The topic of variation in health care has garnered significant attention since Wennberg and Gittelsohn in 1973 identified up to 10-fold variation in use of tonsillectomy and other surgical procedures in small towns within Maine and Vermont. Wennberg and others further described large differences in the propensity to hospitalize patients in Boston and New Haven that were unrelated to case-fatality but highly related to bed supply. These findings suggested that regional treatment variation is in part driven by differences in physician preferences and health resource capacity rather than the health status of patients. These observations of extensive geographic variation in treatment were most extensively formalized in the Dartmouth Atlas of Health Care, a massive undertaking that used Medicare claims data to describe differences in cost and utilization across more than 300 hospital referral regions (HRRs) that were built from zip codes and hospital service areas. The Dartmouth Atlas has been published by Wennberg and colleagues since 1996.

More recently, greater attention has been directed to variation in treatment and outcomes at the hospital level. Health care payers including the Centers for Medicare and Medicaid Services have motivated the creation of performance measures that describe hospital variation in longitudinal outcomes such as rehospitalization and death. These measures have been endorsed by the National Quality Forum and are currently being used to direct financial penalties to hospitals with higher-than-expected rates of adverse outcomes for common conditions such as heart failure, acute myocardial infarction, and pneumonia. In the future, Medicare will likely assess hospital variation in outcomes for specific cardiovascular treatments including percutaneous coronary intervention and percutaneous valve replacement.

Given the increased focus on treatment and outcomes variation at both regional and hospital levels, we have dedicated the reviews in this issue of Circulation: Cardiovascular Quality and Outcomes to the topic of variation in cardiovascular disease. We have included studies describing variation in cardiovascular treatments and outcomes at regional, hospital, and physician levels. We have also included studies describing novel methodologies to characterize variation in outcomes for cardiac pharmacotherapies and procedural interventions. Moving forward, the measurement of risk-standardized and risk-adjusted variation in outcomes by site of care will likely be increasingly used to identify latent signals of quality and guide reimbursement decisions.

Lost in Translation: Health Resource Variability in the Achievement of Optimal Performance and Clinical Outcome

Summary: Data from the US have shown that quality improvement systems, tools, and increased hospital staff can improve guideline-based care and health outcomes. In this study, the authors sought to evaluate the system, provider, and patient factors that can influence guideline adherence and may contribute to the health disparities observed when comparing individuals living in rural and remote locations in Australia versus urban areas. Using the Acute Coronary Syndrome Prospective Audit (ACACIA) registry, the authors performed a cross-sectional evaluation of guideline facilitators and associated outcomes including death and recurrent myocardial infarction. Significant associations with decreased death or reinfarction were observed with hospital strategies to facilitate primary percutaneous coronary intervention for ST-elevation MI patients (38/428 [8.9%] versus 30/154 [19.5%], P=0.001; Odds Ratio (OR) after adjustment 0.47, P<0.023), electronic discharge checklists (none: 233/1956 [11.9%]; electronic: 6/124 [4.8%], OR after adjustment 0.49), and intensive cardiac care unit (ICCU) staff-to-patient ratios (neither: 200/1257 [15.9%]; both: 8/84 [9.5%], ICCU: 8/84 [9.5%], P=0.049).

Conclusion: Study results suggest that the optimal translation of evidence for treating acute coronary syndromes may depend on health service capacity including "guideline facilitators" such as hospital strategies for reducing door-to-balloon time for percutaneous coronary intervention, electronic discharge checklists, and workforce capacity. Variability in use of these facilitators across Australian hospitals may have led to differences in patient outcomes. It is unknown, however, whether these tools and resources are fundamentally improving outcomes through changes in guideline-approved care or via alternate avenues that are more difficult to measure such as improved workplace satisfaction and more intensive patient observation.

Physician and Patient Influences on Provider Performance: β-Blockers in Postmyocardial Infarction Management in the MI-Plus Study

Summary: This study assessed the role of physician and patient characteristics in explaining variation of β-blocker prescription...
to ambulatory postmyocardial infarction (MI) patients. β-Blocker prescription and patient characteristics (age, sex, race, and insurance) were abstracted from charts of post-MI patients treated by 133 primary care physicians between 2003 and 2007 and were linked to physician (age, sex, specialty) and practice characteristics (site and location). Associations of β-blocker prescription with physician and patient-level characteristics were examined using linear mixed-effects models. Mean physician-specific predicted probabilities and intraclass correlations, which assessed the proportion of variance explainable at the physician level, were estimated. Of 1901 patients without major contraindications, 69.1% (range across physicians, 20% to 100%) were prescribed β-blockers. Prescription varied from 78.3% in patients with chronic kidney disease to 54.7% for patients with stroke. Although physician characteristics such as older physician age, group practice, and rural location were each positively associated with β-blocker prescription, physician factors accounted for only 5% to 8% of the variance in β-blocker prescription. The preponderance of the variance, 92% to 95%, was noted at the patient level. The mean physician-specific probability of β-blocker prescription (95% confidence interval) in the fully adjusted model was 63% (61% to 65%).

Conclusion: Patient factors and not physician attributes may be the dominant influence in β-blocker prescription among post-MI patients. Proper assessment of physician compliance with process measures for β-blocker use may therefore involve deeper assessment of patient characteristics, in particular the patient factors that may discourage appropriate β-blocker use. It is possible that other physician factors not tested in this study such as perceived efficacy of β-blockers may have had a greater impact on β-blocker use compared with more easily measured factors such as physician age, sex, race, and practice size.9

Regional and Geographic Variation in Cardiovascular Treatments and Outcomes

Geographic variation in healthcare has increasingly become a matter of national debate and has drawn attention from policymakers, politicians, and stakeholders. Work from Wennberg and others have highlighted regional variation in treatments, outcomes, and cost of care across the nation’s 306 hospital referral regions (HRR). While the source of this variation remains up for debate and may be principally due to either patient or supply-side factors, the high burden of heart disease in tandem with the wide range of technologies associated with its management makes examination of geographic variation in care patterns particularly compelling. The following section contains summaries of studies that examine geographic variation in preventive, diagnostic, and therapeutic interventions in cardiovascular medicine including implantable cardioverter-defibrillator insertion, carotid imaging, carotid endarterectomy and stenting, lower extremity procedures for critical limb ischemia, and hospitalizations for acute myocardial infarction.

Application of Geographic Modeling Techniques to Quantify Spatial Access to Health Services Before and After an Acute Cardiac Event: The Cardiac Accessibility and Remoteness Index for Australia (ARIA) Project

Summary: The Cardiac Accessibility and Remoteness Index of Australia (Cardiac ARIA) was devised to analyze geographic access to health care services. In this study, the authors used the Cardiac ARIA to quantify regional access to cardiac care services pertinent to acute cardiac events, defined as cardiac arrest, acute coronary syndromes, acute decompensated heart failure, or life-threatening arrhythmias. Using Geographic Information Systems data regarding road networks, population centers, and health care facilities, the authors measured both the time required to arrive at an appropriate health care facility following an emergency call and the access to 4 basic aftercare resources including cardiac rehabilitation, a family doctor, and pharmacy in the patient’s community. The Cardiac ARIA acute care score ranged from 1 (<1 hour to a hospital capable of percutaneous coronary intervention) to 8 (>3 hours to any medical facility) and the aftercare score ranged from A (<1 hour to all aftercare resources) to E (no after-care resources within 1 hour). Using this index, the authors found that 71% of Australians reside in category 1A areas. However, only 40% of indigenous people reside in 1A areas. Indigenous people were much more likely to reside in areas with poorer access to both acute care and aftercare needs.

Conclusion: This study presents a novel geographic technique for evaluation of access to acute cardiac care and aftercare. Application of this technique demonstrated that indigenous populations in Australia were much less likely to live in well-resourced areas. However, it is uncertain whether this methodology is also able to demonstrate a gradient in health outcomes by resource availability either in Australia or in other international settings.10

Geographic Variation and Trends in Carotid Imaging Among Medicare Beneficiaries, 2001 to 2006

Summary: Carotid imaging is an important contributor to rising health care costs. The authors used administrative claims data to examine trends in use of carotid ultrasound, carotid magnetic resonance angiography (MRA), and carotid x-ray angiography among a representative sample of Medicare beneficiaries with fee-for-service insurance between 2001 and 2006. The study cohort consisted of patients who were 65 years or older and underwent carotid imaging with the above technologies or a carotid intervention. The authors found that overall rates of imaging increased from 98.2 studies per 1000 person-years in 2001 to 124.3 per 1000 in 2006, a 27% relative increase. Although ultrasound was the most commonly used modality, the highest increases in rates were for MRA and x-ray angiography. Carotid intervention rates decreased from 3.6 interventions per 1000 person-years in 2001 to 3.1 per 1000 person-years in 2006. Rates of carotid ultrasound, MRA, and x-ray angiography varied on a regional basis after adjustment for study year, patient demographic characteristics, history of vascular disease, and other comorbid conditions. On a patient level, imaging was more common for older patients and patients with known vascular disease and was less common for blacks.

Conclusion: This study found substantial growth in use of carotid imaging techniques between 2001 and 2006 with significant variation in growth rates by technology and region. The greater adoption with time of more costly imaging techniques such as MRA and x-ray angiography as well as the increase in overall imaging with concomitant decreases in carotid interventions may signal greater overuse and misuse of imaging tests with time. Formal guidance on the relative merits and appropriateness of each imaging modality are needed.11

Variation in the Use of Lower Extremity Vascular Procedures for Critical Limb Ischemia

Summary: The authors investigated the extent of regional variation in procedural vascular care delivered to patients with critical limb ischemia (CLI). Using Medicare 2003 to 2006 data, they identified 20,464 patients with CLI who underwent major lower extremity amputation in the 306 hospital referral regions described in the Dartmouth Atlas of Healthcare. Overall, the authors identified the performance of 25,800 lower extremity vascular procedures (open surgery or endovascular intervention) in the year before amputation. These procedures were not distributed evenly at the patient level: 54% of patients had no vascular procedures performed in the year before amputation, 14% underwent 1 vascular procedure, and 32%
underwent >1 vascular procedure. These procedures were also not distributed evenly at the hospital referral region level: while vascular procedures were performed in 32% of patients in the year before amputation in regions in the lowest quintile of vascular intensity, procedures were performed in 58% of patients in the year before amputation in the highest quintile regions (P<0.0001). After adjusting for differences in age, sex, race, and comorbidities, patients in high-intensity regions were 2.4 times as likely to undergo revascularization in the year before amputation compared with patients in low-intensity regions (adjusted OR, 2.4; 95% CI, 2.1–2.6; P<0.001).

Conclusions: As with other conditions where clinical equipoise exists in the setting of multiple management options,11 the authors of this study demonstrate wide geographic variation in utilization of vascular interventions for patients with CLI. Significant variation persisted despite adjusting for socio-demographic and clinical factors, thereby suggesting the role of local practice patterns in driving these differences. However, as the current study only examined patients who ultimately underwent amputation, it would be important to additionally investigate how differences in revascularization practices by region were associated with differences in outcomes important to patients such as amputation, functional status, and death.15

Regional Variation in Carotid Artery Stenting and Endarterectomy in the Medicare Population

Summary: For the past 20 years, carotid endarterectomy (CEA) has been the gold standard for invasive management of stroke risk. In recent years, however, carotid artery stenting (CAS) has become a therapeutic option for many patients with significant carotid artery disease. However, it is not known whether the use of CAS has affected rates of CEA across the country. The authors in this study examined Medicare claims and enrollment data from 306 hospital referral regions between 1998 and 2007 in order to describe geographic variation in population-based rates of CEA and CAS. They found that the overall rate of carotid revascularization decreased from 3.8 procedures per 1000 in 1998 to 3.1 procedures per 1000 in 2007 (P<0.0001). Whereas the use of CEA decreased from 3.6 to 2.5 procedures per 1000 beneficiaries in 2007 (P<0.0001), the use of CAS increased from 0.1 to 0.6 CAS procedures per 1000 beneficiaries (P<0.0001). In 1998, 66% of hospital referral regions had a hospital that performed CAS; by 2007, nearly all (95%) hospital referral regions performed CAS (P<0.0001). Moreover, in regions with the highest utilization rates of CAS, it appeared that CAS was being performed as a substitute for CEA. There was little evidence that CAS was being performed in addition to CEA, as no correlation existed between regional rates of CAS and CEA (r=0.06). With time, regional variation was relatively constant for CEA but was increasing for CAS.

Conclusion: The authors found significant growth in the use of CAS within the context of overall reductions in the number of carotid revascularizations. In many regions, CAS appeared to be substituting for CEA. These trends as well as the substantial regional variation in rates of CAS raise concerns that CAS may at times be inappropriately used—CAS has never been shown to be superior CEA and has at times been shown to be inferior. As patients often prefer the use of novel and relatively noninvasive interventions to surgical procedures with a greater evidence base, greater regulatory oversight may be needed to ensure that the introduction and diffusion of novel technologies does not result in patient harm.16

Variation in Cardiologists’ Propensity to Test and Treat: Is It Associated With Regional Variation in Utilization?

Summary: Resource supply has been shown to impact regional variation in health spending at the level of the Hospital Referral Region (HRR). This study aims to evaluate the impact of physician-related behaviors and attitudes on variation in service utilization. To examine provider-level propensity to test and treat cardiovascular conditions with expensive technologies, 598 physicians were surveyed to compute a Cardiac Intensity Score. Cardiologists were also asked whether they would recommend a cardiac catheterization based on more than just “purely clinical reasons.” Cardiac Intensity Score was associated with 2 population-based measures of healthcare utilization: general healthcare spending (the End-of-Life Expenditure Index) and delivery of cardiac services (population-based catheterization rates). About ¼ of cardiologists reported ordering a catheterization if they felt a colleague would frequently do so if in the same situation. Similarly, ¼ reported ordering a catheterization due to fear of malpractice. Both peer influences and fear of malpractice were associated with a cardiologist’s propensity to test and treat, but only the fear of malpractice was associated with regional patterns of healthcare utilization.

Conclusions: Cardiologists’ propensity to use higher cost health services correlated well with established measures of regional health care expenditures. This higher propensity to use expensive technologies was associated with susceptibility to the influence of peers and fear of malpractice. These findings suggest that dissemination of evidence-based information via peer networks and attention to medico-legal risk might reduce variation in health expenditures.18

Ticagrelor Compared With Clopidogrel by Geographic Region in the Platelet Inhibition and Patient Outcomes (PLATO) Trial

Summary: Results of the Platelet Inhibition and Patient Outcomes (PLATO) trial that compared ticagrelor with clopidogrel in patients with acute coronary syndromes showed an unexpected interaction by region, suggesting worse outcomes for ticagrelor in the North American cohort compared with patients enrolled from other parts of the world. In a series of detailed exploratory analyses, the PLATO investigators tried to delineate the reasons behind the interaction between treatment and region. Since PLATO included multiple subgroup analyses, the authors could not exclude the possibility of chance alone in showing suboptimal outcomes with ticagrelor in North America. The exploratory analyses suggested that compared with the rest of the world, patients in the US more frequently took a dose of aspirin that was ≥300 mg/d (53.6% versus 1.7%, P<0.0001). This relatively high dose of aspirin explained a substantial fraction of the regional interaction. Among patients who took low-dose aspirin, ticagrelor was superior to clopidogrel both among US patients and patients in the rest of the world.

Conclusion: The higher dose of aspirin in the US cohort provides a possible explanation for worse outcomes among US patients in PLATO. The lack of any identified systematic errors in trial conduct is reassuring. However, as this study was a post hoc analysis, its results are only hypothesis generating. Post-marketing surveillance should be used to assess whether aspirin dose relates to outcomes in patients with acute coronary syndromes who are treated with ticagrelor. In the interim, aspirin dosing considerations have been incorporated in the 2012 focused update of the ACC/AHA guidelines for management of patients with unstable angina/non-ST-elevation myocardial infarction.16,17

Regional Variation in the Use of Implantable Cardioverter-Defibrillators for Primary Prevention: Results From the National Cardiovascular Data Registry

Summary: Geographic variation in the use of implantable cardioverter-defibrillators (ICD’s) for primary prevention of sudden cardiac death among patients with heart failure is unknown. Using the National Cardiovascular Data Registry, the authors examined the rate of ICD
implantation among patients aged >65 years with traditional Medicare fee-for-service health insurance. The authors calculated age-, sex-, and race-adjusted rates of ICD placement for each hospital referral region (HRR) and assessed the correlation between these rates and (1) physician supply and (2) the proportion of patients meeting trial inclusion criteria. The primary finding was that of substantial variation in rate ratios of ICD implantation across quintiles, which ranged from 0.39 to 1.77 (compared with a national mean rate of 1.0). This ratio was not correlated with the supply of cardiologists ($R^2=0.01$), electrophysiologists ($R^2=0.01$), or with the proportion of patients meeting inclusion criteria from major primary prevention trials ($R^2<0.01$). Overall, 13% of patients receiving ICDs did not meet trial criteria.

**Conclusion:** The implantation of primary prevention ICDs is subject to marked geographic variation across the United States. This variation was not explained by relatively simplistic explanations such as differences across regions in patient characteristics, supply-side factors, or adherence to ICD implementation guidelines. Regional variation in practice may relate more significantly to harder-to-measure factors such as differences in patient preferences for device placement or differences in financial incentives experienced by physicians. It is unknown whether study of regional differences in implantation of related cardiac devices such as biventricular pacemakers would yield similar findings.16

**Geographic Disparities in the Incidence and Outcomes of Hospitalized Myocardial Infarction: Does a Rising Tide Lift All Boats?**

**Summary:** The incidence of myocardial infarction (MI) has declined in recent decades. This study aims to examine trends over time in MI incidence, revascularization rates, and short-term mortality rates by region. The authors examined all hospitalizations for MI among Medicare fee-for-service beneficiaries from 2000 to 2008. They found significant regional variation in age-sex-race-adjusted MI incidence in the year 2000, ranging from 800 per 100,000 person years in the Pacific region to 1150 per 100,000 person years in the East North Central region. Despite an average relative decline in MI incidence of 4.3% per year from 2000 to 2008, geographic disparities between regions increased by 37.6%. In the year 2000, the authors found that rates of cardiac catheterization, percutaneous coronary intervention (PCI), and coronary artery bypass graft (CABG) surgery also varied significantly, with New England and the Mid Atlantic divisions having the lowest rates. Over time, rates of CABG declined while rates of other revascularization procedures increased. Geographic disparities between regions in procedure rates increased only for PCI (31.4% increase). All-cause 30-day mortality declined over time in all regions, with the risk-adjusted odds ratio declining by 0.96 to 0.98 from each year to the next. There was a trend toward decreasing geographic disparity in mortality that did not reach statistical significance; areas with higher mortality rates in 2000 had the most substantial improvement by 2008.

**Conclusion:** Despite significant decreases in MI incidence between 2000 and 2008, regional differences in incidence have increased over time. These results suggest that while improvements in preventing MI are widespread, they have not been experienced equally; greater efforts should be directed toward implementing and enforcing cardiovascular risk reduction strategies in lagging regions. In contrast, decreasing 30-day mortality and decreasing regional variation in mortality after MI with time suggest that national strategies for improving MI mortality in the acute care setting are being adopted effectively.19

**Hospital Variation in Cardiovascular Treatments and Outcomes**

In the last decade, increased attention has been directed to the topic of hospital variation in quality. Within the field of cardiology, initial work focused on variation in delivery of evidence based process measures for patients hospitalized with acute myocardial infarction or heart failure. Attention was given to interventions such as the appropriate use of pharmacotherapies such as aspirin and β-blockers and diagnostic tests such as echocardiograms. With time, some of these process measures were codified as core measures from the Centers for Medicare and Medicaid Services. As compliance with these measures has increased and variability across hospitals has declined, additional attention has been directed toward hospital variation in important 30-day outcomes such as death and readmission. Studies using claims data from Medicare have shown substantial variation in both endpoints across US hospitals even after risk-standardization and adjustment for patient demographic characteristics and comorbidities. Increasingly, studies are seeking to explain the etiology of such variation such as organizational and cultural characteristics that have broad impact across conditions20 as well as more easily measured factors such as hospital volume,21 nursing resources,22 and teaching status. The articles we present below describe variation in outcomes for multiple conditions and endpoints such as risk standardized 30-day complications, readmission, and mortality rates.

**National Patterns of Risk-Standardized Mortality and Readmission for Acute Myocardial Infarction and Heart Failure: Update on Publicly Reported Outcomes Measures Based on the 2010 Release**

**Summary:** Cardiovascular conditions such as acute myocardial infarction (AMI) and heart failure (HF) are now areas of priority for public reporting of hospital-based outcomes. The Centers for Medicare and Medicaid Services (CMS) began publicly reporting hospital 30-day risk-standardized mortality rates (RSMRs) for patients hospitalized with AMI and HF in 2007 and in 2009, started publicly reporting 30-day risk-standardized readmission rates (RSRRs) for the same conditions. The authors used claims data for fee-for-service Medicare beneficiaries 65 years or older who were hospitalized with AMI or HF between July 2006 and June 2009. They calculated hospital RSMRs and RSRRs using the same algorithm used by CMS for the purposes of public reporting. Median RSMR for AMI was 16% and median RSRM for HF was 10.8%. Both measures had a wide range of hospital performance with an absolute 5.2% difference between hospitals in the 5th versus 95th percentile for AMI and a 5.0% difference for HF. Median RSRR for AMI was 19.9% and for HF was 24.5%. Range from the 5th to 95th percentile for AMI was 3.9% and range for HF was 6.7%. Distinct regional patterns were evident for both measures and both conditions.

**Conclusion:** Both mortality and readmission are common after hospitalization for AMI and HF. Variation for these outcomes by site of care is also significant. These results indicate that substantial opportunity exists to decrease both overall rates of these adverse outcomes and interhospital variability in events. It is hoped that new financial penalties to hospitals with higher-than-expected readmission rates for these conditions will lead to improvement in both of these important endpoints.23

**Coronary Artery Bypass Graft: Contemporary Heart Surgery Center Performance in China**

**Summary:** Although use of coronary artery bypass grafting (CABG) surgery is increasing in China, the quality and outcomes associated with CABG surgery across Chinese hospitals is not known. The authors therefore sought to examine in-hospital mortality and major complication rates among hospitals in the Chinese Cardiac Surgery Registry, the largest CABG registry in China. The study included 8,739 patients undergoing isolated CABG from 43 hospitals in 2007 to 2008. There was significant variation in both patient and hospital...
characteristics by region. Mean rate of observed in-hospital mortality was 2.2% (CI 1.9%-2.5%) with a range of 1.6%-2.4% by region. Mean rate of observed in-hospital complications was 6.6% (CI 6.1%-7.1%) with a range of 6.0%-9.1% by region. Following risk standardization with adjustment for age, gender, creatinine, ejection fraction, and comorbidities, the mean risk-standardized mortality rate (RSMR) was 1.9% with a range by hospital of 0.7%-5.8% and range by region of 1.6% in Eastern China to 2.5% in Central China. The mean risk-standardized major complication rate (RSMCR) was 6.4% with a range by hospital of 3.8%-10.1% and a range by region of 5.8% in Eastern China to 7.7% in Southern China.

Conclusion: This study found significant variation in CAGB-related mortality and complication rates across both hospitals and regions of China. These results can be used to create performance standards for benchmarking and can guide the transfer of best practices from better performing to poorly performing hospitals. It is unknown, however, if study results are truly generalizable, as the registry includes only leading CAGB centers in China, which are large, well-resourced hospitals that perform only about 25% of the CAGB surgeries in China.24

Hospital Variation in Readmission After Coronary Artery Bypass Surgery in California

Summary: Coronary artery bypass grafting (CABG) surgery is associated with an average 30-day readmission rate of approximately 15%.25,26 However, previous studies have found wide variation in readmission rates by site of care. This paper examines the relative importance of patient-level versus hospital-level factors in predicting rates of readmission among a recent cohort of CABG patients from California. The authors identified 11,823 patients who underwent CABG from 119 hospitals in the 2009 California CABG Outcomes Reporting Program database. These records were linked to longitudinal outcomes data and 1565 readmissions within 30 days were identified. Observed readmission rates among the 119 hospitals performing CABG varied from 0% to 26.9% with a median of 13.1%. Hospitals with higher readmission rates had more readmissions due to circulatory diseases, infections, complications for surgical and medical care, and digestive diseases (all P<0.05). Although multiple patient factors such as older age, female sex, and body mass index ≥40, among many others, were found to be significant predictors of 30-day readmission after adjustment for patient characteristics, length of stay, and hospital characteristics. The proportion of total cost variation explained by center effects was 19% for ASD repair, 11% for VSD repair, 6% for TOF repair, and 3% for ASO. Higher center volume was associated with significantly lower hospital costs, but only for the relatively low complexity surgeries (ASD and VSD repair).

Conclusion: Total hospital costs for 4 congenital heart surgeries varied significantly across centers; variation in cost was greater for lower complexity surgeries. The reasons for greater cost variability for lower complexity surgeries were not formally explored. The generalizability of study results is uncertain, as the Premier hospital network does not include many children’s hospitals, where many of these procedures are performed at higher rates. In addition, decisions based on cost variability should incorporate an understanding of the drivers of this variability and the association of costs with outcomes.25

Center Variation in Hospital Costs for Patients Undergoing Congenital Heart Surgery

Summary: Although congenital heart conditions account for 6 billion dollars in acute health care costs annually, little is known about the factors affecting resource utilization for these conditions. This study used the Premier database to examine variation in total hospital costs across multiple centers with ≥5 cases of the following congenital heart disease surgeries from 2001 to 2007: isolated atrial septal defect (ASD) repair, ventricular septal defect (VSD) repair, tetralogy of Fallot (TOF) repair, and arterial switch operation (ASO). The authors identified 2124 survivors to hospital discharge: 719 ASD patients at 19 centers, 792 VSD patients at 20 centers, 420 TOF patients at 17 centers, and 193 ASO patients at 13 centers. Total costs increased with increasing complexity of the operation (ASD repair costs < VSD repair costs < TOF repair costs < ASO costs). Models accounting for center level-effects on total cost variation performed significantly better than models without these variables. Center effects persisted after adjustment for patient characteristics, length of stay, and hospital characteristics. The proportion of total cost variation explained by center effects was 19% for ASD repair, 11% for VSD repair, 6% for TOF repair, and 3% for ASO. Higher center volume was associated with significantly lower hospital costs, but only for the relatively low complexity surgeries (ASD and VSD repair).

Conclusion: Understanding the drivers and consequences of center variation in congenital heart surgery costs is an important step toward improving clinical outcomes and cost-effectiveness.27

Recent National Trends in Readmission Rates After Heart Failure Hospitalization

Summary: The Centers for Medicare and Medicaid Services (CMS) began in 2009 publicly reporting hospitals’ risk-standardized 30-day all-cause readmission rates (RSRRs) among fee-for-service beneficiaries discharged alive after hospitalization for heart failure (HF). In order to provide baseline estimates of hospital readmission performance for HF, the authors report on national trends in hospital RSRRs after HF hospitalization between 2004 and 2006 using Medicare administrative data. For each hospital, the authors estimated mean annual RSRRs, a National Quality Forum-endorsed metric for quality, using hierarchical models that accounted for age, sex, and comorbidities. They found 570 996 distinct hospitalizations for HF in which the patient was discharged alive from 4728 hospitals in 2004, 544 550 from 4694 hospitals in 2005, and 501 234 from 4674 hospitals in 2006. Unadjusted 30-day all-cause readmission rates were similar over this period: 23.0% in 2004, 23.3% in 2005, and 22.9% in 2006. The mean and standard deviation of hospital RSRRs were also similar, suggesting comparable hospital variation throughout the study period.

Conclusion: The study finds that the 30-day RSRRs for Medicare beneficiaries hospitalized with HF were virtually identical between 2004 and 2006, prior to the period of public reporting. This data will serve as a useful baseline when comparisons are made to the recent era of public reporting between 2009 and 2012 and the current era of financial penalties to hospitals with higher-than-expected readmission rates. As approximately 1 in 4 patients hospitalized with HF is rehospitalized within 1 month of discharge, there is substantial room and opportunity for improvement.28

Sources of Hospital Variation in Short-term Readmission Rates After Percutaneous Coronary Intervention

Summary: The variation in risk-standardized 30-day readmission rates (RSRRs) and factors leading to this variation among hospitals following percutaneous coronary intervention (PCI) are not well known. The authors estimated 30-day, all-cause RSRRs for all non-federal PCI-performing hospitals in Massachusetts between 2005 and 2008. The Massachusetts Department of Public Health had collected data on all PCIs over this period using an instrument from the CathPCI registry of the National Cardiovascular Data Registry.
Measures of Variation in Health Care

As patients, payers, and policymakers have become more concerned with promoting high quality, high value health care, the issue of quality measurement has taken on added significance. In the past decade, the Centers for Medicare and Medicaid Services in tandem with academic researchers created risk adjustment methodologies using claims data to measure both 30-day readmissions and 30-day mortality that compare favorably with chart-based risk-adjustment. These methodologies have led to public reporting of 30-day outcomes on the Hospital Compare website and now, increased penalties to hospitals who undergo PCI and were alive at discharge, 4469 (12.4%) were readmitted within 30 days of hospitalization. Hospital RSRRs ranged from 9.5% to 17.9%, with 8 of 24 hospitals being identified as outliers (4 had lower-than-expected performance and 4 had higher-than-expected performance). Differences in clinical presentation, comorbidities, procedural type and characteristics, race, insurance, and discharge related factors could account for only 10.4% of the between-hospital variance in RSRRs.

Conclusion: This study demonstrates that drivers for readmissions post PCI are currently poorly accounted-for by registry-based variables. This is an important finding since tangible targets amenable to intervention are necessary for quality improvement drives to succeed. Further studies examining the factors beyond simple patient and procedural characteristics such as cognitive status at discharge, functional status at discharge, social support, availability of outpatient follow-up, access to cardiac rehabilitation and medication compliance may be useful in explaining this variation and identifying appropriate targets for care.

Impact of Independent Data Adjudication on Hospital-Specific Estimates of Risk-Adjusted Mortality Following Percutaneous Coronary Interventions in Massachusetts

Summary: The success of public reporting of healthcare provider performance relies, in part, on the quality of the data used to measure performance. In this study, the authors examined procedural and clinical data associated with percutaneous coronary intervention (PCI) that was prospectively collected as part of a state-mandated effort to publicly report quality outcomes. The authors examined the impact of an independent adjudication of variables associated with higher mortality on the identification of hospitals with possible deficiences inPCI quality. They studied 15,721 admissions for PCI from 21 nonfederal Massachusetts hospitals between October 2005 and September 2006. Of the 864 high-risk variables from 822 patients, 201 were changed after audit, with reassignment to lower acuities in 97 (30%) of the 321 shock cases, 24 (43%) of the 56 salvage cases, and 73 (15%) of the 478 emergent cases. Logistic regression models were used to predict patient-specific in-hospital mortality. Model accuracy was excellent with either adjudicated or unadjudicated data. In addition, hospital-specific risk-standardized mortality rates were estimated using both adjudicated and unadjudicated data through hierarchical logistic regression. Although adjudication reduced between-hospital variation by one third, risk-standardized mortality rates were similar using unadjudicated and adjudicated data. None of the hospitals were identified as statistical outliers; however adjudicated data resulted in an increased number of borderline outliers.

Conclusion: In a statewide observational registry of PCI procedures, variables highly predictive of mortality were erroneously overcoded more than one-third of the time. This overcoding decreased between-hospital variation in PCI outcomes and may have reduced the ability to identify hospitals with borderline outcomes that may be at risk of becoming outliers. As PCI-related outcomes become used to guide reimbursement decisions, greater checks may be needed to avoid overestimation of procedural risk. Lessons may be learned from the New York experience of predicting expected risk from coronary artery bypass graft procedures, where recoding decreased expected mortality rates by as much as 52%.

Risk-Adjusted Percent Time in Therapeutic Range as a Quality Indicator for Outpatient Oral Anticoagulation: Results of the Veterans Affairs Study to Improve Anticoagulation (VARIA)

Summary: Although oral anticoagulants are used by millions of patients, there are no organized approaches to measuring the quality of oral anticoagulation across sites providing this care. Rose and colleagues determined the variation in crude and risk-adjusted time in therapeutic range (TTR) for patients receiving oral warfarin therapy across 100 Veterans Health Administration sites. TTR is a widely accepted marker of optimal anticoagulation for patients receiving warfarin. The authors included factors such as individual patient demographics, physical and mental health conditions, number of medications taken, number of recent hospitalizations, driving distance to the site of care, and area-level poverty when performing risk adjustment. Mean TTR for the entire sample was 58%. Site-observed TTR varied from 38% to 69%. Site risk-adjusted performance ranged from 18% below expected to 12% above expected. Although crude and risk-adjusted rankings were highly correlated (r=0.93; P<0.001), risk adjustment led to major reclassification of several sites that had distinctly different case mixes.

Conclusion: This work provides a foundation for measuring the quality of anticoagulant therapy across practice settings. However prior to widespread implementation, knowledge is needed of the association between site-level risk-adjusted TTR and site-level risk-adjusted rates of thrombotic and hemorrhagic events. In addition, hospitals should remain aware that quality of care pertaining to anticoagulant therapy includes other factors such as appropriate patient selection for anticoagulation as well as prompt reconsideration of the benefits and risks of anticoagulation and anticoagulation treatment intensity with changes in the clinical status of patients.

Prompt Repeat Testing After Out-of-Range INR Values: A Quality Indicator for Anticoagulation Care

Summary: Control of warfarin anticoagulation using the international normalized ratio (INR) has been shown to improve individual and center-level outcomes. In follow-up to a previous study, the authors determined the time interval for repeat INR testing after a low (≤1.5) or high (≥4.0) INR across 100 Veterans Health Administration centers. They also determined the association between time to repeat INR testing and center-level risk-adjusted time in therapeutic range (TTR). The mean site-level follow-up interval after a low INR or high INR...
result ranged between 10 to 24 days and 6 to 18 days, respectively. The mean site-level follow-up interval after a low INR or high INR result was inversely associated with the risk-adjusted site-level percent TTR (r = -0.59 and -0.57, respectively, P<0.001 for both comparisons).

**Conclusion:** The authors suggest that timely center-level response to suboptimal (low or high) INR could serve as a measure of anticoagulation quality. It is unknown, however, if faster responding sites achieve better risk-adjusted rates of thrombotic and hemorrhagic events. Further qualitative study can identify the factors that are associated with better response to out of range INR at top performing centers, by they unmeasured patient characteristics such as willingness to undergo prompt repeat testing or hospital factors such as timely reporting of data and automated processes to schedule expedited repeat blood draws.34

**Development of 2 Registry-Based Risk Models Suitable for Characterizing Hospital Performance on 30-Day All-Cause Mortality Rates Among Patients Undergoing Percutaneous Coronary Intervention**

**Summary:** No methodology has been proposed to monitor and improve national hospital 30-day mortality rates following percutaneous coronary intervention (PCI). The authors therefore developed hierarchical logistic regression models to calculate hospital risk-standardized 30-day all-cause PCI mortality rates. Patients were divided into 2 cohorts: those with ST-segment elevation myocardial infarction (STEMI) or cardiogenic shock, and those with non ST-segment elevation myocardial infarction (NSTEMI) and no cardiogenic shock. The models were derived using 2006 data from the CathPCI Registry of the National Cardiovascular Data Registry and were linked to Medicare fee-for-service administrative claims data. Validation was performed using comparable 2005 data. In the derivation cohort of the STEMI or shock model (n=15 123), the unadjusted 30-day mortality rate was 9.2%. The final model included 13 variables with observed mortality rates of 1.4% to 40.3% across deciles of predicted patient mortality rates. The 25th and 75th percentiles of the risk-standardized mortality rate were 8.5% and 9.7%, with 5th and 95th percentiles of 7.6% and 11.0%. In the derivation cohort of the NSTEMI and no shock model (n=110 529), the unadjusted 30-day mortality rate was 1.4%. The final model included 16 variables with observed predicted mortality rates ranging from 0.1% to 7.0% across deciles of the predicted patient mortality rates. The 25th and 75th percentiles of the risk-standardized mortality rate across 612 hospitals were 1.3% and 1.6%, with 5th and 95th percentiles of 1.0% and 2.0%.

**Conclusion:** The authors propose novel methodologies suitable for characterizing hospital performance after PCI that leverage preexisting infrastructure and data collection practices at the majority of hospitals currently performing PCI. Unlike previous risk scores, these models establish a standard period of assessment while accounting for differences in case mix and volume by hospital. These methodologies are consistent with consensus standards for publicly reported outcomes measures and have been approved by the National Quality Forum for the purposes of hospital performance measurement after PCI. Extension of the models to patients less than 65 years of age who comprise more than 50% of patients in the CathPCI Registry may require further validation.35

**References**


