2014) and thus rely less on the practice of defensive medicine (Mello and Kachalia 2010).

The Communication-and-Resolution Program at the University of Illinois

We studied whether the implementation of a CRP at the University of Illinois Hospital and Health Sciences System (UIH) reduced select markers of defensive medicine. The UIH is a large, urban, tertiary-care academic medical center located in Cook County, Illinois, a jurisdiction considered to be among the most plaintiff-friendly counties in the United States, which exacerbates its exposure to professional liability claims and enhances incentives for defensive medicine. The medical center is self-insured but purchases reinsurance against very large liability claims.

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In April 2006, the UIH adopted a novel strategy for managing its professional liability risk by instituting a CRP (Lambert et al. 2016). This program marked a complete reversal of the medical center's earlier risk management strategy of categorically denying negligence and refusing payment after an adverse event, which in the eyes of many had triggered a number of avoidable lawsuits. Throughout the resolution process under the CRP, physicians and medical staff involved in the incident, along with the hospital's risk managers, are now expected to communicate with patients and their families about adverse outcomes. The program allows physicians to admit negligence and administrators to offer patients compensation proactively before a claim is filed. The program consists of "Seven Pillars" (McDonald et al. 2010), which are meant to ensure a consistent application of the principles of transparent communication, swift and fair patient compensation, a vigorous defense of the hospital staff when care was reasonable, and a commitment to learn from mistakes (Boothman et al. 2009). The program's seven core components include the following: patient safety incident reporting, investigation, communication and disclosure, apology and remediation, system improvement, data tracking and performance evaluation, education, and training.

In addition to the hospital's senior administrators, the development of the program involved representatives of its risk management, legal, and financial services departments, and the University's College of Medicine. Three months before launch, more than 100 employees and medical staff were trained by outside experts to communicate with patients about unexpected adverse outcomes (Hickson et al. 2002). The Seven Pillars program was publicly launched with notification of all hospital employees and medical staff in April 2006. The first major full disclosure with rapid remediation occurred 2 months later.

To encourage the prompt reporting of adverse events, the program raised a hospital department's contribution to the hospital's self-insurance fund by \$50,000 per incident if that department failed to notify risk management of an event before the patient or family members filed a formal claim against the hospital.

Patients Admitted with Chest Pain

We examined how the implementation of a CRP may have affected physicians' patterns of treating patients admitted with chest pain. Chest pain is a common and costly reason for hospital admissions. In our sample, 1,46

percent of discharges from UIH and 2.50 percent of discharges from the comparison hospitals recorded chest pain as the principal diagnosis.

While frequently benign and temporary, chest pain can point to life-threatening conditions, including myocardial infarction, pulmonary embolus, and ruptured thoracic aortic aneurysm (Carrier et al. 2013). To rule these out, physicians may supplement their initial evaluation with conventional and advanced imaging and admit the patient to the hospital for observation and blood tests. Moreover, physicians practicing in hospital emergency departments, which in our sample received virtually all patients discharged with a principal diagnosis of chest pain, must often render a diagnosis under conditions of uncertainty and severe time constraints (Waxman et al. 2014). A patient's death has been estimated to trigger more than half of all medical professional liability claims against cardiologists (Mangalmurti et al. 2014), while diagnostic errors have been shown to account for as many as 37 percent of emergency department medical malpractice claims, with chest pain often triggering the highest indemnity payments (Brown et al. 2010). The substantial and costly risk of a missed diagnosis among emergently admitted patients with chest pain in turn creates conditions that encourage the practice of defensive medicine.

To the extent that physicians expected a declining incidence of lawsuits and thus a reduced need for defensive medicine after implementation of the CRP at UIH, we predicted that the program would be associated with fewer diagnostic tests, lower charges for radiology and clinical laboratory services, and shorter hospital stays.

In addition, official coding guidelines mandate that any established diagnosis, such as pulmonary embolism, supersede chest pain as the principal diagnosis (Centers for Disease Control and Prevention 2011). Therefore, if the program reduced physicians' use of tests and imaging services among patients presenting with chest pain, we would expect a decrease in the number of patients with a superseding diagnosis of pulmonary embolism and an increase in the number of patients with a principal diagnosis of chest pain.

METHODS

Data Source and Sample Definition

The study sample comprised all 140,347 records of patients who were discharged with a principal diagnosis of chest pain between January 1, 2002, and December 31, 2009, from the UIH or any nonfederal general hospital in Cook

County, Illinois, that recorded at least 800 discharges in each quarter under study.¹

By Illinois statute, all nonfederal Illinois hospitals are required to submit their discharge records to the Illinois Hospital Association (IHA) on a quarterly basis. The IHA screens these files for inconsistencies and makes them available to IHA members within 91 days after the quarter ends. These long-standing and uniform reporting requirements ensured that the data were complete and comparable across hospitals and over time. The data included eight-digit identifying numbers of attending clinicians but no patient identifiers.

Statistical Analysis

To account for unobserved countywide changes in the legal environment, medical technology, prices, and treatment protocols that could have affected the outcomes we study, we compared cost and use trajectories at UIH to those at up to 43 large and medium-sized comparison hospitals in the same jurisdiction. Specifically, we matched each discharge from UIH to up to 200 discharges from the comparison hospitals whose propensity scores were closest to and within 1 percentage point of the propensity score for a discharge from UIH (Rubin 1997). We estimated propensity scores by fitting for each quarter a separate logistic regression model of the probability of being discharged from UIH to patient age, sex, primary payer, admission type, admission day of the week, Major Diagnostic Category, number of Elixhauser comorbidities, and ZIP code of residence. Propensity-score matching ensured that we were comparing patients discharged from UIH to patients who were discharged from the comparison hospitals in the same quarter and who had near-identical probabilities of being discharged from UIH. We plotted the quarterly mean number of Elixhauser comorbidities per discharge for the intervention and comparison hospitals before and after matching and computed the standardized percentage bias (Garrido et al. 2014).

To investigate how the program may have affected selection into the sample, we plotted the quarterly number of patients discharged with a diagnosis of pulmonary embolism from UIH and the comparison hospitals and overlaid these graphs with piecewise-linear ordinary least squares estimates for the pre- and postimplementation periods. We prepared a similar graph of the number of patients discharged with a principal diagnosis of chest pain.

For radiology and clinical laboratory charges, we graphed the unadjusted quarterly averages for the matched discharges from UIH and the

comparison hospitals and overlaid these graphs with piecewise-linear ordinary least squares estimates for the pre- and postimplementation periods.

For seven outcomes, we computed difference-in-differences estimates of quarterly growth rates at UIH and the comparison hospitals. Specifically, we allowed both the levels and the growth rates of the outcomes (intercept and slope parameters of linear quarterly trends) to vary separately for UIH and the comparison hospitals and for the pre- and postimplementation periods. This approach allowed us to detect both an immediate and a gradual impact of the program, reflecting how physicians learned about the CRP and its possible implications for their liability risk, and how they adapted their practice patterns in response.

We used ordinary least squares to fit the natural logarithm of total and four category-specific charges. We used Poisson regressions to fit the number of diagnostic radiology procedures per discharge and length of stay (measured in days).² In all models, we weighted each discharge from a comparison hospital by the reciprocal of the number of all discharges from comparison hospitals that were matched to the same discharge from UIH. As a result, the weighted sum of discharges from the comparison hospitals matched the number of discharges from UIH. All regression models included the demographic and clinical patient characteristics shown in Table 1.

We estimated all models for the full sample, which included all attending physicians, and a restricted sample, which included only attending physicians at UIH or the comparison hospitals who recorded at least two discharges per quarter in at least two quarters before and two quarters after program implementation. Because the identifiers of attending physicians changed in 2008, we limited the restricted sample to years 2002–2007. To account for time-invariant differences in treatment protocols, capacity, availability of diagnostic equipment and services, billing and coding practices, and discharge policies across hospitals, we included hospital fixed effects in the models drawing on the full sample. To account for time-invariant differences in practice styles across clinicians, we included physician fixed effects, in addition to hospital fixed effects, in the models drawing on the restricted sample.

The marginal effect of interest was the change in the quarterly growth rate at UIH at the time of program implementation relative to the pre-implementation trend at UIH and relative to any contemporaneous trend change at the comparison hospitals (shown in the row labeled “UIH · Quarter · Post” in Tables 2 and 3). To account for the non-linearity of the regression models, we

Table 1: Summary Statistics

	<i>Discharges from UIH*</i>	<i>Weighted Discharges from Comparison Hospitals[†]</i>	<i>Unweighted Discharges from Comparison Hospitals</i>
Propensity score (%) [‡]	7.8	7.8	1.8
Age (years)	55.8	55.7	58.1
Female (%)	57.5	56.9	56.9
Primary payer (%)			
Medicaid	24.7	25.0	12.7
Medicare	33.5	33.6	35.3
Private	29.0	29.0	33.8
Other	12.8	12.5	18.1
Admission type (%)			
Emergent or urgent	97.5	97.6	96.1
Elective	2.5	2.4	3.9
Major diagnostic category (%)			
Circulatory system	97.8	97.6	97.7
Respiratory system	2.2	2.4	2.3
Number of Elixhauser comorbidities [§]	1.9	1.9	1.7
Most frequent patient ZIP codes (%)			
60608	10.2	9.6	0.7
60612	5.8	5.7	0.8
60624	5.6	5.6	1.0
60623	5.1	5.3	1.3
Most frequent comparison hospitals (%)			
Mount Sinai		11.5	2.6
Stroger (Cook County)		7.1	3.9
Rush		5.3	2.1
Advocate Christ		5.2	6.3
Holy Cross		4.1	2.3
Inpatient mortality (%)	0.1	0.1	0.1
Year of discharge	2005.5	2005.5	2005.5
Discharges [¶]	2,215	102,220	140,347
Hospitals	1	43	43

*University of Illinois Hospital and Health Sciences System.

[†]Includes only discharges from the comparison hospitals whose propensity scores were closest to and within 1 percentage point of the propensity score for a discharge from UIH. Each discharge from a comparison hospital was weighted by the reciprocal of the number of all discharges from comparison hospitals that were matched to the same discharge from UIH.

[‡]Estimated probability that the patient was discharged from UIH with a principal diagnosis of chest pain.

[§]Elixhauser (1998).

[¶]Unweighted count.

used the method of recycled predictions to estimate this interaction effect (Ai and Norton 2003; McConnell 2013). We bootstrapped the standard errors based on 200 replications.

RESULTS

During the study period, 2,215 discharges from UIH with a principal diagnosis of chest pain were recorded (Table 1). Patients were on average nearly 56 years old and had nearly two comorbidities at the time of admission. More than half were female and about a third were Medicare beneficiaries. Nearly all admissions in the sample were emergent or urgent. Four ZIP codes accounted for more than a quarter of all discharges.

Propensity-score matching led us to retain 102,220 discharges from the comparison hospitals, or an average of 46 for each discharge from UIH. Nearly a third of all matched discharges were drawn from only five hospitals, of which two are immediately adjacent to UIH and one lies within 1.5 miles from UIH. Matching reduced the standardized percentage bias of the number of comorbidities per discharge from 16.1 to -0.3 (Figure A1). The average number of comorbidities per discharge at UIH practically stopped increasing after program implementation.

Chest Pain and Pulmonary Embolism Discharges

After CRP implementation, the number of patients discharged with a diagnosis of pulmonary embolism was lower (Figure A2) and the number of UIH patients discharged with a principal diagnosis of chest pain was higher (Figure A3) than predicted by the pre-program trend at UIH and the contemporaneous trend at the comparison hospitals.

Charges

Before program implementation, unadjusted charges for clinical laboratory services grew faster at UIH than at the comparison hospitals; after program implementation, they grew at about the same rate (Figure 1). Charges for radiology services grew at similar rates before program implementation, but growth was markedly slower, and negative in fact, for UIH than for the comparison hospitals after program implementation.

After adjusting for hospital fixed effects, we estimated that clinical laboratory charges grew 4.2 percentage points faster at UIH than at the comparison hospitals before program implementation; after program implementation, the excess growth rate declined by 3.8 to 0.4 percentage points (Table 2A and Figure 2A). Table 2A shows that the growth rate reduction was statistically significant at .001; Figure 2A shows that after program implementation, the

Figure 1: Clinical Laboratory and Radiology Charges per Discharge (Current Dollars)

Notes. —, fitted linear spline for UIH (●); - - -, fitted linear spline for comparison hospitals (○);
 |, program implementation (April 2006). [Color figure can be viewed at wileyonlinelibrary.com]

growth rate at UIH was no longer statistically distinguishable from the average growth rate at the comparison hospitals. Relative to the sample mean of \$2,162 per discharge, the 3.8 percentage-point growth rate reduction implies that in the postimplementation period, quarter-to-quarter increases in clinical laboratory charges at UIH were about \$82 less per discharge than they would have been otherwise.

Similarly, the excess growth rate for radiology charges at UIH declined by 6.9 percentage points, translating to a reduction in quarter-to-quarter increases of \$101 per discharge. While covariate-adjusted radiology charges at UIH grew 4.6 percentage points faster than at the comparison hospitals before program implementation, charges at UIH in this category were in fact no longer increasing after.³

By contrast, for room and board charges, we did not detect statistically or economically meaningful differences in growth rates between UIH and the comparison hospitals either before or after program implementation.

Table 2: Total and Category-Specific Charges for (A) All Attending Physicians; (B) Attending Physicians Observed before and after CRP Implementation[†]

	Clinical Laboratory	Pharmacy	Radiology	Room and Board	Total
(A)					
Sample mean (\$)	2,162	1,197	1,458	2,717	11,859
Quarterly growth rate and before—after change at comparison hospitals					
Quarter	1.7*** (0.2)	1.4*** (0.4)	5.1*** (0.5)	1.5*** (0.2)	1.9*** (0.2)
Post	4.1 (3.1)	-1.6 (6.2)	-5.3 (6.7)	5.2 (3.7)	-0.1 (3.2)
Quarter-Post	-0.5 (0.3)	-0.6 (0.6)	-2.9*** (0.8)	-0.9* (0.4)	-0.5 (0.4)
Difference UIH—comparison hospitals					
UIH-Quarter	4.2*** (0.4)	4.3*** (0.7)	4.6*** (0.9)	0.2 (0.4)	3.1*** (0.4)
UIH-Post	-14.1** (5.0)	-25.7** (8.8)	23.7 (17.0)	-15.4** (5.9)	-12.8* (5.7)
UIH-Quarter-Post	-3.8*** (0.6)	-2.9* (1.2)	-6.9*** (1.5)	0.5 (0.7)	-2.9*** (0.7)
R ²	0.40	0.18	0.30	0.20	0.32
Discharges	101,093	99,989	99,339	104,433	104,435
Weighted discharges	4,295	4,250	4,140	4,430	4,430
Attending physicians	8,991	8,827	9,036	9,299	9,299
Hospitals	43	42	43	43	43
(B)					
Sample mean (\$)	2,060	1,131	1,338	2,623	11,564
Quarterly growth rate and before—after change at comparison hospitals					
Quarter	1.7*** (0.3)	1.0 (0.6)	3.2*** (0.7)	1.4*** (0.4)	1.4*** (0.3)
Post	-1.0 (4.0)	-2.7 (8.2)	-6.4 (9.1)	-3.4 (5.3)	-4.3 (4.4)
Quarter-Post	-0.2 (0.8)	-0.3 (1.9)	1.4 (2.2)	0.1 (1.1)	0.6 (0.9)

Continued

Table 2: Continued

	Clinical Laboratory	Pharmacy	Radiology	Room and Board	Total
Difference UIH—comparison hospitals					
UIH-Quarter	3.6*** (0.6)	3.9* (1.2)	5.4*** (1.6)	−0.5 (0.8)	3.7*** (0.8)
UIH-Post	3.3 (8.9)	−27.5* (13.9)	61.8 (39.1)	−3.1 (10.9)	−3.4 (10.6)
UIH-Quarter-Post	−4.9** (1.7)	0.4 (3.7)	−16.6*** (4.7)	1.3 (2.2)	−6.0** (2.2)
R ²	0.49	0.29	0.38	0.33	0.42
Discharges	33,038	32,629	32,383	33,857	33,857
Weighted discharges	1,368	1,349	1,305	1,398	1,398
Attending physicians	913	884	928	935	935
Hospitals	42	41	42	42	42

Notes: Table entries expressed in percent (Quarter, Post) or percentage-point differences. Controls include patient demographic and clinical characteristics shown in Table 1, hospital fixed effects (Tables 2A and B) and physician fixed effects (Table 2B). Each discharge from a comparison hospital was weighted by the reciprocal of the number of all discharges from comparison hospitals that were matched to the same discharge from UIH. Standard errors based on 200 stratified bootstrap samples.

* Attending physicians at UIH or the comparison hospitals who recorded at least two discharges per quarter in at least two quarters before and two quarters after program implementation (April 2006).

Asterisks denote the *p*-value of a test that the marginal effect is zero: **p* < .05, ***p* < .01, ****p* < .001.

Figure 2: Differences in Estimated Quarterly Growth Rates (UIH—Comparison Hospitals) before and after Program Implementation

Notes. —, 95 percent confidence interval [truncated at -3 and 6 in (A) and at -12 and 6 in (B)].
^aAttending physicians at UIH or the comparison hospitals who recorded at least two discharges per quarter in at least two quarters before and two quarters after implementation of the communication-and-resolution program at UIH in April 2006. [Color figure can be viewed at wileyonlinelibrary.com]

The pattern of sharply declining growth rates was even more pronounced when the sample was restricted to a stable group of attending physicians (Table 2B and Figure 2B). The patterns were estimated less precisely than in the full sample because, as noted, we could not include years 2008 and 2009 due to the lack of concordant physician identifiers.

In the full sample, we also estimated large and statistically significant immediate reductions in clinical laboratory, pharmacy, room and board, and total charges at the time of program implementation.

Diagnostic Radiology Procedures per Discharge and Length of Stay

The number of diagnostic radiology procedures per discharge remained essentially constant throughout the entire sampling period at the

comparison hospitals but was increasing at UIH before the program was implemented (Table 3A and Figure 2A). In the full sample, we did not detect a meaningful change in the growth rate differential after program implementation. By contrast, in the restricted sample, we estimated a substantial reduction in the growth rate differential of 12.8 percentage points ($p = .088$; Table 3B and Figure 2B). Consistent with our estimates for radiology charges, we found that, among physicians who were present at UIH before and after the intervention, the number of radiology procedures per discharge was no longer growing after the program was implemented. The growth rate differential of patient length of stay declined by 2.2 percentage points in the full sample; it was more than twice as large in the restricted sample ($p = .082$).

DISCUSSION

By encouraging transparency about and proactive remediation of unanticipated adverse patient events, CRPs may help resolve potential medical malpractice disputes faster, more equitably, and at lower cost. To the extent that CRPs reduce the perceived likelihood of lawsuits as well as physicians' uncertainty about compliance with current standards of care (Frakes 2015), they may in turn also reduce physicians' incentives for defensive medicine and thus change practice patterns toward less costly care, without compromising health outcomes.

We tested whether the implementation of a comprehensive CRP at a large, urban, tertiary-care academic medical center was associated with changes in the growth rates of select charge categories, the number of diagnostic radiology procedures per discharge, and length of stay among patients who were discharged with a principal diagnosis of chest pain.

Compared to a sample of matched discharges from 43 large- and medium-size hospitals in the same jurisdiction, we found that implementation of the program was associated with substantial and statistically significant reductions in the growth rates of charges for clinical laboratory and radiology services and, to a lesser extent, of length of stay. By contrast, the growth rates of room and board charges remained essentially unchanged.

When we restricted the sample to a stable group of attending physicians, we found that the program was associated with large and similar growth rate reductions for radiology charges and the number of diagnostic radiology procedures per discharge.

Table 3: Diagnostic Radiology Procedures and Length of Stay: (A) All Attending Physicians; (B) Attending Physicians Observed before and after CRP Implementation[†]

	Diagnostic Radiology (Procedures per Discharge)	Length of Stay (Days)
(A)		
Sample mean	0.30	1.85
Quarterly growth rate and before—after change at comparison hospitals		
Quarter	0.9 (0.9)	0.2 (0.4)
Post	−1.5 (11.9)	−1.2 (5.3)
Quarter·Post	−0.6 (1.5)	−0.7 (0.6)
Difference UIH—comparison hospitals		
UIH·Quarter	3.2 (1.9)	1.3 (0.7)
UIH·Post	−32.9 (20.0)	−14.0 (10.4)
UIH·Quarter·Post	−0.9 (3.0)	−2.2* (1.1)
Discharges	104,435	104,435
Weighted discharges	4,430	4,430
Attending physicians	9,299	9,299
Hospitals	43	43
(B)		
Sample mean	0.32	1.87
Quarterly growth rate and before—after change at comparison hospitals		
Quarter	0.2 (1.4)	−0.4 (0.5)
Post	2.5 (20.1)	−4.1 (6.9)
Quarter·Post	0.3 (3.8)	0.1 (1.4)
Difference UIH—comparison hospitals		
UIH·Quarter	4.8 (2.8)	0.6 (1.2)
UIH·Post	−24.3 (32.9)	12.0 (15.2)
UIH·Quarter·Post	−12.8 (7.5)	−5.4 (3.1)
Discharges	33,857	33,857
Weighted discharges	1,398	1,398
Attending physicians	935	935
Hospitals	42	42

Notes. Table entries expressed in percent (Quarter, Post) or percentage-point differences. Controls include patient demographic and clinical characteristics shown in Table 1, hospital fixed effects (Tables 3A and B), and physician fixed effects (Table 3B). Each discharge from a comparison hospital was weighted by the reciprocal of the number of all discharges from comparison hospitals that were matched to the same discharge from UIH. Standard errors based on 200 stratified bootstrap samples.

[†]Attending physicians at UIH or the comparison hospitals who recorded at least two discharges per quarter in at least two quarters before and two quarters after program implementation (April 2006). Asterisks denote the *p*-value of a test that the marginal effect is zero: **p* < .05.

The IHA data do not include cost measures or hospital- and year-specific cost-to-charge ratios, only charges. To the extent that hospital-specific cost-to-charge ratios remained constant throughout the sampling period, our growth rate estimates for charges reflect growth rates for cost.

Moreover, the growth rate reductions we observed for radiology procedures and length of stay suggest that the growth rate reductions in clinical laboratory and radiology charges at UIH were driven, at least partially, by relative reductions in resource utilization, such as less imaging and shorter observation periods, rather than decreases in the hospital's input prices or an erosion of the hospital's bargaining power vis-à-vis payers. Consistent with this interpretation, room and board charges, which should not have been affected by changes in physicians' practice patterns but should have responded to changes in prices or billing practices, grew at practically the same rates at UIH and the comparison hospitals both before and after program implementation.

We tracked a stable group of attending physicians over time to eliminate physician turnover as an explanation for the observed patterns. The fact we observed more pronounced growth rate reductions in the restricted sample than in the full sample suggests that the growth rate reductions primarily reflect program-induced changes in practice patterns rather than changes in clinical personnel.

By the same token, given that almost all admissions in our sample were urgent or emergent, it is unlikely that changes in patient self-selection accounted for the observed growth rate reductions in radiology charges and procedures.

Some observers have noted that, after a period of rapid increases, Medicare payments for noninvasive diagnostic imaging began to decrease between 2007 and 2010 (Levin et al. 2012), which largely overlaps with the postimplementation period of our study. To minimize the confounding effects of such jurisdiction-wide trends in charges, we included all mid-sized and large nonfederal hospitals as contemporaneous comparison units in all of our analyses. The large and statistically significant growth rate reductions that we estimated for radiology charges at UIH exceeded the declines predicted by the contemporaneous trends at the comparison hospitals.

Despite these adjustments, we cannot conclusively infer that the associations reported here are causal. To our knowledge, no other CRP of this scope was implemented at another hospital in Cook County, and no new utilization management measures or less expensive diagnostic tests and imaging procedures were adopted exclusively at UIH at the same time. To the extent that any comparison hospitals implemented elements of CRPs before or after April 2006, the growth rate reductions we estimated understate the effectiveness of the CRP at UIH. One recent demonstration at nine Chicago area hospitals has aimed to identify causal links between CRPs and

outcomes relating to patient safety, medical liability, and practice patterns (Agency for Healthcare Research and Quality [AHRQ] 2010, Mello et al. 2014).

The relative decrease in the number of patients discharged from UIH with an established diagnosis such as pulmonary embolism (PE) and the concomitant relative increase in the number of patients discharged with a principal diagnosis of chest pain are consistent with a reduced reliance on testing among patients presenting with chest pain after the program was implemented and with adherence to one “Choosing Wisely” list, which cautions that “computed tomography pulmonary angiography . . . has limited value in patients . . . with low pre-test probability of PE” (American College of Radiology 2012). Indeed, the fact that the mean number of Elixhauser comorbidities among chest pain patients at UIH in our sample nearly stopped increasing after CRP implementation (Figure A1) could reflect a decline in testing among patients with low pre-test probability of a superseding diagnosis and a resulting selection of healthier-than-average individuals into our postimplementation sample of UIH patients. As noted, we sought to account for these program-related compositional changes in patient-level predictors of resource use by including the number of comorbidities, along with the other demographic and clinical patient characteristics reported in Table 1, as covariates in all regression models and by matching patients discharged from UIH to patients who were discharged from the comparison hospitals in the same quarter. Insofar as these adjustments fail to capture the full extent to which UIH patients in the postimplementation period were healthier and thus would be expected to need fewer diagnostic services, our estimated growth rate reductions may overstate the resource-reducing impact of the program.

The program-related improvement in UIH patients’ baseline health could also explain the observed reduction in the growth of pharmacy charges. It is also possible that the reduced use of tests and imaging services in turn reduced the frequency of diagnoses responsive to medication. Such a drop could explain the large and statistically significant drop in pharmacy charges immediately after implementation that we estimate for the full sample.

As the data contain no patient identifiers, we were unable to test if the program was associated with a change in readmissions (Friedman et al. 2009). The data also did not allow us to identify the exact diagnostic tests, assess their appropriateness, or measure patient outcomes other than mortality.⁴ For these reasons, we could not determine if the reduced reliance on clinical laboratory and diagnostic radiology services represents a retreat from the practice of

defensive medicine (fewer tests of little medical value) or resulted in undertesting.

Insofar as the costs of these tests and procedures were borne by payers and patients rather than the attending physicians (Thomas 2010) and because the risk of iatrogenic injury is comparatively low in the diagnostic setting (Frakes 2015), incentives for undertesting or refraining from defensive medicine should have been reduced. Therefore, the growth rate reductions reported here should be viewed as conservative estimates, in that we would expect physicians to respond more strongly if they could share in the savings from fewer unnecessary tests and procedures, as they would under episode-based payment arrangements.

The remediation component of the CRP may have increased resource use if injured patients now received more tests and procedures (Helmchen, Richards, and McDonald 2011). To the extent that remedial medical care was provided during the same hospitalization that led to the adverse event, the estimated growth rate reductions reflect the net effect of greater resource use due to remediation and less resource use due to less reliance on defensive medicine. The prediction that greater provision of remedial care would raise length of stay was not borne out by the data.

CONCLUSIONS

Without relying on sweeping, politically contentious tort reforms at the state or federal levels, CRPs enable physicians and administrators to modify and thus adapt the medico-legal environment to the particular patient safety profile of their hospital. We found that among patients with chest pain, the implementation of a comprehensive CRP was associated with substantially reduced growth rates in the use of diagnostic testing and imaging services. Future research using other diagnostic cohorts with less opportunity for test-related selection and richer data on patients' clinical characteristics and care outcomes should seek to validate the results reported here and establish to what extent these changes were attributable to the program and clinically appropriate. Although the principal impetus for implementation of the CRP at UIH was to achieve faster, more patient-centric, and less costly remediation and resolution of adverse patient events, our estimates suggest that the program may have been effective in changing physician practice patterns even vis-à-vis patients who were not injured.

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NOTES

1. Following Carrier et al. 2013, we defined chest pain using ICD-9 codes 411.1, 411.89, 413.0, 413.1, 413.9, 786.50, 786.51, 786.52, and 786.59.
2. The IHA data only contain ICD-9 procedure codes. We defined diagnostic radiology procedures as valid two-digit procedure codes of 87 or 88.
3. The estimated growth rate of radiology charges at UIH in the postimplementation period is found by summing over the marginal effects of Quarter (5.1), Quarter · Post (−2.9), UIH · Quarter (4.6), and UIH · Quarter · Post (−6.9), which yields −0.1 percent per quarter.
4. During the entire 8-year sampling period, only two patients who were discharged from UIH with a principal diagnosis of chest pain, or about 0.1 percent, died before discharge. For this reason, we were not able to estimate reliably the program's association with changes in inpatient mortality.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

Figure A1: Number of Elixhauser Comorbidities per Patient, by Quarter.

Figure A2: Number of Patients Discharged with a Diagnosis of Pulmonary Embolism, by Quarter.

Figure A3: Number of Patients Discharged with a Principal Diagnosis of Chest Pain, by Quarter.