



Uncharted Paths*

Hospital Networks in Critical Care

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Wide variation between hospitals in the quality of critical care lead to many potentially avoidable deaths. Regionalization of critical care is a possible solution; regionalization has been implemented for trauma and neonatal intensive care, and it is under active discussion for medical and cardiac critical care. However, regionalization is only one possible approach to reorganizing critical care services. This commentary introduces the technique of network analysis as a framework for the following: (1) understanding how critically ill patients move between hospitals, (2) defining the roles hospitals play in regional care delivery, and (3) suggesting systematic improvements that may benefit population health.

We examined transfers of critically ill Medicare patients in Connecticut in 2005 as a model system. We found that patients are systematically transferred to more capable hospitals. However, we find the standard distinction of hospitals into either "secondary hospitals" or "tertiary hospitals" poorly explains observed transfer patterns; instead, hospitals show a continuum of roles. We further examine the implications of the network pattern in a simulation of quarantine of a hospital to incoming transfers, as occurred during the severe acute respiratory syndrome epidemic.

Network perspectives offer new ways to study systems to care for critically ill patients and provide additional tools for addressing pragmatic problems in triage and bed management, regionalization, quality improvement, and disaster preparedness. (CHEST 2009; 135:827–833)

Key words: critical care; health-care organization; Medicare; network analysis; regionalization

Abbreviation: SARS = severe acute respiratory syndrome

Some hospitals provide better outcomes to their critically ill patients than others. One way to improve critical care is to identify and export elements of care that characterize the best performing ICUs to elevate the practices of other hospitals, through training or telemedicine. A complementary approach is to move critically ill patients from lower quality to higher quality centers, perhaps following a

model similar to the regionalization of trauma care. Formal plans to regionalize portions of adult critical care are under active discussion.^{1,2} In this commentary, we suggest, first, that variation between hospitals in quality presents an important opportunity to improve outcomes for patients with critical illness; second, that transfer of patients between hospitals is a feasible way to improve care; and third, that the tools of network analysis are revealing and persuasive when applied in this arena.

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The Problem: Wide Variation Between Hospitals in the Quality of Critical Care Leads to Large Numbers of Potentially Avoidable Deaths

Critical care quality varies widely across hospitals. Hospital ICUs vary in their compliance with standards of care for the prevention of ventilator-associated pneumonia, catheter-related bloodstream infections, and thromboembolic disease.^{3,4} Caring for patients in more experienced hospitals rather than less experienced hospitals is associated with 25 to 50% reductions in the adjusted odds of death for many critical illnesses (Table 1).

Large relative differences in quality are important given the high absolute mortality seen in critical care settings: 18% of Medicare beneficiaries died within 30 days of hospitalization for myocardial infarction.^{5,6} A third of nonpostoperative mechanically ventilated patients died prior to hospital discharge.⁷ There were 20.7 million critical care patient-days in 2000, up 28.7% vs 1985.⁸ The combination of large scale and high stakes means that even small improvements in the quality of critical care might save many lives. In eight large states, we estimated that every year 4,000 mechanically ventilated patients die who might have been saved had they been in another hospital.⁹ Half of those patients died in a low-volume hospital within 5 miles of a high-volume center. Krumholz and colleagues¹⁰ have estimated that an additional 10,000 acute myocardial infarction patients might be saved annually if they received the same quality of care as provided by better hospitals. Of note, these lives might be saved using *existing* technology and knowledge without discovering new therapies.¹¹

Centralization Is a Possible Solution for Potentially Avoidable Deaths

In the 1970s, trauma patients faced similar variations in their quality of care, motivating the creation of formal networks for the care of trauma patients.¹² This reorganization of care is associated with remarkable improvements in outcomes.¹³⁻¹⁵ Centralization of care in centers of excellence is being considered for other patients, including those with acute myocardial infarction^{16,17} and general critical care.¹

Table 1—Examples of Reduction in Mortality of Large-Volume vs Small-Volume Centers

Condition	Benefit, %	Reference
Cardiogenic shock requiring intraaortic balloon pump	29	38
Percutaneous coronary intervention	25-50	16, 39-41
Severe blunt trauma and coma	51	42
Mechanical ventilation (excluding postoperative patients)	37	7 but see also 43

Three conditions are necessary for centralization to improve public health: (1) transport between centers must be safe¹⁸ and timely, (2) some centers must be identifiably better at providing care, and (3) patients must be moved from lower quality centers to higher quality centers. Many quality improvement efforts focus on designating centers of excellence; however, unless patients are directed to these centers, there may be no population health benefits.^{19,20} Even in mature trauma systems, getting patients to designated trauma centers is a persistent problem.^{21,22}

Critical Care Patients Are Transferred Frequently, But We Know Little About These Transfers

Although formal systems transfer trauma and neonatal patients, no such formal system exists for most critically ill patients. Nonetheless, transfers between hospitals are common. In recent data from an all-payer multicenter cohort of critically ill patients, 6.4% of patients in the ICU were admitted directly from another acute care hospital.²³ However, little is known about how and why these transfers occur or whether patients systematically move toward sites that provide better care. Patient transfers between two hospitals are known to be generally safe.²⁴⁻²⁶

The current system of interhospital critical care transfers is informal, but it is not random. Most hospitals transfer to only a subset of other nearby hospitals. Network analysis provides an approach for examining and improving these patterns and testing whether they achieve the same goals as formal regionalization. Bureaucratic regionalization can be seen as one of several possible approaches to optimizing the flow of patients between hospitals. The remainder of this article introduces these emerging scientific methods and suggests their usefulness for improving the critical care transfer system.

Theoretical Perspective and Testable Hypotheses

Critical care transfers reflect relationships between hospitals. This conception is informed by a significant social scientific tradition demonstrating that organizational performance can be understood in terms of the specific connections a given organization has with others.²⁷ The selection of relationships is a key strategic decision.²⁸⁻³⁰ An organization's history of relationships places constraints on its formation of new ties, making some ties easy and some more difficult.³⁰ These relationships make some resources readily accessible; they may even change awareness that resources exist, such as novel therapies in the ICU. For example, it may be important not only where hospitals send their critically ill patients, but also from what other hospitals those referral centers receive patients. This interde-

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