Most Important Papers in Health Costs, Cost-Effectiveness, and Resource Utilization

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The following are highlights from the new series, Circulation: Cardiovascular Quality and Outcomes Topic Review. This series will summarize the most important manuscripts (as selected by the Editor) that have published in the Circulation portfolio. The objective of this new series is to provide our readership with a timely, comprehensive selection of important papers that are relevant to the quality and outcomes, and general cardiology audience. The studies included in this article represent the most significant research in the area of health costs, cost-effectiveness, and resource utilization. (Circ Cardiovasc Qual Outcomes. 2012;5:e9-e15.)

The rising cost of health care is front-page news. According to the Kaiser Family Foundation, health spending, as a share of the country’s gross national product, has increased from 14.1% to 17.7% between 2001 and 2012. Government, the private sector, and individual households have all felt the financial crunch, and there is greater acknowledgement that health spending may trade off with spending in other important areas. As a result, studies of cost, cost-effectiveness, and resource utilization have become increasingly important as we try to “bend the cost curve” and guide health spending to areas with the highest value for patients.

We have therefore dedicated our topic review in this issue of Circulation: Cardiovascular Quality Outcomes to studies of health costs, cost-effectiveness, and resource utilization. We have intentionally included papers from diverse areas of cardiology and vascular disease, including coronary artery disease, heart failure, atrial fibrillation, congenital heart disease, peripheral arterial disease, and genetic disorders. The interventions studied were similarly diverse and include diagnostic testing for cardiac ischemia, percutaneous coronary intervention, medical management of atrial fibrillation, complex congenital heart surgery, exercise in heart failure, and genetic testing for long QT syndrome.

We hope you find these summaries stimulating and useful. Considerations of cost are here to stay.

Vascular Hospitalization Rates and Costs in Patients With Peripheral Artery Disease in the United States

Summary: Peripheral artery disease (PAD) is common, is associated with a major risk of ischemic events, and contributes to significant cost burden. The REDuction of Atherothrombosis for Continued Health (REACH) Registry is an international prospective registry of patients at risk of atherothrombosis, caused by established arterial disease or the presence of ≥3 atherothrombotic risk factors. This study includes 2137 patients from the REACH cohort with PAD at baseline. These patients were enrolled from 937 sites between December 2003 and June 2004. Patients were classified into 4 PAD subgroups. Authors compared the 2-year rates of vascular-related hospitalizations and associated costs in US patients with established PAD across patient subgroups to understand how healthcare resources vary according to PAD symptom status. Results suggest that costs of patients with asymptomatic PAD are higher than for patients with symptomatic PAD.

Conclusion: This study breaks new ground by analyzing hospitalization rates and costs according to PAD subgroups, defined by symptoms and history of previous interventions to treat PAD. Interestingly, asymptomatic patients have a higher cost burden due to the elevated incidence of cardiovascular events and procedures relative to patients with symptoms of PAD. Asymptomatic PAD may therefore be a surrogate for increased risk of future vascular events.1

Cost-Effectiveness of Genetic Testing in Family Members of Patients With Long-QT Syndrome

Summary: Family members of patients with established Long QT syndrome (LQTS) may also have inherited the LQTS mutation and be at risk of sudden cardiac death. The authors used a Markov model to assess the cost-effectiveness of 3 strategies for treating an asymptomatic 10-year-old who has a first-degree relative with clinically evident LQTS: (1) genetic testing with initiation of beta-blockers if mutation positive; (2) empirical beta-blocker treatment; or (3) watchful waiting with treatment on development of symptoms. Genetic testing resulted in higher survival and quality-adjusted life years at a higher cost, relative to watchful waiting. Cost-effectiveness improved to $50,000 per quality-adjusted life year, gained when genetic testing was selectively applied to relatives with a higher pretest suspicion of LQTS, families with a higher risk of sudden death, and when 2 or more first-degree relatives were tested; however, cost-effectiveness estimates were sensitive to multiple assumptions, including those relating to annual risk of death, pretest probability of LQTS in first-degree relatives of the index case, probability of symptom onset, efficacy of beta-blocker treatment, and reductions in quality of life due to beta-blocker therapy.

Conclusion: Genetic testing of young first-degree relatives of patients with definite LQTS can be cost-effective when applied to selected patients. As genetic testing becomes progressively cheaper, the cost-effectiveness of the testing strategy should further improve; however, as the study model demonstrates, cost-effectiveness of the various treatment strategies is very sensitive to multiple assumptions and may therefore be difficult to accurately calculate for any given patient.2

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Cost-Effectiveness of Statin Therapy for Primary Prevention in a Low-Cost Statin Era

Summary: The authors studied the cost-effectiveness of expanded statin-prescribing strategies, with the recent availability of low-cost generic statins. Using a Markov Model of the US population >35 years of age, they simulated aggressive statin-prescribing strategies for primary prevention in patients with low to moderate risk of coronary heart disease and identified risk thresholds at which aggressive prescribing ceases to be cost-effective. Assuming that statins are universally available at a cost of $4/mo and efficacious in all persons >35 years of age, reduced treatment thresholds, compared with Adult Treatment Panel III guidelines, would reduce annual healthcare costs by $430 million and lower coronary heart disease burden for $9900 per quality-adjusted life year. These findings were insensitive to known and hypothetical side effects but were sensitive to large reductions in efficacy of statins or a long-term disutility burden, for which a patient would trade 30 to 80 days of life to avoid 30 years of statins.

Conclusion: Prescriptions of statins can be safely expanded to persons with low to moderate risk of coronary heart disease. In the present era of healthcare cuts, such an expanded strategy can result in cost savings. Given the upcoming release of Adult Treatment Panel IV guidelines, it will be interesting to see if cost-effectiveness considerations are included in management guidelines.

Cost-Effectiveness of Community-Based Strategies for Blood Pressure Control in a Low-Income Developing Country: Findings From a Cluster-Randomized, Factorial-Controlled Trial

Summary: Evidence on economically efficient strategies to lower blood pressure (BP) in low- and middle-income countries remains scarce. The Control of Blood Pressure and Risk Attenuation (COBRA) trial randomized 1341 hypertensive subjects in 12 randomly selected communities in Karachi, Pakistan, to 3 intervention programs compared with usual care: (1) combined home health education (HHE) by lay health workers plus management by trained general practitioners (GPs); (2) HHE only; and (3) trained GPs only. Total costs and effects were assessed at baseline and 2 years to estimate incremental cost-effectiveness ratios based on (1) intervention cost; (2) cost of physician consultation, medications, diagnostics, changes in lifestyle, and productivity loss; and (3) change in systolic BP. The authors found HHE plus trained GP to be the most cost-effective intervention, with an incremental cost-effectiveness ratio of $23 per mm Hg reduction in systolic BP compared with usual care.

Conclusion: The combined intervention of home health education plus a trained GP was affordable and more cost-effective for BP control than usual care or either strategy alone in a low- to middle-income country. Focus on decreased blood pressure versus hard outcomes, such as mortality due to myocardial infarction, should be acknowledged as a shortcoming, albeit a minor one, given the challenging environment in which the study was conducted. Studies like the present one provide quality data to policy makers for cost-effective allocation of scarce healthcare resources.

Resource Use Among Adult Congenital Heart Surgery Admissions in Pediatric Hospitals: Risk Factors for High Resource Use and Association With Inpatient Death

Summary: This paper examines resources used by adults undergoing congenital heart surgery in pediatric hospitals, explores the association between high resource use (HRU) and inpatient death, and identifies HRU risk factors. The authors obtained inpatient data from 42 pediatric hospitals from 2000 to 2008 and selected adult congenital heart surgical admissions. They defined HRU admissions as those exceeding the 90th percentile for total hospital charges and performed multivariable analyses to identify risk factors for HRU. Of all the congenital heart surgery admissions to pediatric hospitals, 3.1% were adults and accounted for 2.2% of total hospital charges. Mortality rate was 16% for HRU admissions and 0.7% for others. HRU was associated with higher case complexity, DiGeorge syndrome, depression, weekend admission, and government insurance.

Conclusion: This study found that costs associated with adult congenital heart surgery comprised only 2.2% of total hospital charges in pediatric hospitals. Cases with HRU were associated with increased mortality and complexity. These findings will gain further importance with time, given the increasing number of persons with congenital heart disease surviving to adults; however, these results may not be generalizable to congenital heart surgery performed on adults outside of pediatric hospitals.

Using Stress Testing to Guide Primary Prevention of Coronary Heart Disease Among Intermediate-Risk Patients: A Cost-Effectiveness Analysis

Summary: It is unclear whether stress testing to guide treatment with statins or aspirin for prevention of coronary heart disease (CHD) is cost effective for patients at intermediate risk of CHD (10-year risk of 10% to 20%). The authors compared the existing practice of statin and aspirin therapy with 3 postulated scenarios among such patients: (1) complete implementation of the Adult Treatment Panel III guidelines; (2) universal use of statins (for men and women) and aspirin (for men); and (3) a test-and-treat strategy of stress testing with subsequent statin (men and women) and aspirin (men only) therapy for those with positive results. Coronary events, quality-adjusted life years, and costs were projected from 2011 to 2040. Universal statin therapy was the most cost-effective strategy, resulting in cost savings if statins were provided at a price of $4/mo. The results were consistent under a variety of sensitivity analyses. Stress testing was cost-saving only if the results of testing improved adherence to statin therapy from <21% to >75%. Stress testing reserved only for patients nonadherent to drug therapy was cost-effective and cost-saving if it raised adherence to ≥5% and 13%, respectively.

Conclusion: This study suggests that universal statin and aspirin therapy may be more cost-effective than test-and-treat strategies for those at intermediate risk of CHD. As with all modeling studies, the results need to be confirmed by empirical data. Nevertheless, the imminent availability of high-potency statins at low prices and the added benefits of statins and aspirin in reducing noncoronary vascular events make the findings of this study particularly promising.

Provider-Directed Imaging Stress Testing Reduces Health Care Expenditures in Patients With Lower-Risk Chest Pain Presenting to the Emergency Department

Summary: This study was a single-center clinical trial where 123 low-risk patients presenting to the emergency department with chest pain were randomly assigned to receive observation unit care with Cardiac Magnetic Resonance (CMR) or a modality of the provider’s choice. Participants underwent a record review and telephone interview at 30 days to determine outcomes such as length of stay, clinical outcomes, and cost. In comparison to a mandatory CMR pathway, participants in a Provider Choice care pathway (with an option for CMR) had decreased costs, similar lengths of stay, and similar clinical outcomes.

Conclusion: Allowing physicians to choose the cardiac stress test modality (including echocardiography, CMR, or radionuclide test-
ing) is more cost-effective than a pathway that mandates CMR stress testing in all patients with low-risk chest pain. This may not be surprising, as CMR is usually the most expensive modality. Nevertheless, this study illustrates the importance of physician judgment in the care of patients with suspected acute coronary syndromes.7

Percutaneous Coronary Intervention

According to the most recent American Heart Association Heart Disease and Stroke Statistics, nearly 600,000 patients underwent percutaneous coronary intervention (PCI) for ischemic heart disease in 2009. The associated annual costs of the procedure itself, intracoronary stents, and continued antiplatelet therapy are enormous and have been estimated at more than $12 billion. These costs may further increase, as acute coronary syndromes are more often treated with primary PCI. The following summaries address topics relevant to PCI and costs, including stent choice, periprocedural anticoagulant strategies, use of fractional flow reserve, PCI regionalization strategies, the degree of patient benefit from PCI based on angina severity, and patients’ willingness to pay to eliminate the risk of restenosis after PCI.

Cost-Effectiveness of Targeting Patients Undergoing Percutaneous Coronary Intervention for Therapy With Bivalirudin Versus Heparin Monotherapy According to Predicted Risk of Bleeding

Summary: Bivalirudin has been shown to reduce the incidence of major bleeding compared with heparin in patients undergoing percutaneous coronary intervention (PCI). The authors studied the cost-effectiveness of substituting bivalirudin for heparin monotherapy in 81,628 patients from the National Cardiovascular Data Registry (NCEDR) CathPCI Registry. The predicted baseline risk of bleeding in the selected patients was 2.2% using a previously validated model for predicting risk of major bleeding. They developed a decision-analytic Markov model to estimate lost life expectancy associated with a major bleed. Bivalirudin was estimated to increase costs by $571 per patient for all patients, yielding cost-effectiveness ratios of $287,473 per bleeding event averted and $1,173,360 per quality-adjusted life year gained. At willingness-to-pay thresholds of $50,000 and $100,000 per quality-adjusted life year gained, bivalirudin was cost-effective for patients with a bleeding risk ≥5% (2.5% patients) and ≥5% (7.9% patients), respectively.

Conclusion: Routine use of bivalirudin in place of heparin monotherapy in patients undergoing PCI will increase costs for virtually all patients. Bivalirudin tends to be cost-effective in only a minority of patients who have a higher predicted risk of bleeding. The present study is helpful in identifying appropriate risk thresholds at which treatment with bivalirudin would be most cost-effective. Given limited healthcare funds, modeling studies such as the present one may assist in the judicious use of emerging newer, costly treatment modalities.8

Comparative Effectiveness of ST-Segment-Elevation Myocardial Infarction Regionalization Strategies

Summary: Primary percutaneous coronary intervention (PCI) is superior to thrombolysis for patients with ST-elevation myocardial infarction (STEMI) but is not available at many US hospitals. The authors mathematically modeled several scenarios of development, or expansion, of PCI facilities for hospitals, or an emergency transport approach to PCI-capable hospitals, versus the standard-base case of existing care for 2000 patients in a regional system of 16 hospitals in Dallas County. Hospital-based strategies increased the number of patients receiving PCI, their quality-adjusted life years, and total costs and were cost-effective in some scenarios. The emergency transport system approach was more effective and much less costly than all hospital-based interventions. The results were consistent across a wide range of sensitivity analyses.

Conclusion: As the study by Concannon and colleagues demonstrates, in emergency medical service systems capable of timely detection and transfer of patients with STEMI to PCI-capable hospitals, an emergency medical service-based strategy is more effective and less costly than regionalized strategies of constructing and staffing new PCI facilities.9 Interestingly, another very recent study by Concannon and colleagues showed that marked expansion of PCI facilities has provided only modest improvement in geographic access to PCI.10 These 2 studies have important implications, as implementing regional strategies to provide timely reperfusion is in line with recent efforts of the American College of Cardiology and the American Heart Association to improve the outcomes of patients with STEMI.

Economic Evaluation of Fractional Flow Reserve-Guided Percutaneous Coronary Intervention in Patients With Multivessel Disease

Summary: Results of the Fractional flow reserve versus Angiography for Multivessel Evaluation (FAME) trial showed that fractional flow reserve (FFR) measurement for guiding percutaneous coronary intervention is associated with improved 1-year outcomes, compared with the traditional angiography-guided approach. The authors conducted a cost-utility analysis of FFR measurement among the FAME trial participants. Mean overall costs were lower in the FFR-guided arm ($14,315 versus $16,700; P<0.001). Assuming a threshold of $50,000 per quality-adjusted life year, FFR-guided strategy was cost-effective for 99.9% of patients and cost-saving for more than 90% of participants. The results were robust across a variety of sensitivity analyses.

Conclusion: In this economic evaluation of the FAME trial, the authors found that an FFR-guided strategy not only improves outcomes but also saves money at 1 year. This finding provides further support for the routine measurement of FFR in patients with multivessel coronary artery disease undergoing percutaneous coronary intervention.11

Willingness to Pay to Eliminate the Risk of Restenosis Following Percutaneous Coronary Intervention: A Contingent Valuation

Summary: Restenosis following percutaneous coronary intervention (PCI) may mandate repeat revascularization. The authors surveyed patients undergoing PCI to check their willingness to pay (WTP) $X for an unnamed therapy to eliminate an existing Y% risk of restenosis. Each patient was assigned a random value for $X ($500, $1000, $1500, $2000, $2500, or $3000) and a random restenosis risk (10% or 20%). They were then asked about their WTP if the new therapy cost an additional $500. Out of 312 surveyed patients, 87% responded. More than 90% believed that PCI prolonged their lives. Nearly 60% had WTP for both bids, with median WTP to eliminate the restenosis risk estimated at $2802. Higher income was an independent predictor of WTP. A quadratic relation was found between price increase and WTP. Among those with similar income and bids, greater risk of restenosis increased the likelihood of WTP.

Conclusion: Even though no intervention was named in the study, the authors tried to capture patients’ WTP for drug-eluting stents versus bare metal stents for PCI. The findings are not truly comparable to reality, as the authors assumed no residual risk of restenosis after intervention, and the additional costs of prolonged dual antiplatelet therapy with drug-eluting stents were not considered, either. Given the relatively small sample size, assignment of 12 different scenarios to patients limited the strength of interpretations. Nevertheless, the
The study provides important information about the patients' willingness to pay a substantial amount to eliminate a nonfatal complication of PCI.12

**Cost-Effectiveness of Drug-Eluting Stents Versus Bare Metal Stents in Clinical Practice**

**Summary:** Drug-eluting stents (DES) have higher initial hospital acquisition costs compared with bare metal stents (BMS) but reduced repeat target vessel revascularization rates (TVR) compared with BMS. In the present study, the authors compared clinical outcomes and costs of care for 1147 patients undergoing BMS and 1247 patients undergoing DES from 2002 to 2005. Costs for index stenting, TVR, and clopidogrel use were assessed. After matching the 2 groups for baseline characteristics, index stenting costs were $1846 higher per patient for DES versus BMS. At 3 years, DES reduced the absolute TVR by 8.8 events per 100 patients compared with BMS. This resulted in cumulative cost savings of $2065 in patients with DES over a 3-year period. With the inclusion of clopidogrel cost, the incremental cost-effectiveness ratio per TVR avoided with DES was $4731, $4703, and $6379 through 1, 2, and 3 years, respectively.

**Conclusion:** The present study provides valuable insight into the real world comparison of DES versus BMS. The higher index cost of DES was offset by lower TVR-related costs compared with BMS, thus supporting continuation of its use; however, the study findings were quite sensitive to the initial stent cost, as well as duration of dual antiplatelet therapy, implying that implantation of DES may not be cost-effective in all patient subgroups.13

**Clinical and Economic Outcomes of Liberal Versus Selective Drug-Eluting Stent Use: Insights From Temporal Analysis of the Multicenter Evaluation of Drug Eluting Stents and Ischemic Events (EVENT) Registry**

**Summary:** Drug-eluting stents (DES) are known to reduce the rate of target vessel revascularization in patients undergoing percutaneous coronary intervention; however, there is clinical and economic uncertainty on the optimal rate of DES use in percutaneous coronary intervention. Using data from the Evaluation of Drug-Eluting Stents and Ischemic Events (EVENT) multicentric registry, the authors compared the outcomes and costs in 2 time periods: a time of near-universal DES use (2004–2006), and a time of more selective DES use (2007). The proportion of patients receiving at least 1 DES decreased from 92% from 2004 to 2006 to 68% in 2007 (P<0.001). Procedure-related success and complications, as well as in-hospital mortality, were comparable in the 2 time periods. There was an absolute 1% increase in target lesion revascularization rates in 2007 while total 1-year cardiovascular costs per patient were reduced by $401. The risk-adjusted incremental cost-effectiveness ratio for the liberal as compared with the selective DES strategy was $433 000 per quality-adjusted life year gained.

**Conclusion:** By leveraging a “natural experiment” of reduced DES use, the authors demonstrated similar hard clinical end points but slightly higher target lesion revascularization with a more conservative, versus a more liberal, practice pattern of DES use. Importantly, the cost-effectiveness of using DES in 92% versus 68% of patients was cost-prohibitive. More judicious use of DES, perhaps as a function of restenosis risk, could improve the cost-effectiveness of percutaneous coronary intervention.14

**The Cost-Effectiveness of Percutaneous Coronary Intervention as a Function of Angina Severity in Patients With Stable Angina**

**Summary:** The Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) trial compared percutaneous coronary intervention (PCI) plus optimal medical therapy with optimal medical therapy alone in reducing the risk of cardiovascular events in 2287 patients with stable coronary disease. The authors examined the cost-effectiveness of PCI as a function of angina severity at the time of randomization. Angina severity was assessed with the Seattle Angina Questionnaire. Patients were grouped into tertiles based on the distribution of baseline scores, such that higher tertiles represented better health status. The incremental cost-effectiveness ratio for PCI was calculated as the difference in costs divided by the difference in proportion of patients with clinically significant improvement. Improvement in angina severity was significantly greater for PCI patients in the lowest and middle tertiles. Incremental cost-effectiveness ratios ranged from $80 000 to $330 000 for the lowest and middle tertiles and from $520 000 to >$3 million for the highest tertile for 1 additional patient to achieve significant clinical improvement in health status.

**Conclusion:** This study shows that the incremental cost incurred in performing a PCI versus optimal medical therapy in patients with stable coronary disease depends on the severity of angina symptoms. Patients with less severe angina symptoms tend to have a higher cost for PCI compared with patients with more severe angina; however, the high cost of performing PCI, even among patients with severe angina symptoms, will act as a significant deterrent in the widespread societal adoption of this procedure.15

**Heart Failure**

Management of heart failure is highly resource-intensive, as reflected by an estimated total expenditure of $39.2 billion in 2010, representing 1% to 2% of total healthcare spending. Inpatient hospital care represents the bulk of these expenses. Unfortunately, total costs have not declined despite reductions in heart failure hospitalizations over the previous decade, thereby necessitating further evaluation of the cost-effectiveness of current management strategies. The following studies examine various aspects of healthcare costs in heart failure, including methods of economic evaluation, variation in costs by healthcare setting, and emerging interventions.

**Costs of Inpatient Care Among Medicare Beneficiaries With Heart Failure, 2001 to 2004**

**Summary:** The study aimed to determine whether recent advances in heart failure (HF) care have reduced the costs to Medicare among hospitalized HF patients. In a retrospective cohort study of 1 363 977 elderly Medicare beneficiaries hospitalized with HF between January 1, 2001, and December 31, 2004, the authors examined costs to Medicare for all inpatient care, inpatient cardiovascular care, and inpatient HF care and the adjusted relationships between patient characteristics and costs. Among those with an index HF hospitalization, 901 885 (66%) had a subsequent inpatient claim during the following year. Mean 1-year inpatient costs for HF declined from $1985 in 2001 to $1797 in 2004 (P<0.001). Noncardiovascular costs accounted for 57% of total inpatient costs, and costs associated with HF hospitalizations accounted for 15% of total inpatient costs. No significant changes occurred in total, cardiovascular, and heart failure inpatient costs over time.

**Conclusion:** Given that HF is mainly a disease of the elderly, knowledge about healthcare costs associated with this condition will assume increasing importance as our population ages. Substantial inpatient costs incurred by these patients for non-HF admissions highlight the need to approach HF management in a more comprehensive way. The modest decline in mean 1-year inpatient costs for HF during the study period is encouraging, with potential to decrease further in the setting of more coordinated management of the full range of problems in elderly patients.16
Economic Evaluation of the HF-ACTION (Heart Failure: A Controlled Trial Investigating Outcomes of Exercise Training) Randomized Controlled Trial: An Exercise Training Study of Patients With Chronic Heart Failure

Summary: This study assigned 2331 outpatients with medically stable heart failure to exercise training or usual care. The authors compared medical resource use and costs incurred by these patients during follow-up. Intervention costs were estimated using patient-level trial data, administrative records, and published unit costs. Mean follow-up was 2.5 years. The exercise group had 2297 hospitalizations with 13.6 mean inpatient days. In comparison, the usual care group had 2332 hospitalizations with 15.0 mean inpatient days. Other measures of resource use were similar between groups, except for trends indicating that fewer patients in the exercise group underwent high-cost inpatient procedures. Total direct medical costs per participant were an estimated $50 857 in the exercise group and $56 177 in the usual care group ($P=0.10). The direct cost of exercise training was an estimated $1006. Patient time costs were an estimated $5018.

Conclusion: Incorporation of exercise training as a standard part of chronic heart failure management has been debated over the years. This study clarifies that the modest clinical and significant health status benefits for an exercise training program is associated with less direct costs but more patient-time costs. Underrepresentation of women and elderly and suboptimal adherence to exercise guidelines (33%) were notable limitations that challenge the generalizability of these findings and should be addressed in future studies.17

Lifetime Costs of Medical Care After Heart Failure Diagnosis

Summary: Heart failure (HF) care constitutes an increasing economic burden on the healthcare system; however, there are limited data on the lifetime healthcare costs for individuals with HF after initial diagnosis. Using population-based administrative data from Olmsted County, the authors obtained direct medical costs incurred by 1054 residents with incident HF from 1987 to 2006, from the time of HF diagnosis until death or last follow-up. Inpatient, outpatient, and total costs were estimated, using a 2-part model, with adjustment for right censoring of data. After a mean follow-up of 4.6 years, 765 (72.6%) patients had died. The estimated total lifetime costs were $109 541 per person, with the majority accumulated during hospitalizations. After adjustment for age, year of diagnosis, and comorbidity, diabetes mellitus and preserved ejection fraction (≥50%) were associated with significantly higher lifetime costs. Also, higher costs were observed at initial HF diagnosis and in the months immediately before death in those surviving >12 months after diagnosis.

Conclusion: The high prevalence of HF and improved survival after diagnosis make it important to understand the temporal distribution of HF costs incurred during lifetime. Data from this population study show that maximum costs accrue as a result of hospitalizations and toward the end of life. Policy makers and healthcare providers need to take steps to improve efficiency and eliminate unnecessary utilization of resources in these settings. Measures to increase compliance of patients with recommended HF therapies may facilitate decrease in incidence of hospitalization and thus costs.18

Introduction of the Tools for Economic Analysis of Patient Management Interventions in Heart Failure Costing Tool: A User-Friendly Spreadsheet Program to Estimate Costs of Providing Patient-Centered Interventions

Summary: Variability in costing methods and assumptions in economic evaluations of interventions in heart failure management limit the comparability of cost estimates across studies. The authors developed the Tools for Economic Analysis of Patient Management Interventions in Heart Failure (TEAM-HF) Costing Tool, a spreadsheet program that can be used by researchers and healthcare managers to systematically generate cost estimates for economic evaluations and to inform budgetary decisions. The tool guides users on data collection and cost assignment for associated personnel, facilities, equipment, supplies, patient incentives, miscellaneous items, and start-up activities. The tool generates estimates of total program costs, cost per patient, and cost per week and presents results, using both standardized and customized unit costs for side-by-side comparisons. Results from pilot testing indicated that the tool was well-formatted, easy to use, and followed a logical order. Cost estimates of a 12-week exercise training program in patients with heart failure were generated with the costing tool and were found to be consistent with estimates published in a recent study.

Conclusion: Constantly evolving heart failure management strategies necessitate the adoption of a standardized tool to bring uniformity to the methodology of cost comparisons among various treatment options. The authors have introduced a comprehensive heart failure costing tool to aid researchers in conducting high-quality economic evaluations, which may be revised further to expand its applicability to other chronic conditions.19

Cost-Effectiveness Analysis of Continuous-Flow Left Ventricular Assist Devices as Destination Therapy

Summary: Continuous-flow left ventricular assist devices (LVADs) have become the dominant devices for mechanical circulatory support. The authors developed a Markov decision-analysis model to assess cost-effectiveness of continuous-flow devices for destination therapy versus optimal medical management, using results from the REMATCH trial and HeartMate II Destination therapy trial. They also compared the results with previous estimates for pulsatile devices. Survival, hospitalization rates, quality of life, and cost data were obtained for advanced heart failure patients treated medically or with a continuous-flow left ventricular assist device. Compared with medically managed patients, patients with continuous-flow left ventricular assist device had higher 5-year costs ($360 407 versus $62 856), quality-adjusted life years (1.87 versus 0.37), and life years (LY) (2.42 versus 0.64). The incremental cost-effectiveness ratio of the continuous-flow device was $198 184 per quality-adjusted life year. This equates to a 75% reduction in incremental cost-effectiveness ratio compared with the $802 700 per quality-adjusted life year for the pulsatile-flow device. The results were most sensitive to the cost of device implantation, long-term survival, cost per rehospitalization, and utility associated with patients’ functional status.

Conclusion: Given the increasing proportion of patients with heart failure in need of long-term mechanical circulatory support, it becomes important to evaluate the cost-effectiveness of current strategies in practice. Improved cost-effectiveness of continuous-flow left ventricular assist devices suggests that the future of destination therapy is promising, as treatment strategies, patient selection criteria, and technology continue to evolve; however, the results were sensitive to multiple assumptions and were based on data drawn from differing time periods, mandating careful interpretation.20

Variation in Health Care

Per capita healthcare spending in the United States has consistently been the highest in the world. One of the biggest drivers of these costs has been the large and potentially unnecessary variation in healthcare resource use. Much of this variation is driven by individual physician preferences, especially in circumstances where guidelines are weak or unavailable. Higher use of diagnostic tests with questionable benefit; adoption of expensive treatment modalities in...
The presence of cheaper, more cost-effective alternatives; or an increased frequency of follow-up have all been shown to increase economic burden; however, as has previously been demonstrated, higher resource use does not necessarily translate to better outcomes. The studies presented below examined variation in cardiovascular procedure rates and elucidated potential areas of intervention to make the delivery of cardiovascular care more cost-effective.

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

**Summary:** Cardiovascular procedure rates can differ across regions by up to 8-fold. To ascertain regional variation in physicians’ self-reported propensity to test and treat patients with cardiovascular problems, 598 physicians were surveyed, and a Cardiac Intensity Score for each was computed, based on his or her responses. The Cardiac Intensity Score was associated with 2 measures of population-based healthcare use within geographic regions: general healthcare spending and delivery of cardiac services, with the former more closely related to treatment propensity. Although nearly all physicians denied ordering a potentially unnecessary cardiac catheterization for financial reasons, some physicians acknowledged ordering the test for other nonclinical reasons, including meeting patient and referring physician expectations, meeting peer expectations, and malpractice concerns.

**Conclusion:** Findings suggest that cardiologists’ propensity to use invasive or high-tech cardiovascular tests is often affected by factors unrelated to patient clinical status, including geographic variation in resource use, fear of malpractice, and peers’ practice patterns.

**Center Variation in Hospital Costs for Patients Undergoing Congenital Heart Surgery**

**Summary:** A total of 2124 children undergoing isolated atrial septal defect repair, ventricular septal defect repair, tetralogy of Fallot repair, or arterial switch operation were included from 2001 to 2007 from 69 Premier centers. Mixed models were used to evaluate the impact of center on total hospital costs after adjusting for patient and center characteristics and length of stay. Total hospital cost varied between centers for all conditions studied; the most prominent difference in costs was found among the less complex procedures (atrial septal defect repair) to (arterial switch operation). The proportion of total cost variation explained by center was 19%, 11%, 6%, and 3% for repair of ventricular septal defect, atrial septal defect, tetralogy of Fallot, and arterial switch operation, respectively.

**Conclusion:** Findings suggest that cardiologists’ propensity to use invasive or high-tech cardiovascular tests is often affected by factors unrelated to patient clinical status, including geographic variation in resource use, fear of malpractice, and peers’ practice patterns.

**Atrial Fibrillation**

As our population ages, and atrial fibrillation becomes more prevalent, attempts to address the substantial morbidity associated with the disease will become increasingly important. For the first time, we have oral alternatives to warfarin, each of which possesses unique efficacy and side effect profiles; however, these novel agents’ added costs, lack of proven benefit outside of nonvalvular atrial fibrillation, and potential adverse effects in older persons and patients with chronic kidney disease continue to make warfarin a very important alternative. The following studies address questions relevant to these issues, including the cost-effectiveness of dabigatran therapy relative to warfarin and oral antithrombotic agents, costs associated with anticoagulation monitoring, and the incremental costs associated with atrial fibrillation at the societal level.

**Estimation of Total Incremental Healthcare Costs in Patients With Atrial Fibrillation in the United States**

**Summary:** To provide a contemporary estimate of the national costs associated with atrial fibrillation, the authors conducted a retrospective, observational cohort study using 2004 to 2006 administrative claims from the MarketScan Commercial and Medicare Supplemental research databases. A total of 89,066 patients with atrial fibrillation were propensity-matched 1:1 to control subjects without atrial fibrillation. Medical costs ($2006) (including costs from atrial fibrillation, costs from other cardiovascular conditions, and costs from noncardiovascular disease) were examined for 1 year’s worth of claims for each matched pair. The total incremental cost associated with atrial fibrillation was $8705 per patient, translating into a national incremental cost of $26 billion per year. The majority of this national incremental cost was owed to medical costs associated with other cardiovascular disease ($9.9 billion) and noncardiovascular disease ($10.1 billion). Incremental medical cost directly attributable to atrial fibrillation was $6 billion per year.

**Conclusion:** National medical costs associated with atrial fibrillation are substantial and will continue to rise, given our aging population; however, it is notable that the great majority of these incremental costs are owed to other cardiovascular diseases and noncardiovascular conditions, implying that patients with atrial fibrillation are medically complex and may especially benefit from more holistic and coordinated approaches to care.

**Cost-Effectiveness of Dabigatran for Stroke Prophylaxis in Atrial Fibrillation**

**Summary:** Using results from RELY and other trials, the authors developed a Markov decision-analysis model to compare the cost and quality-adjusted survival of various antithrombotic therapies in a hypothetical cohort of 70-year-old patients with atrial fibrillation. The cost-effectiveness threshold was set at $50,000 per quality-adjusted life year. Assuming a dabigatran cost of $9 per day and an average risk of major bleeding (~3% per year), the most cost-effective therapy depended on stroke risk. Only aspirin was cost-effective for persons with a CHADS2 score of 0. Warfarin was cost-effective for persons with a CHADS2 score of 1 or 2 unless bleeding risk was high or anticoagulation control was poor. Dabigatran 150 mg BID was cost-effective unless anticoagulation control was excellent. Neither dabigatran 110 mg BID or dual antithrombotic therapy was ever cost-effective.

**Conclusion:** The cost-effectiveness of various anticoagulation strategies in atrial fibrillation is dependent on the risk of stroke, risk of bleeding, and adequacy of anticoagulation control. Dabigatran 150 mg BID is favored when risk of bleeding or stroke is high unless INR control is excellent. Therapy with both aspirin and clopidogrel is never cost-effective. Given the recent introduction of rivaroxaban and anticipated approval of additional oral anticoagulants in the near future, further cost-effectiveness analyses comparing these novel agents with warfarin and one another is needed.

**The Business Case for Quality Improvement: Oral Anticoagulation for Atrial Fibrillation**

**Summary:** The authors’ objective was to demonstrate the potential cost savings from improved international normalized ratio control among 67,077 Veterans Health Administration patients anticoagulated with warfarin for atrial fibrillation. A simulation model was created that calculated the number of ischemic strokes, major bleeds, and deaths, based on the percentage of time the international
normalized ratio was in a therapeutic range of 2 to 3. Patients were at high risk of adverse events, as almost 50% had a CHADS2 score ≥3. Improving the time in therapeutic range by 5% prevented 1114 adverse events and reduced costs by $15.9 million over 2 years. Improving the time in therapeutic range by 10% prevented 2087 events and saved $29.7 million. In sensitivity testing, cost savings were most sensitive to estimated stroke risk and the estimated stroke reduction from improved international normalized ratio control.

**Conclusion:** A quality improvement program to advance anticoagulation control in atrial fibrillation can be cost-saving for the payer, even if only modestly effective in improving international normalized ratio control. This finding remains important, despite the introduction of new oral anticoagulants, given warfarin’s frequent use for atrial fibrillation and other conditions, concerns about bleeding in the elderly from use of the novel agents, and the increasing prevalence of atrial fibrillation as our population ages. It is unclear, however, if cost savings would be as pronounced in lower-risk populations.25

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