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

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Background—Primary percutaneous coronary intervention (PCI) is more effective on average than fibrinolytic therapy in the treatment of ST-segment–elevation myocardial infarction. Yet, most US hospitals are not equipped for PCI, and fibrinolytic therapy is still widely used. This study evaluated the comparative effectiveness of ST-segment–elevation myocardial infarction regionalization strategies to increase the use of PCI against standard emergency transport and care.

Methods and Results—We estimated incremental treatment costs and quality-adjusted life expectancies of 2000 patients with ST-segment–elevation myocardial infarction who received PCI or fibrinolytic therapy in simulations of emergency care in a regional hospital system. To increase access to PCI across the system, we compared a base case strategy with 12 hospital-based strategies of building new PCI laboratories or extending the hours of existing laboratories and 1 emergency medical services–based strategy of transporting all patients with ST-segment–elevation myocardial infarction to existing PCI-capable hospitals. The base case resulted in 609 (95% CI, 569–647) patients getting PCI. Hospital-based strategies increased the number of patients receiving PCI, the costs of care, and quality-adjusted life years saved and were cost-effective under a variety of conditions. An emergency medical services–based strategy of transporting every patient to an existing PCI facility was less costly and more effective than all hospital expansion options.

Conclusion—Our results suggest that new construction and staffing of PCI laboratories may not be warranted if an emergency medical services strategy is both available and feasible. **(*Circ Cardiovasc Qual Outcomes*. 2010;3:506-513.)**

Key Words: cost-benefit analysis ■ fibrinolysis ■ percutaneous coronary intervention ■ ST-segment–elevation myocardial infarction ■ thrombolysis

For patients with ST-segment–elevation myocardial infarction (STEMI), primary percutaneous coronary intervention (PCI), if administered in a timely manner, is better than fibrinolytic therapy (FT) at reducing mortality.[1–3] However, PCI is available only at hospitals with cardiac catheterization laboratories, and FT remains the standard of care in the majority of US hospitals.[4] One recent study indicates that 80% of the US population lives within a 1-hour drive of a PCI facility, but empirical estimates suggest that far fewer than 80% of eligible patients with STEMI actually receive PCI.[5,6]

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To increase access to PCI, there is considerable interest in regional planning for the procedure,[7,8] but few opportunities are available to evaluate regionalization strategies in head-to-head comparisons. In the present study, we used our recently developed triage and allocation model[9] to compare the incremental benefits and costs of 2 approaches for increasing patient access to PCI: (1) hospital-based strategies, in which new PCI capacity is added to a region through hospital laboratory construction and staffing, and (2) an emergency medical service (EMS)–based strategy, in which patients with STEMI are transported by EMS to existing PCI-capable hospitals.

Methods

To estimate the costs and effectiveness of alternative strategies for increasing access to PCI, we compared a strategy of standard emergency resources and transport procedures (the base case) with 13 scenarios in which hospital PCI capability was expanded (the hospital-based strategies) and 1 scenario in which EMS was used to transport all patients with suspected STEMI to an existing PCI-capable hospital (the EMS strategy). The strategies and scenarios are presented in Table 1. The base case (A) assumed that EMS providers transport patients to the closest hospital, regardless of which reperfusion method is available at the time of arrival. This scenario assumed no new PCI laboratory construction and no new staffing of existing PCI laboratories. In the base case, 2 hospitals were capable of performing PCI full time, 12 were capable of doing so part-time

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WHAT IS KNOWN

- For patients with STEMI, PCI is better than FT, but PCI is available only at a minority of US hospitals. Detection of patients with STEMI in the EMS system setting and diversion to PCI-capable hospitals have been shown to be both safe and effective.

WHAT THE STUDY ADDS

- This article estimates the comparative benefits and costs of building new PCI capability at US hospitals versus diverting patients with STEMI to existing PCI-capable hospitals. In EMS systems wherein STEMI detection and diversion are feasible, such a strategy may be more effective and less costly than construction and staffing of new hospital PCI capability. Construction and staffing of new PCI hospitals may not be warranted if an EMS strategy is both available and feasible.

(Monday through Friday, 7 AM to 5 PM), and 2 were capable of providing FT only. In scenario B, a high-volume hospital that was capable of providing FT only was selected for PCI expansion. This hospital built and staffed a part-time PCI laboratory and operated it Monday through Friday, 7 AM to 5 PM. In this scenario, we assumed that back-up coronary artery bypass graft (CABG) surgery could be provided off-site, saving the cost of building and staffing a new suite dedicated to the procedure. In scenario C, we added a CABG suite to the costs in scenario B. All new construction scenarios were tested both with and without a new on-site CABG suite (D and E, G and H, I and J, K and L, M and N). One scenario (F) involved only an increase in staffing hours at 2 existing PCI-capable hospitals, and therefore, construction of a new PCI laboratory and CABG suite were not necessary. The EMS strategy (O) involved EMS transport of patients with suspected STEMI to existing PCI-capable hospitals. In this scenario, we used the regional configuration of hospital PCI capability that existed in scenario A.

We simulated EMS transport, reperfusion strategy, clinical outcomes, and costs for 2000 patients, representing ≈1 year of STEMIs in a municipal area the size of Dallas County, Texas. We bootstrapped the simulation 500 times and estimated the bootstrap mean and confidence intervals at the 2.5 and 97.5 percentiles.

Patients

Patient data were sampled from the Atlantic Cardiovascular Patient Outcomes Research Team Trial.[10] The Atlantic Cardiovascular Patient Outcomes Research Team Trial was a randomized, controlled trial of 451 patients with STEMI conducted from July 1996 through June 1999 that compared PCI and FT at 11 community-based hospitals in Maryland and Massachusetts. Clinical data needed for the mortality predictive model were available for 408 of the 451 subjects recruited into the Atlantic Cardiovascular Patient Outcomes Research Team Trial. All hospital-, EMS-, and patient-level variables were used in or computed from a model of Dallas County that was built by using ArcGIS version 9.1 (Environmental Systems Research Institute, Redlands, Calif). The model is described further in a previous work.[9]

Outcomes

We used the PCI–Thrombolytic Predictive Instrument to predict 30-day mortality for each patient.[11,12] For individual patients, the PCI–Thrombolytic Predictive Instrument trades off the incremental mortality benefit of PCI over FT with delays to treatment. Rates of post MI stroke, congestive heart failure, and reinfarction at 30 days

Table 1. STEMI Regionalization Strategies

		Hospital Capabilities		
Scenario	Strategy	Full-Time PCI Hospitals	Part-Time PCI Hospitals	FT-Only Hospitals
Base case				
A	No new construction or staffing	2	12	2
Hospital strategies				
B	One new part-time lab*	2	13	1
C	One new part-time lab and CABG suite	2	13	1
D	One new full-time lab†	3	12	1
E	One new full-time lab and CABG suite	3	12	1
F	Night and weekend staffing for 2 part-time labs	4	10	2
G	Night and weekend staffing for 2 part-time labs and one new part-time lab	4	11	1
H	Night and weekend staffing for two part-time labs and 1 new part-time lab and CABG suite	4	11	1
I	Night and weekend staffing for 2 part-time labs and 1 new full-time lab	5	10	1
J	Night and weekend staffing for 2 part-time labs and 1 new full-time lab and CABG suite	5	10	1
K	Night and weekend staffing for 2 part-time labs and 2 new part-time labs	4	12	0
L	Night and weekend staffing for 2 part-time labs and 2 new part-time labs and CABG suites	4	12	0
M	Night and weekend staffing for 2 part-time labs and 2 new full-time labs	6	10	0
N	Night and weekend staffing for 2 part-time labs and 2 new full-time labs an CABG suites	6	10	0
EMS strategy				
O	No new construction or staffing: EMS transports only to PCI-capable hospitals	2	12	2

*Staffed Monday through Friday 7 AM to 5 PM.
†Staffed 24 hours/day, 7 days/week.

Table 2. Follow-Up Events, Quality of Life Estimates, and Event Rates

Event	Quality of Life (Lower)	Quality of Life (Upper)	Event Rates (PCI)	Event Rates (FT)
Mortality				
In-hospital			0.04[13]	0.063[13]
4–6 weeks			0.05[1]	0.07[1]
6–18 months			≈0.095[1]	≈0.135[1]
Nonfatal reinfarction	0.73[14]	0.91[14]		
In-hospital			0.025[13]	0.064[13]
4–6 weeks			0.03[1]	0.07[1]
6–18 months			≈0.05[1]	≈0.1[1]
Total stroke	0.60[15]	0.85[16]		
In-hospital			0.0022[13]	0.0145[13]
4–6 weeks			0.01[1]	0.02[1]
6–18 months			0.022[10]	0.04[10]
Rescue PCI				
In-hospital			0.133[17]	0.63[17]
4–6 weeks			0.19[10]	0.49[10]
6 months			0.236[10]	0.496[10]
CABG				
In-hospital			0.082[17]	0.12[17]
4–6 weeks			0.124[10]	0.186[10]
6 months			Flat	Flat
CHF	0.63[18]	0.85[19]		
In-hospital			Flat	0.18[20]
4–6 weeks			0.152[21]	Flat
6 months			Flat	Flat

CHF indicates congestive heart failure. Other abbreviations are as defined in text. Superscripted numbers refer to References in text.

and 6 months were taken from the outcomes literature (Table 2[1,10,13–21]). Survival for each additional year was stochastically estimated from rates published in 2007 National Center for Health Statistics age- and sex-adjusted actuarial tables. We assumed a small additional mortality risk due to MI up to 5 years after the initial event, an approach that has been shown in previous work[22] to calibrate well with 5-year survival rates after STEMI.[23] In our main analysis, we added a 0.005 risk of mortality for patients treated with PCI and a 0.015 risk for patients treated with FT. In a sensitivity analysis, we added a 0.01 risk to both groups to explore how results would change if longer-term mortality were equal in the 2 treatment groups.

For every year survived, we adjusted for reduced quality of life from complications related to the index event or to the mode of reperfusion. Utility estimates for stroke, congestive heart failure, and reinfarction were drawn from the Cost Effectiveness Analysis Registry[24] (Table 2). We used high and low estimates from a search of the registry to estimate the upper and lower bounds for each utility measure. We assumed the higher bound in our main analysis and the lower bound in a sensitivity analysis. Future years were discounted at 3% per year in our main analysis and at 5% in sensitivity analyses.

Our main analysis thus assumed unequal risk of death in the 2 treatment groups at year 1 after the index event, a high quality of life after complications, and a 3% discount for future years. In sensitivity analyses, we changed these assumptions individually and simultaneously to account for uncertainty surrounding survival, quality of life, and discounting.

Costs

We updated a previously developed framework for hospital operations and costs[25] to 2008 US dollars by using the National Income and Product Accounts GDP deflator.[26] We assumed that newly purchased laboratory equipment and facilities would be in use for 10 years.

In randomized, controlled trials comparing PCI and FT, the initial costs of PCI have been higher typically, but additional complication and procedure rates in the FT arm have been found to yield similar cumulative costs.[27–29] Two studies from the mid-1990s drew different conclusions: 1 that used registry data found lower costs in the FT group[30] and another that used administrative data found lower costs in the PCI group.[31] Our base case assumed equal costs for PCI and FT over the lifetime of patients. In each successive scenario, we added costs when new construction, staffing, in-hospital CABG back-up, or diverted transport was needed. SAS version 9.1 (SAS Institute, Cary, NC) was used for all statistical analyses.

Results

Table 3 shows the number of new PCI patients, total costs, quality-adjusted life-years (QALYs) saved, and cost per QALY for each of the 14 scenarios. In the base case (A), 609 (95% CI, 569 to 647) primary PCI procedures, representing 30.4% of all patients with STEMI, were performed annually in 14 hospitals. Roughly 250 of these were performed during weekdays at a time when elective procedures would otherwise be scheduled. With 14 PCI laboratories operating on 260 weekdays per year, we assumed that the demand for elective PCI was already being met and that no additional elective procedures would be performed as a result of new capacity. In this context, new construction and staffing costs could not be defrayed with elective procedures.

The costs and effectiveness of each successive scenario (B through O) were compared with the base case (A). An additional 82 patients had access to PCI after construction of a new part-time laboratory in a hospital seeing >200 patients with STEMI annually (B). This scenario resulted in nearly $4.8 million additional costs in 10 years, and the additional 82 PCI procedures performed during this period saved 157.4 QALYs. The cost per QALY saved was $30 399, well below the costs of other accepted life-saving therapies. When that same hospital built a new laboratory and staffed it full time (D), an additional 272 PCI treatments could be performed in a year, and the cost per QALY saved dropped to $14 765. If a new program of on-site CABG back-up was needed for this new laboratory, costs increased to $85 032 per QALY saved in the part-time scenario (C) and to $31 021 in the full-time scenario (E). Building a new laboratory was most cost-effective if it could be opened full time and if a new on-site CABG back-up program was unnecessary (D). Costs per QALY saved are graphed for each scenario in the Figure.

Expansion of PCI capability in the 2 highest-volume hospitals that already had a part-time PCI laboratory in place (F) resulted in 304 additional procedures and 605.2 QALYs saved at a cost of $10 000 per QALY saved. This expansion, involving only the additional costs of night and weekend on-call staff, was the most cost-effective of hospital-based scenarios. We explored a series of combinations involving new laboratory construction and expansion of part-time PCI laboratories to full-time hours (G through N). When compared with the base case, each scenario cost <$100 000 per QALY saved.

Table 3. Cost-Effectiveness of Strategies to Increase Access to PCI

Scenario	Strategy	PCI Patients, N=2000, % (SD)	New PCI Patients, n	Costs in 2008 Dollars, 1000s	QALYs Saved (95% CI)	Cost per QALY (95% CI)
Base case						
A	No new construction or staffing	30.4 (1.0)				
EMS strategy						
O	No new construction or staffing: EMS transports only to PCI-capable hospitals	100 (0.0)	1391	1391	2749.8 (2678.4–2936.6)	506 (474–519)
Hospital strategies						
F	Night and weekend staffing for 2 part-time labs	45.6 (1.1)	304	6052	605.2 (550.8–788.8)	10 000 (7673–10 988)
I	Night and weekend staffing for 2 part-time labs and 1 new full-time lab	59.2 (1.1)	576	13 863	1125.6 (1109.4–1210.6)	12 316 (11 451–12 496)
G	Night and weekend staffing for 2 part-time labs and 1 new part-time lab	49.7 (1.1)	385	10 837	754.0 (719.2–877.0)	14 373 (12 357–15 068)
D	One new full-time lab	44.0 (1.1)	272	7811	529.0 (544.8–650.2)	14 765 (12 013–14 337)
M	Night and weekend staffing for 2 part-time labs and 2 new full-time labs	61.3 (1.1)	617	21 674	1247.0 (1147.2–1356.0)	17 381 (15 984–18 893)
K	Night and weekend staffing for 2 part-time labs and 2 new part-time labs	50.3 (1.1)	398	15 622	788.6 (803.0–1039.0)	19 810 (15 035–19 454)
J	Night and weekend staffing for 2 part-time labs and 1 new full-time lab and CABG suite	59.2 (1.1)	576	22 462	1125.6 (1109.4–1210.6	19 956 (18 555–20 247)
H	Night and weekend staffing for 2 part-time labs and 1 new part-time lab and CABG suite	49.7 (1.1)	385	19 436	754.0 (719.2–877.0)	25 778 (22 162–27 025)
B	One new part-time lab	34.5 (1.0)	82	4785	157.4 (37.2–302.8)	30 399 (15 802–128 623)
E	One new full-time lab and CABG suite	44.0 (1.1)	272	16 410	529.0 (544.8–650.2)	31 021 (25 239–30 122)
N	Night and weekend staffing for 2 part-time labs and 2 new full-time labs and CABG suites	61.3 (1.1)	617	38 873	1247.0 (1147.2–1356.0	31 173 (28 667–33 885)
L	Night and weekend staffing for 2 part-time labs and 2 new part-time labs and CABG suites	50.3 (1.1)	398	32 820	788.6 (803.0–1039.0)	41 619 (31 588–40 872)
C	One new part-time lab and CABG suite	34.5 (1.0)	82	13 384	157.4 (37.2–302.8)	85 032 (44 201–359 787)

Incremental cost-effectiveness ratios are presented in the last column, measured as the cost in 2008 dollars per QALY saved. Strategies are presented in order from least to most cost-effective. Results assume that the risk of death is unequal for the 2 treatment groups through 5 years after treatment; an upper bound for health-related quality of life if survival with STEMI is followed by stroke, congestive heart failure, or reinfarction; and future years discounted at 3%.

Finally, we estimated the incremental costs and effectiveness of 1 EMS strategy for increasing access to PCI (O). In this scenario, EMS personnel identified patients with STEMI before hospital arrival and transported directly to PCI-capable hospitals. Because our previous work on EMS triage strategies for PCI[9] showed that this approach achieved the largest reduction in short-term mortality, we selected direct transport as the EMS strategy of interest for the present study. A strategy of interhospital transfer performed almost as well in our previous work and is of interest for our future work. For the present study, we assumed that the EMS transport strategy would cost an additional $1000 per diverted patient.

In 2000 patients, this strategy resulted in 1391 diversions at a cost of nearly $1.4 million and a cost per QALY saved of $506. Because it was less costly and more effective than any of the hospital-based strategies, we considered the EMS strategy to be dominant. It would no longer be the most cost-effective strategy if the average cost per diverted patient rose to more than $19 769 (a 20-fold increase). Alternatively, it would no longer be the most cost effective strategy if the most favorable hospital-based scenario (F) cost <$306 231 (a 20-fold decrease).

We assumed 100% adherence to each tested strategy, including the assumption that all patients called 911 for emergency assistance. This assumption could lead to an overestimate of benefit for the EMS strategy in an actual regional emergency system, wherein nearly half of all patients with STEMI arrive at the hospital by transportation other than EMS.[32] Evidence suggests that patients who arrive by EMS are older, at higher risk, and more likely to benefit from PCI than are those who arrive by other means.[32] To test the sensitivity of our results to 100% adherence, we iteratively reduced the EMS strategy's total benefit by the average benefit per diverted patient until the strategy was no longer more effective than the next most effective hospital strategy. This method would indicate how many walk-ins would be

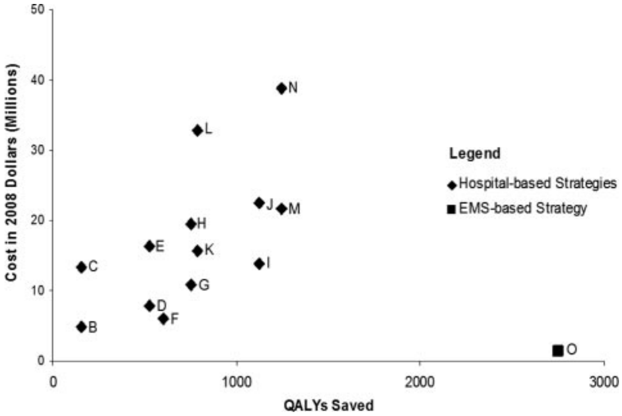

Figure. STEMI regionalization strategies: cost per QALY. QALYs saved are presented on the *x* axis, and cost in 2008 dollars, on the *y* axis. The base strategy is positioned at (0,0). Hospital strategies (B–N) are depicted with a diamond. The EMS strategy (O) is depicted with a square.

needed until the EMS strategy was no longer dominant. In the EMS strategy (O), 1391 patients were diverted, producing a total benefit of 2749.8 QALYs, or an average benefit of 1.98 QALYs per diverted patient. The next most beneficial strategy (M) produced 1247.0 QALYs. To fall below this level of benefit, 762 of 1391 diversions (55%) would have to be replaced by walk-ins. The EMS strategy would therefore continue to be more effective and less costly than the next best hospital strategy if at least 45% of all patients with STEMI were to call 911 for assistance. Below that number, the EMS strategy would continue to be more cost-effective but would not dominate hospital strategies. This calculation is conservative if patients who are more likely to benefit from PCI are more likely to call 911, as the evidence suggests they are.

Conclusions

To increase access to PCI in our model of a large urban, suburban, and rural region, an EMS strategy of transporting all patients to existing PCI-capable hospitals was more effective and less costly than 13 hospital-based strategies of new construction and staffing. Whereas hospital strategies were cost-effective under a variety of conditions, the EMS strategy dominated in all of the scenarios that we tested and in multivariate sensitivity analyses. Our results strongly suggest that construction and staffing of new PCI hospitals may not be warranted if an EMS strategy is both available and feasible. Demonstration programs have shown that EMS detection and diversion of patients with STEMI for delayed PCI are both safe and effective.[33,34] Our results suggest that, in EMS systems where STEMI detection and diversion are feasible, such a strategy is more effective and less costly than hospital-based regionalization alternatives. This finding persisted even when the estimated new cost of an EMS strategy was multiplied by a factor of nearly 20 or when its expected benefits were decreased by 55% or more.

Expansion of access to timely PCI is widely considered to be critical for improving outcomes after STEMI. To accomplish this goal, a range of regionalization approaches have been reviewed or evaluated in the research literature.[35–39] To understand the potential of STEMI regionalization strategies in their full context, however, it is critical that the benefits, risks, and costs of all hospital and EMS strategies be compared in head-to-head match-ups. Although the preferred method to compare such strategies might be a randomized effectiveness trial,[39] such an approach would not likely be feasible, given the large numbers needed to measure rare outcomes after heart attack, as well as the ethical problem of randomizing patients to receive FT when timely PCI is known to be superior.

In this context, the use of mathematical modeling to compare predicted outcomes from PCI expansion strategies is a promising approach. The model we used combined empirical data from clinical, health systems, and geographic sources with clinical predictive instruments to perform head-to-head comparisons of regionalization strategies. Our model for estimating outcomes was sensitive to the number of new PCI treatments resulting from an expansion strategy and therefore, to the regional population's baseline rate of access to PCI. In our model of Dallas County, we estimated a baseline access rate of 30.4%. Two aspects of our model explain why our baseline rate was 50 percentage points lower than a recent national estimate indicating that 80% of the population lives within a 1-hour drive of a PCI-capable hospital.[4] First, patients in our base case were transported to the closest hospital even when PCI was available within a 1-hour drive. Second, the 80% estimate assumes that hospitals with a PCI laboratory operate the laboratory 24 hours per day, 7 days per week. Of the 16 hospitals in our model of a large county, 14 had a PCI laboratory but only 2 operated the laboratory full time. In the base case, we operated the part-time PCI laboratories from Monday through Friday, 7 AM to 5 PM. Two classic articles on the circadian and weekly patterns of heart attack onset estimate that ≈39% begin during these weekday hours.[40,41] We used these estimates to stochastically estimate STEMI onset day and time. In our model, therefore, ≈61% of patients with STEMI onset in locations served by a part-time laboratory received immediate FT in the local hospital or delayed PCI after transport to a more-distant, full-time laboratory. We believe that our method of accounting for the part-time operation of PCI laboratories is reflective of actual operations in a region that has not yet introduced regionalization measures. Assuming full-time operation at all hospitals would have led to a significant overestimate of the true baseline access rate.

Nevertheless, in regions with a higher baseline rate of access to primary PCI, we would expect that an EMS strategy would fare better and the hospital strategies would fare worse than in our model. In a hospital strategy, the high fixed costs of construction can be defrayed only by increasing the number of patients with newly created access to PCI. In an EMS strategy, new costs are substantially lower and vary with the number of new transports that are needed. This relatively low variable cost is the primary advantage of an EMS strategy. A second advantage was explored in our previous work: the opportunity to select for transport to existing PCI hospitals only those patients who are predicted to benefit most from PCI. We did not exploit this opportunity in the present study; we transported every patient with suspected STEMI directly to a PCI-capable hospital regardless of predicted benefit. The EMS strategy dominated hospital strategies on the basis of its low variable costs and its potential to reach every patient with STEMI, but we believe an even stronger case could be made for a strategy that involves selective transport of only those patients who are individually predicted to benefit from delayed PCI.

Public policy remains unsettled on the optimal strategy to increase access to PCI. In some states, certificate-of-need laws are used to control the widespread diffusion of high cost and volume-sensitive procedures such as PCI. In 2008, these laws existed in 36 states, but only 23 had provisions for cardiac catheterization services review.[42] From 2001 through 2006, American Hospital Association data show a steady increase of 50 to 125 new hospitals with PCI capability in the United States each year, in both urban and rural areas.[43,44] There is substantial contradictory activity in the public arena that is aimed both at curtailing and at sustaining the diffusion of PCI laboratories. We believe our approach to comparing alternative strategies can help clarify the impact of such decisions.

For several reasons, Dallas County represents an ideal place to test our model. First, Dallas has a diversity of urban, suburban, and rural areas. The majority of census tracts in Dallas County are designated as urban (comprising 69.7% of the county's dry land area), but a substantial portion of the county is suburban and rural. Second, there is significant variation in PCI capability at hospitals inside the county. Our model showed that just 30.4% of the county's population lived closest to a PCI-capable hospital, leaving room for growth in the availability of PCI. Third, Dallas is bordered to the north, east, and south by sparsely populated areas and to the west by Dallas–Fort Worth Airport, creating natural and manmade barriers to EMS transport outside the county's borders. These factors allowed us to test the EMS strategy inside a diverse yet nearly closed emergency system.

Although Dallas County offered an excellent choice for the first test of our model, large and less densely populated regions are of great interest for further testing. In rural areas where access to PCI is lowest, the need for further study is especially urgent. Empirical evidence suggests that new hospital PCI capability results in modest new access to PCI.[45] To answer the question about what works best in urban, suburban, and rural counties, head-to-head comparisons of all available strategies are needed. Our triage and allocation model can help planners and policy makers decide on the approach that best fits the specific features of a county or region.

Our main finding, that an EMS strategy is more effective and less costly than any hospital strategy, was based on the estimated societal impact of alternative regional planning strategies in the care of patients with STEMI. The implications for individual hospitals are less clear. However, if it were recast to take in the hospital perspective, our model could help to inform the business case for regional planning. This would lend a great deal of clarity to discussion about the implications of our main finding.

In some circumstances, we recognize that a hospital strategy may be warranted even when it is dominated by an EMS strategy. First, resource constraints may preclude EMS strategies from being considered. Ambulance staff must be able to identify patients with STEMI accurately, the vehicles must be equipped with electrocardiograms, and EMS-hospital handoff should be organized to prenotify receiving hospitals. Second, hospital expansion may be particularly important in some suburban and rural settings, where the risks of exceptionally lengthy drive times to PCI hospitals can be prohibitive. Third, hospital strategies may be acceptable or desirable if the geographic distribution of PCI hospitals is inequitable and hospital expansion could lead to outcome improvements for a presently underserved population.

Our study has limitations. First, there are limitations inherent to simulations, insofar that they incorporate empirical data from multiple sources and resort to assumptions where empirical data are unavailable. Our simulation was no different in this regard. However, we conducted a wide range of multivariate sensitivity analyses, and the results were robust to all potential changes. Perhaps the strongest assumptions made concerned the costs of EMS transport and hospital laboratory construction, which were estimated from a study of new construction and staffing at US hospitals from the mid-1990s. We chose this model because it allowed us to compare a range of hospital costs in discrete categories and thus to compare 13 alternative hospital strategies with each other and with the EMS strategy. We updated the cost model by using the most reliable index for inflation of medical care and construction costs, the National Income Products Account GDP deflator. In a sensitivity analysis, our main finding was robust to changes in baseline costs by a factor of nearly 20 across the board. A second important assumption included adherence to the tested strategies. We assumed that 100% of patients use 911, an assumption that would lead to overestimates of benefit in the EMS strategy in locales where hospital walk-ins occur at a high rate. In a post hoc sensitivity analysis, our findings were robust until 55% or more of patients arrived at the hospital by means other than EMS. A third important set of assumptions included the utility weights for quality adjustment. In sensitivity analyses, we used high and low estimates from a search of the Cost Effectiveness Analysis Registry to estimate the upper and lower bounds for each utility measure in our model. Quality adjustment had minor effects on the ordering of preferred hospital strategies but did not change the main result, showing that the EMS strategy was both more effective and less costly than all hospital strategies.

A second limitation was that we conducted the study in a single county. We selected Dallas County for its size, diversity, and composition of urban, suburban, and rural districts, but the primary advantage of this setting was its self-contained emergency system. Further research is planned in a broadly representative sample of US counties.

In summary, while expansion of hospital PCI capability can be cost-effective for improving quality-adjusted survival after STEMI, a strategy of EMS transport to existing PCI-capable hospitals was dominant in a regional hospital system with 30% baseline access to PCI. Further inquiry is needed into the relation of regional health system characteristics and optimal strategies for increasing access to PCI, and we have begun a 5-year research project funded by the Agency for Healthcare Research and Quality to explore these relations. Our results suggest that regional planners should consider EMS strategies for increasing access to PCI before adopting strategies involving new construction or increased staffing of PCI hospitals.

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Disclosures

None.

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