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Lower Medicare Mortality Among a Set of Hospitals Known for Good Nursing Care

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The objective of this study is to investigate whether hospitals known to be good places to practice nursing have lower Medicare mortality than hospitals that are otherwise similar with respect to a variety of non-nursing organizational characteristics. Research to date on determinants of hospital mortality has not focused on the organization of nursing. We capitalize on the existence of a set of studies of 39 hospitals that, for reasons other than patient outcomes, have been singled out as hospitals known for good nursing care. We match these "magnet" hospitals with 195 control hospitals, selected from all nonmagnet U.S. hospitals with over 100 Medicare discharges, using a multivariate matched sampling procedure that controls for hospital characteristics. Medicare mortality rates of magnet versus control hospitals are compared using variance components models, which pool information on the five matches per magnet hospital, and adjust for differences in patient composition as measured by predicted mortality. The magnet hospitals' observed mortality rates are 7.7% lower (9 fewer deaths per 1,000 Medicare discharges) than the matched control hospitals ($P = .011$). After adjusting for differences in predicted mortality, the magnet hospitals have a 4.6% lower mortality rate ($P = .026$ [95% confidence interval 0.9 to 9.4 fewer deaths per 1,000]). The same factors that lead hospitals to be identified as effective from the standpoint of the organization of nursing care are associated with lower mortality among Medicare patients. Key words: nursing care; Medicare; mortality rates. (Med Care 1994;32:771-787)

In this study we find that *magnet hospitals*, hospitals that embody a set of organizational attributes that nurses find desirable (and that

are conducive to better patient care), have lower mortality than matched hospitals, which are similar along other organizational dimensions, but that are not known as settings that place a high institutional priority on nursing. Those familiar with the inner workings of hospitals will not be surprised there is a relationship between the practice of nursing and the mortality experience of hospital patients.¹⁻³ The connection between nursing and mortality rates dates as far back as the reforms in British hospitals made under Florence Nightingale during the Crimean War.⁴

Nurses are the only professional caregivers in hospitals who are at the bedside of hospital patients around the clock. What nurses do—or do not do (or in some circum-

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stances are not allowed to do)—is directly related to a variety of patient outcomes, including in-hospital deaths.⁵ American physicians typically combine office and hospital-based practice, and therefore observe their hospitalized patients only periodically. Nurses are physicians' primary source of information about changes in their patients' conditions. Nurses often must act in the absence of the physician when timely intervention is required.⁶ As hospital care has become increasingly complex, the exercise of professional judgment by nurses is ever more important in preventing adverse and sometimes catastrophic events.⁷

The modern hospital has been described as having two lines of authority, medicine and administration.⁸ Nurses have traditionally been subordinate to both, even though they have the most direct knowledge and understanding of patient care requirements by virtue of their constant contact with patients. Lewis Thomas⁹ has described nurses in contemporary hospitals as the "glue" that keeps the highly specialized, often fragmented system of hospital care together. The potential for using nursing to improve patient outcomes is apparent in the multihospital study of variation in intensive care death rates, by Knaus and associates,¹⁰ in which patterns of communication between nurses and physicians were the single most significant factor associated with excess mortality—more important, for example, than whether the unit had a medical director, or whether it was in a teaching hospital. Yet contemporary hospital nursing practice is most often characterized by a lack of professional autonomy, poor control over the practice setting, and inadequate provisions for routine communication with physicians about crucial clinical decisions. All of these compromise the ability of nurses to exercise their professional judgment on behalf of the well-being of their patients.⁸

The degree to which hospitals empower nurses to use their professional nursing skills in a timely manner during in-patient hospital care varies. Certain forms of hospital organization

and institutional culture, ranging from unit-level specialization (e.g., dedicated AIDS units) to the implementation of hospital-wide professional nursing practice models, do indeed result in more autonomy, control, and status for nurses.* We conjecture that hospitals that facilitate professional autonomy, control over practice, and comparatively good relations between nurses and physicians will be ones in which nurses are able to exercise their professional judgment on a more routine basis, with positive implications for the quality and outcomes of patient care.

In this paper we show that a group of hospitals characterized by nurses as being good places to work also achieved better patient outcomes as reflected by lower mortality. Although we cannot document the entire causal chain by which nurses affect mortality, we do review studies showing that the hospitals in which nurses prefer to work have distinct organizational features. The study provides new evidence that these features are more professional autonomy, greater control over the practice environment, and better relationships with physicians. We were able to demonstrate that the superior mortality experience in the study hospitals cannot be attributed to either differential patient characteristics or other organizational features not related to nursing, but previously shown to be associated with differential hospital mortality. The proportion of physicians who are board certified, whether the hospital is a teaching facility, type of ownership, financial status, are examples of such findings.

Review of Previous Studies

The literature on the organization of hospital nursing and variation in hospital mortality have developed independently of one

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another for the most part. Research on the organization of nursing care primarily has been motivated by debates over the causes and potential solutions to hospital nursing shortages. The focus has been on determining how hospital work environments could be restructured to make them more desirable places for professional nurses to practice.¹¹⁻¹⁸ The dominant outcome variables studied have been nurse satisfaction, job turnover, and hospital nurse vacancy rates. Far less attention has been given to the relationship between nursing organization and patient outcomes.

Conversely, the large literature on variations in mortality across hospitals¹⁹⁻²⁴ has concentrated on methodological issues and the association between the institutional and organizational characteristics of hospitals and their in-patient mortality. The methodological focus of the research primarily is on how to separate components of variation due to severity of illness and other characteristics of patients, from manipulable dimensions of hospital organization. Development of measures to stage severity of illness has advanced considerably; measures of organizational dimensions have lagged by comparison.^{10,25,26}

When institutional attributes or characteristics are the focus of hospital mortality studies, a large number of organizational correlates are examined, which sometimes includes nursing.^{19,27-32} Board certification of physicians has been found uniformly to be associated with better quality of hospital care and lower mortality.^{28,30,32-35} The teaching status of hospitals is another variable of frequent interest. The referral patterns characteristic of such hospitals may result in a more severely ill patient population and higher mortality than at nonteaching hospitals.³⁶ Conversely, teaching hospital status may denote a better qualified staff, greater technological sophistication, etc., and thus be expected to yield better outcomes.^{28,37} As would be expected from such competing hypotheses, findings are inconsistent across studies, some documenting more adverse outcomes, some less and some showing no differences at teaching

hospitals.³² The ambiguity of both findings and interpretation can also be found concerning other postulated or observed correlates of mortality, including ownership, size, financial status, and urban vs. rural location.^{29-34,37}

The nursing variable in multivariate hospital mortality studies, usually registered nurse (RN) to patient ratios or RNs as a percentage of total nursing personnel, is usually found to be a significant correlate of mortality. Little substantive or analytic consideration is given to this association, which is variously interpreted as representing the effect of "clinical skill level"^{29,30} or "service intensity."³¹

Magnet Hospitals

Hospitals do differ from one another in their quality of nursing care. This is an important dimension of a hospital's reputation.^{2,3} Rather than undertaking a large, detailed, national study of the mortality experience of hospitals known for good nursing care, we are capitalizing on the existence of a set of studies of several dozen hospitals that have been singled out as hospitals known for good nursing care for reasons other than the study of patient outcomes.

Among experts on nursing, there is general agreement on the attributes of a good nursing service.^{15,38,39} In the early 1980s, the American Academy of Nursing (AAN) set about the task of identifying a set of hospitals with reputations as being good places in which to practice nursing.¹⁵ These hospitals were not identified by low mortality rate, nor were they selected according to any overt organizational features. Rather, the intent of the original study was to demonstrate that hospitals differed from one another with respect to their attractiveness to nurses, and that attractive hospitals were better able to maintain low rates of nursing turnover and vacancy, which led to their eventual designation as *magnet* hospitals.

The magnet hospitals were identified in the original study as follows:¹⁵ six AAN hospital nursing experts in each of eight regions of the country who were selected to nominate

6 to 10 hospitals that met the following three criteria: 1) nurses consider the hospital a good place to practice nursing; 2) the hospital has the ability to recruit and retain professional nurses, as evidenced by a relatively low turnover rate; and 3) the hospital is located in an area where it will have competition for staff from other institutions and agencies. A total of 165 hospitals were nominated; 155 agreed to participate in the study. Each participating hospital provided information on a range of nursing-related issues including nurse vacancy, turnover, and absentee rates; the ratio of inexperienced to experienced nurses; use of supplemental staffing agencies; nurse staffing policies; educational preparation of nurses in leadership positions; and the predominant mode of nurse organization on the units (i.e., primary, team, functional, or other). Hospitals were then ranked according to evidence of being able to attract and retain professional nurses and to create an environment conducive to good nursing care. The top-ranked 41 institutions were subjected to a subsequent round of data collection involving interviews with staff nurses and directors of nursing. These were the hospitals that ultimately came to be designated as magnet hospitals.

The in-patient mortality rates of the hospitals were *not* considered. At that time comparative, standardized hospital rates probably were not available to either institutions or the AAN panelists. Moreover, important as they may be in the aggregate, the magnitude of mortality differences that exist among hospitals is comparatively small, and difficult for even a well-qualified observer to discern at the scene, especially when measured against a backdrop of stochastic fluctuation over time. When we subsequently compare the mortality rates of magnet hospitals with nonmagnet hospitals, we are reasonably confident that the distinction between hospital types pertains to features of the organization of nursing, and is not in itself, another measure of hospital mortality.

The process by which these hospitals were selected does not necessarily guarantee that

the magnet hospitals include *all* hospitals that might meet the original specified criteria. However, the selection process appears to have been sufficiently stringent as to lead us to expect that the 41 magnet hospitals would share some common characteristics with respect to nursing that would differentiate them from the vast majority of American hospitals.

The nurses practicing in the designated magnet hospitals cited the following organizational attributes as important in making their hospitals good places to work:^{15,40-43} 1) the importance and status of nurses in the organization as reflected in the formal organizational structure of nursing and its relationship to the organization of the hospital, i.e., a flat organization of the nursing department with few supervisors, and a chief nurse executive with a strong position in the bureaucratic hierarchy of the hospital; 2) nurse autonomy to make clinical decisions within their areas of competence, and to control their own practice; 3) control over the practice environment, including decentralized decision-making at the unit level, adequate staffing, a limit to the proportion of nurses who were new graduates, and established mechanisms to facilitate communication between nurses and physicians; 4) organization of nurses' clinical responsibilities at the unit level to promote accountability and continuity of care, e.g., primary nursing, and less use of "floating" of nurses to equalize staffing across units; and 5) an established culture signifying nursing's importance in the overall mission of the institution, as reflected in salaried practice (compared to hourly wages), institutional investment in nurses' continuing education, and supervisory personnel who support nurses' decision-making responsibilities.

The original study of these hospitals was conducted in 1982.¹⁵ A follow-up study was conducted in a geographically stratified subsample of the magnet hospitals in 1986,^{40,41} and again in 1989.^{42,43} At each point, the magnet hospitals were found to have maintained their ability to attract and recruit nurses, and to have retained the organizational features found in the initial study.

The organizational dimensions found to be common among the magnet hospitals are similar to those associated with lower mortality in the few previous studies on the topic, i.e., decentralized decision-making at the nursing unit level, ward specialization, standardization of nursing procedures, qualifications of nurses, and good relations with physicians.^{10,27,34} What is not clear from these earlier studies is how or why these particular organizational dimensions of hospitals would be likely to affect what nurses do. Our contention is that they result in enhanced intra-organizational status for nurses that provides a level of professional autonomy and control that enables nurses to put into action what they know and can do for patients. We viewed the magnet hospitals, which are clearly at one end of the scale on which the organization of nursing can be evaluated, as representing an opportunity to test whether there is any payoff in terms of reduced hospital mortality.

Enhanced Autonomy, Control, and Status in Magnet Hospitals

Before tackling our primary question, we briefly explore whether the broad organizational features observed in magnet hospitals do in fact enhance the autonomy, control, and status of nurses within these hospitals. Our argument is that hospitals known to be good places for nurses to work have this reputation in part because of an organizational orientation that permits nurses to practice in an environment in which their authority is closer to their traditionally high level of responsibility. This should enhance the outcomes of patients. However, without a demonstration that autonomy, control over practice, and status of nurses are greater in the magnet hospitals, any finding of lower mortality in these hospitals is subject to skepticism, for want of an operant mechanism.

Evidence in support of the proposition that the magnet hospitals are characterized

by greater nurse autonomy and control, and better relations with physicians, can be found in Table 1, which summarizes the reports of nurses concerning the presence of various job characteristics at 25 hospitals, including 17 magnet hospitals, from two different studies. The first study is by Kramer and Hafner,⁴⁰ and involves a geographically stratified sub-sample of 16 of the original 41 magnet hospitals. Kramer generously provided to us a unit-record data tape from this study, without which the following comparison would have been impossible. The second study is by the present authors (see footnote, page 772), and involves a geographically stratified set of hospitals selected originally to serve as controls in a study of hospitals with specialized AIDS units. Coincidentally, it also includes two magnet hospitals from the original AAN study,¹⁵ one of which is among the 16 magnet hospitals studied by Kramer and Hafner.⁴⁰

In both studies, nurses at these hospitals were asked to evaluate a battery of items (the Nursing Work Index). Each nurse was asked to indicate, for each item, their agreement with the statement, "This is present in my current job situation." Response options were "strongly agree," "somewhat agree," "somewhat disagree," and "strongly disagree." We scored these responses, respectively, 4, 3, 2, and 1. These items included six that measured nurse autonomy, seven that measured control over the practice setting, and two that measured nurses' relations with physicians. Responses were summed across respondents to create scales, the average values of which are found, by study and hospital type, in Table 1.

There are two important aspects to Table 1. First, the magnet hospitals studied by Kramer and Hafner⁴⁰ were evaluated by the nurses in them as being significantly higher in autonomy, control, and good relations of nurses with physicians than were the eight nonmagnet hospitals for which we have comparable data. Second, this is more likely a real difference between magnet and nonmagnet hospitals than it is an artifact of different studies carried out by different re-

TABLE 1. A Comparison of the Presence of Autonomy, Control, and Relations with Physicians, as Assessed by Nurses, for Magnet and Other Hospitals, From Two Studies

Study	Hospital Type	Number of Hospitals	Number of Nurses ^a	Means (and Standard Deviations) for Scales ^b Measuring the Assessed Presence of:		
				Autonomy	Control	Relations With Physicians
Kramer and Hafner ⁴⁰	Magnet	16	1609	20.71 (2.08)	22.34 (2.49)	6.97 (0.91)
Aiken and Smith (See footnote, page 772)	Magnet	2	141	20.89 ^c (2.52)	23.19 ^c (2.89)	6.62 ^c (1.23)
	Other	8	277	17.48 ^d (3.91)	17.87 ^d (4.44)	5.83 ^d (1.32)

^aAverage; actual number responding may vary slightly from scale to scale.

^bThe Autonomy scale has six items (e.g., "Freedom to make important patient care and work decisions"), the Control scale has seven items (e.g., "Enough time and opportunity to discuss patient care problems with other nurses"), and the Relations with Physicians scale has two items (e.g., "Physicians and nurses have good relationships"). For each item, nurses were asked to indicate the extent of their agreement that the statement is reflective of their current job situation. Item responses were "Strongly Agree," "Somewhat Agree," "Somewhat Disagree," and "Strongly Disagree," and were scored, respectively, 4, 3, 2, 1.

^cDoes not differ significantly (i.e., $P > .10$) from the corresponding scale mean in the 16 magnet hospitals studied by Kramer and Hafner.⁴⁰

^dIs significantly less than the corresponding scale mean in the magnet hospitals ($P < .0001$).

searchers. The two magnet hospitals in our later study have scale scores across the three dimensions of nurse status and autonomy that are very similar to the scale scores as obtained by Kramer and Hafner several years earlier at the 16 magnet hospitals that they studied.

We conclude that the features of the hospital's reputation that are responsible for their designation as magnet hospitals proxy for organizational distinctiveness with respect to nurse autonomy, nurse control over practice, and the relations of nurses with physicians, which are all factors that should be positively related to the quality of patient care and, hence, mortality. With this as backdrop, we turn now to the question of whether magnet hospitals do indeed have lower mortality than hospitals with similar structural features, except for the organizational facilitation of professional nursing practice.

Data and Methods

Our analysis of the mortality experience of Medicare patients at the magnet hospitals is based on a comparison of these hospitals with a set of hospitals not known for good nursing

care, but comparable with respect to other factors thought to be correlated with hospital mortality. The 195 control hospitals, five for each magnet hospital, were selected by a multivariate matching procedure. The pool of hospitals from which these control hospitals were selected, and the method by which they were selected, are described in the following two subsections.

Magnet Hospitals versus Potential Control Hospitals

The original set of magnet hospitals was identified in 1982¹⁵ and reexamined in 1986^{40,41} and 1989.^{42,43} Our response variable is the 1988 mortality rate (death within 30 days of admission) among hospitalized Medicare beneficiaries, as reported in the Health Care Financing Administration (HCFA) Medicare hospital mortality rate file.⁴⁴ Thirty-nine of the original 41 magnet hospitals could be found in this file; one hospital had closed, and one has a Veterans Administration hospital, which had no Medicare hospitalizations.

Potential control hospitals were sought among the 5,053 “nonmagnet” hospitals in the HCFA Medicare mortality rate file that had at least 100 Medicare discharges (because annual mortality rates are otherwise highly unreliable) and could be linked to the 1988 American Hospital Association (AHA) annual survey of hospitals.⁴⁵ The AHA annual survey of hospitals provides the most comprehensive data available on hospital organizational structure, facilities and services, beds and utilization, finance, personnel by occupational category, medical staff, and other hospital characteristics. We compare magnet hospitals with other hospitals along a variety of dimensions; and then use these organizational characteristics to construct a matched sample of control hospitals.

The 39 magnet hospitals have lower mortality rates than the other hospitals, on the order of 20 fewer Medicare deaths per 1,000 discharges; see Variable No. 17, Table 2. Magnet hospitals also differ from other hospitals on a variety of organizational characteristics (Variable Nos. 1–10) that have been found to be correlated with mortality, including type of ownership (public, private non-profit, or private for-profit), teaching status (membership in the Council of Teaching Hospitals), hospital size (average daily census, total hospital beds, and volume of Medicare discharges), financial status (total hospital payroll and occupancy rate), physician credentials (the proportion of board-certified physicians on staff), resources for patient care (payroll-to-hospital-beds ratio), and technological sophistication (high technology index score).^{30,31} Magnet hospitals have significantly fewer emergency visits per average daily census (Variable No. 11). Because Medicare patients are a disproportionately small component of emergency admittances, like all of the other control variables discussed so far this variable is better conceptualized as an organizational feature of the hospital than as characteristic of the patient mix. Finally, magnet hospitals are more likely

than other hospitals to be in large metropolitan areas (Variable No. 12).

There are two other dimensions on which magnet hospitals differ from other hospitals in the sample: first, they employ more registered nurses (RNs), both relative to patients (RNs/ADC) and as a proportion of all nurses (RNs/total nursing personnel); see Variable Nos. 14 and 15 in Table 2. Thus magnet hospitals do differ from other hospitals along the nursing organization dimensions typically operationalized in multivariate studies of differential hospital mortality.

Second, magnet hospitals have lower rates of *predicted* mortality, by a factor of 10 per 1,000 (Variable No. 16). Predicted hospital mortality rates are based on the following patient characteristics: age, sex, the presence of four comorbidities (cancer, cardiovascular disease, liver disease, and renal disease), the type and source of admission, and the presence and risk of hospitalizations within the previous 6 months. Predicted mortality is thus a proxy for patient composition. Inter-organizational variability in mortality reflects in large part differences in patient populations, with respect to both morbidity (case mix) and demographic status.^{46,47}

Construction of a Matched Control Sample

To control for organizational differences between hospitals, we employed matching⁴⁸⁻⁵⁰, a traditional form of adjusting for confounding variables in observational data. By analogy with experimentation, we have a key treatment—those aspects of hospital nursing organization embodied in the “magnet hospital” rubric—whose effects we seek to measure. Case-by-case matching across multiple dimensions is impracticable, and limited theory makes it difficult to specify a small, tractable number of important factors for which control is essential. Fortunately, recent developments in multivariate matched sampling⁵¹ simplify the task, and allow us to control for all of the hospital characteristics

TABLE 2. Characteristics of the Study Hospitals

Variable Number	Characteristics	Matched Control Hospitals						
		Magnet Hospitals (n=39)	Potential Control Hospitals (n=5,053)	1st (n=39)	2nd (n=39)	3rd (n=39)	4th (n=39)	5th (n=39)
1.	Ownership—percent							
	Public	7.7	28.2 ^a	2.6	12.8	0.0	5.1	10.3
	Private for-profit	7.7	14.2	18.0	5.1	12.8	12.8	2.6
	Private not-for-profit	84.6	57.7 ^a	79.5	82.1	87.2	82.1	87.2
2.	Member—Council of Teaching Hospitals (%)	28.2	5.8 ^a	23.1	33.3	30.8	30.8	28.2
	Hospital size							
3.	Average daily census (ADC)	305.5±148.9	112.0±137.6 ^a	326.2	323.5	294.1	274.6	302.9
4.	Hospital beds	412.6±180.4	160.6±167.4 ^a	444.9	452.4	399.9	372.9	407.7
5.	Medicare discharges	5,006±2,229	1,873±1,927 ^a	5,357	5,227	4,877	4,915	5,306
	Financial status							
6.	Payroll (million dollars)	46.7±29.5	13.3±20.4 ^a	45.1	49.6	42.3	45.6	45.1
7.	Occupancy rate	0.722±0.115	0.556±0.190 ^a	0.720	0.697	0.707	0.712	0.737
8.	Board-certified physicians/all physicians	0.756±0.086	0.661±0.194 ^a	0.759	0.749	0.741	0.774	0.743
9.	Payroll expense/hospital bed (1,000 dollars)	109±35	64±35 ^a	95 ^b	105	100	110	108
10.	High-technology index score ^c	2.57±1.68	0.59±1.12 ^a	2.68	2.75	2.74	2.68	2.36
11.	No. of emergency visits/ADC	117.7±69.6	181.6±144.4 ^a	121.9	127.0	96.4	127.2	129.8
12.	Metropolitan statistical area size ^d	4.49±1.254	2.14±2.296 ^a	4.26	4.44	4.54	4.33	4.51
13.	Propensity score	3.530±1.142	6.589±1.956 ^a	3.531	3.532	3.533	3.525	3.523
14.	RNs/ADC	1.569±0.556	1.216±0.704 ^a	1.471	1.503	1.329 ^b	1.454	1.424
15.	RNs/total nursing personnel	0.760±0.130	0.581±0.149 ^a	0.692 ^b	0.690 ^b	0.682 ^a	0.708 ^b	0.671 ^a
16.	Predicted mortality	0.113±0.016	0.123±0.024 ^a	0.117	0.114	0.117	0.115	0.119
17.	Mortality rate	0.105±0.021	0.126±0.035 ^a	0.117 ^b	0.109	0.117 ^b	0.111	0.116 ^b

Notes: Plus-minus values are means ± standard deviation.

^a*P* < .01.

^b*P* < .05.

^cThe High-technology index score ranges from zero to five based on the presence or absence of the following items: a cardiac-catheterization laboratory, an extracorporeal lithotripter, a facility for magnetic resonance imaging, a facility for open-heart surgery, and organ transplantation capability.

^dMetropolitan statistical area size is an ordinal variable with values ranging from 0 to 6 corresponding to the following Census Bureau MSA population size categories: 0 = non-metropolitan area—areas with no city with a population of 50,000 or more nor a total population of 100,000 or more; 1 = Under 100,000; 2 = 100,000 to 250,000; 3 = 250,000 to 500,000; 4 = 500,000 to 1,000,000; 5 = 1,000,000 to 2,500,000; 6 = Over 2,500,000.

in the first panel of Table 2 (Variables Nos. 1–12), without matching each case on each of 12 characteristics. Matching has been shown to be a robust method for reducing bias due to observed covariates^{52,53}, and is

intuitively easy to understand.⁵¹ The matching procedure worked as follows:

Propensity scores. For the entire sample, a dichotomous variable (coded 1 if the hospital was a magnet hospital and 0 otherwise)

was (logistically) regressed on the 12 organizational characteristics in the top panel of Table 2.⁵¹ The resultant discriminant function was used to obtain, for each hospital in the sample, a predicted logit (log-odds on being a magnet hospital). This predicted logit is the propensity score.

Most of the discrimination (matching) is effected by five variables: the average daily census, the occupancy rate, the number of hospital beds, the metropolitan statistical area size, and the high-technology index score. The discriminant function is not well specified from the standpoint of hypothesis testing, first, because the number of predictor variables (12) is high relative to the number of hospitals being discriminated (39); second, because there is high collinearity among several of the predictor variables. However, the goals of this function are prediction (discrimination) and data reduction (creating a matching variable that is a linear combination of the original 12 control variables). Redundancy and collinearity are of little account; and, as a prediction/classification model, the estimated function works quite well: 1) the area under the receiver operating characteristic curve⁵⁴ (.904) is high; 2) at a predicted positive classification probability close to the (low) proportion of magnet hospitals in the sample (i.e., $\approx .01$), both sensitivity (percentage of magnet hospitals classified correctly) and specificity (percentage of non-magnet hospitals classified correctly) are in excess of 80%; and 3) for fairly "thick" partitions of the predicted-probability-ordered data (e.g., 10 groups of ≈ 500 hospitals) the Hosmer-Lemeshow⁵⁵ goodness-of-fit X^2 is low and nonsignificant ($X^2 = 4.05$, 8 DF, $P > .85$), strongly suggesting the classification model *not* be rejected.

Random order, nearest available pair-matching. A set of random numbers was generated, one for each of the 39 magnet hospitals.⁵⁶ Beginning with the lowest random number, and proceeding in random-number size order, each magnet hospital was matched with the non-magnet hospital

in the sample with the nearest propensity score.⁵⁶ That control hospital, or "match," was then removed from the sample, so that no hospital served as the control for more than one magnet hospital.

Multiple controls per case. Random order, nearest available pair-matching was repeated four more times, until each magnet hospital was matched with five unique control hospitals. Variances for matched differences decline by a factor of two as the number of matched controls per treatment observation increases from one to infinity, with most of the increase in efficiency occurring in the first two to five matches. Conversely, bias *increases* with number of matches because of inappropriate matches.⁵⁸ Our analysis of these data shows that after the fifth or sixth match, bias increases dramatically. Compensating for such bias would involve proper specification of a large regression; it is to avoid this that we have limited our control to 195 (39 magnet hospitals \times 5 matches per hospital) of the 5,053 potential control hospitals.

Results of the matching procedure can be described with reference to the final five columns of Table 2. In only one out of 60 cases (12 variables \times 5 matches per hospital) does a control variable in the discriminant function have a mean (or proportion) that differs significantly ($P < .05$) from the magnet hospital sample (payroll expense/hospital bed, for the first set of matches). The propensity scores (Variable No. 13), which are linear combinations of the control variables in the discriminant function, are virtually the same for magnet hospitals and matched control hospitals; there is thus no evidence that the quality of match degrades from the first to the fifth matching cycle.

Even after matching on numerous organizational characteristics, magnet hospitals clearly employ more registered nurses as a percentage of total nursing personnel (Variable No. 15; this was *not* a predictor in the discriminant function) than do their matched controls. Matching on organizational characteristics does, however, reduce differences between

hospitals in patient characteristics affecting mortality. Predicted mortality rates are uniformly lower among matched control hospitals than in the potential population of controls, and in none of the five match sets is this predicted mortality significantly in excess of predicted mortality in the magnet hospital sample (Variable No. 16; also *not* a predictor in the discriminant function).

Table 2 shows that after equating hospitals with respect to numerous organizational features, matched hospitals still have mortality rates in excess of those in magnet hospitals, by approximately between four and 12 deaths per 1,000 (Variable No. 17). However, the precision of this estimated effect is unclear, because in only three of the five sets of matches is the difference statistically significant. In the next section, we provide results from a model that pools information on the five matches per case (magnet hospital), as well as adjusts for uncontrolled differences in patient composition (i.e., predicted mortality). We also test whether any remaining effect can be accounted for by standard organizational measures of nursing (e.g., RNs as a proportion of total nursing personnel).

Results

The matching procedures previously described result in five comparison hospitals for each of our 39 magnet hospitals. In concept, our analysis is simple. We compare the average mortality of the 39 magnet hospitals with those of the 195 (= 5 × 39) comparison (control) hospitals. In practice, the analysis is somewhat more complex, because having multiple controls (matches) for each magnet hospital allows us to examine whether the mortality differences between magnet and nonmagnet hospitals varies across the set of magnet hospitals. Thus, we have embedded familiar *t*-tests for paired comparisons in the framework of the random-effects analysis-of-variance (ANOVA). We do this by conceptualizing each difference between a magnet hospital and a matched control hos-

pital as attributable to 1) the "general" effect of magnet hospitals on mortality; 2) an effect that is specific to a particular magnet hospital; and 3) chance error. An advantage of this general model is that it is easily extended to include control variables, such as predicted mortality (as a function of patient composition). Because the details of the statistical model will not be of interest to all readers, we have consigned them to an Appendix. Here we restrict ourselves to specific results.

The first row of Table 3 gives the basic ANOVA estimates (Model I). The estimate of $-.0087$ corresponds to a reduction of approximately nine deaths per 1,000 Medicare admissions. With hospital death rate averages on the order of 113 per 1,000 in the study sample, this is equivalent to an estimated 7.7% diminution in mortality.

Table 3 also contains estimates of the variation in mortality differences between magnet hospitals and matched control hospitals in its final two columns. There are significant differences between magnet hospitals regarding their effects on mortality, as indicated by the high level of variance between blocks of matched hospitals. This means that the average mortality reduction, of nine deaths per 1,000 Medicare admissions, blends substantial differences in effects, across magnet hospitals. Having multiple matches per magnet hospital allows us to estimate these hospital-specific effects with moderately good precision: The reliability of the estimated mortality reduction effect for specific hospitals is 0.75.

As previously detailed, hospitals appear well-matched with respect to a variety of organizational characteristics, such as size, and ownership, found by some previous studies to be related to mortality. However, as revealed in Table 2, the predicted mortality of magnet hospitals is somewhat lower than that of matched controls. The estimated mortality difference under Model I might reflect differences in patient composition, as measured by their functional composite,

TABLE 3. Estimated Parameters for Three Models of Hospital Mortality

Model	Control for Predicted Mortality?	Response Variable	Fixed Effects			Variances	
			Mean Difference Between Magnet Hospitals and Matched Controls	Between-Block		Between Blocks of Matched Hospitals	Within Blocks of Matched Hospitals
				Progression of Predicted Mortality Difference on Observed Differences	Within-Block Regression of Predicted Mortality Differences on Observed Mortality Differences		
			γ_{00}	γ_{01}	γ_{10}	τ_{00}	σ^2
I	No	Mortality difference between magnet hospital and matched control hospital	-.0087 (.0032) $P = .011$.00029 ($\chi^2 = 154$) $P < .001$.00048
II	Yes	Mortality difference between magnet hospital and matched control hospital	-.0052 (.0022) $P = .026$	0.93 (.133) $P < .001$	1.01 (.074) $P < .001$.00013 ($\chi^2 = 145$) $P < .001$.00022
III	Yes	Natural logarithm of the ratio of excess (observed over predicted) mortality in magnet versus control hospitals	-.048 (.021) $P = .034$.0139 ($\chi^2 = 197$) $P < .001$.0167

Note: "Blocks" are a magnet hospital and its five matched control hospitals. There are 39 blocks in the analysis. For fixed effects, estimated standard errors are in parentheses. For variance components, estimated χ^2 statistics are in parentheses.

predicted mortality. Thus, in Model II of Table 3, we control for differences between magnet hospitals and matched control hospitals in predicted mortality. Some, but not all, of the observed mortality difference is attributable to differences in patient characteristics, as the estimate of the general magnet hospital effect on mortality shrinks from $-.0087$ to $-.0052$. The 95% confidence interval for the effect of magnet hospitals on mortality, with adjustment for hospital-specific predicted mortality, is from 0.9 to 9.4 fewer deaths per 1,000.

Controlling for differences in patient composition (i.e., predicted mortality) also substantially attenuates differences between magnet hospitals in their effect on observed mortality. A comparison, between Models I and II, of the estimated variance in effects between blocks of matched hospitals reveals that over half the original variability in estimates of mortality reduction across magnet hospitals is attributable to not having controlled for differences between hospitals in patient characteristics.

Similar results are obtained when we adjust for predicted mortality not as a covariate, but as the denominator in a measure of excess mortality (i.e., the ratio of observed to expected mortality). This is Model III, the final line of Table 3. In this formulation, the estimated effect of $-.048$ corresponds to 4.8% less excess mortality in the magnet hospitals. There is still significant variance across magnet hospitals in the extent to which their mortality differs from that of their matched controls. Excess mortality across magnet hospitals is well-measured: The reliability of estimates of hospital-specific excess mortality, under Model III, is .81.

Discussion

The magnet hospitals were selected on the basis of their reputations, not on objective evidence of the presence of a unique set of organizational attributes. Their common organizational dimensions were only identi-

fied subsequently. The estimated effects on mortality might not be the same as would be found were we to: 1) enumerate the important organizational characteristics; 2) seek to identify hospitals on the basis of objective measures of those characteristics; and 3) compare them to hospitals without such characteristics. We do not know the extent to which our matched comparison hospitals share those organizational features of nursing that we have deemed conducive to lower mortality, because the only information available on the matched comparison hospitals is macro-level hospital characteristics from the AHA annual survey. However, to the extent that the control hospitals do share these characteristics, our estimates are conservative with respect to their effects on mortality.

One thing we can do to clarify these issues is to examine nursing skill mix (RNs as a percent of total nursing personnel) in magnet and matched nonmagnet hospitals. The mix of nursing personnel is one of the distinguishing characteristics of magnet hospitals and a variable on which information is available on matched hospitals from the AHA annual survey of hospitals. Additionally, higher ratios of registered nurses to other nursing personnel have been associated with lower hospital mortality in other studies,^{30,34} raising the possibility that this is the major explanation for lower mortality in magnet hospitals. As noted in Table 2, magnet hospitals do have significantly higher ratios of RNs to total nursing personnel and slightly higher nurse to patient ratios. This provides some evidence that nonmagnet hospitals do indeed differ from magnet hospitals in nursing organizational features that comprise the "intervention" in our quasi-experimental study design.

To test whether this particular variable provides the full explanation for the mortality effect, we extended Model II to include terms for both within-block and compositional differences in the ratio of RNs to total nursing personnel. We found no evidence

that average differences between magnet hospitals and matched controls, with respect to either skill mix or nurse to patient ratios, significantly affect mortality, nor do they explain any of the variability in effects across magnet hospitals. Moreover, inclusion of these variables does not significantly alter the estimate of our treatment effect ($t = 1.27, P > .10$).⁵⁸

On the basis of this analysis, we conclude that the matched comparison hospitals are not identical in nursing organization to the magnet hospitals. At the same time, we have also demonstrated that one of the attributes of magnet hospitals—a greater proportion of nursing service personnel being registered nurses—is not the sole explanation for their lower mortality. This finding reinforces our belief that the mortality effect derives from the greater status, autonomy, and control afforded nurses in the magnet hospitals, and their resulting impact on nurses' behaviors on behalf of patients.—i.e., this is not simply an issue of the number of nurses, or their mix of credentials.

As with any observational comparison, our results are potentially subject to biases for unobserved covariates.⁵¹ We cannot rule out the possibility that variables omitted from the analysis explain the lower mortality in magnet hospitals. If this is the case, such omitted variables will be correlated with the set of nursing variables operationalized by the magnet hospital construct. Although there may be other variables that we have not measured that affect mortality on their own accord, we believe they are as likely to be functions of the within-hospital organization of nursing as determinants of it.

We have utilized Medicare mortality data because of its availability for the hospitals of interest even though data on patients of all ages would have been preferable. It is uncertain how expanding the age range of patients on which mortality is observed would affect our findings. Mortality rates are lower among younger patients, which argues for a diminution in the size of the effect. However, within the aged Medicare population

there are limits to the proportion of mortality that can be expected to be prevented by any intervention.

The practical importance of our findings is influenced by the extent to which the organizational characteristics of magnet hospitals can be replicated elsewhere. In another paper, we have demonstrated that hospital unit level reforms, such as enabling nurses to specialize, also stimulate greater autonomy, control, and intra-organizational status toward nursing. However, institution-wide professional nursing practice models (as in the magnet hospitals) stimulate them further. The authors of the original magnet hospital study¹⁵ and researchers conducting the follow-up studies⁴³ believe that the attributes of magnet hospitals can be widely replicated, and we concur. The organizational attributes distinguishing magnet hospitals are almost identical to those characterizing the best-run companies, and thus have potentially wide applicability across a range of organizational types.⁴¹⁻⁴³ As noted in Table 2, there is considerable variability among magnet hospitals in hospital size, teaching status, ownership, and financial status, all of which suggests that replication is not bound by hospital "type." Indeed, approximately 900 (18%) of the nonmagnet hospitals in the classification sample have combinations of organizational characteristics (teaching status, percentage of board-certified physicians, ownership, financial status, etc.) that would lead them (under certain optimal classification rules) to be predicted to be magnet hospitals.

Conclusion

Our narrowest conclusion is that the hospitals in the magnet hospital study have mortality rates that are lower than those among matched control hospitals, by a factor of approximately five per 1,000 Medicare discharges. This corresponds to a reduction in "excess mortality" of 5%. The magnet hospitals do differ from their matched controls

in their nursing "skill mix," but this is not the explanation for the mortality differential. Based on adjunct studies of the magnet hospitals, we are inclined to attribute this differential to hospital-level differences in the organization of nursing care. Our broader conclusion is that such organizational factors are important in understanding why some hospitals achieve better patient outcomes than others. We point to the 39 magnet hospitals, that appear to be in many respects like other hospitals, except in the organization of nursing, as evidence that further reductions in excess hospital mortality may well be within our reach.

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Appendix: Analytic Equations Corresponding to Results

These are equations and statistical considerations pertaining to estimates reported in the Results section. This Appendix should be read in parallel with that section.

There are $I = 39$ magnet hospitals, each matched to $J = 5$ control hospitals. Let y_{ij} be the mortality rate in the j^{th} match to the i^{th} magnet hospital, $i = 1, \dots, 39, j = 1, \dots, 5$. Denote by y_{i0} the mortality rate in the i^{th} magnet hospital. Then there are $I \times J = 195$ pairs of mortality differences, $\Delta y_{ij} = y_{i0} - y_{ij}$.

A random-effects analysis-of-variance (Model I) for the effect of magnet hospital characteristics on mortality is

$$(A1) \quad \Delta y_{ij} = \beta_{0i} + e_{ij} \text{ and}$$

$$(A2) \quad \beta_{0i} = \gamma_{00} + u_{0i},$$

where $E(e_{ij})=0, \text{Var}(e_{ij})=\sigma^2$, and $\text{Var}(u_{0i})=\tau_{00}$. This posits a fixed effect of magnet hospitals γ_{00} across all comparisons, as well as a randomly varying effect (u_{0i}) specific to each magnet hospital and its block of five differences. Tests of the hypothesis $\gamma_{00}=0$ are equivalent to t -tests of the difference between magnet hospital mortality and the average mortality in matched (paired) control hospitals.⁵⁷ The test of the hypothesis $\tau_{00}=0$ is the test of the assumption that the magnet hospital effect on mortality is common across all magnet hospitals. The reliability of β_{0i} is estimated as $\hat{\tau}_{00} / (\hat{\tau}_{00} + [\hat{\sigma}^2/n])$, where $n=5$, the number of matched control hospitals in each block.

To adjust for the effects of predicted mortality, define x_{ij} as predicted mortality for the j^{th} hospital matched to the i^{th} magnet hospital, and x_{i0} is predicted mortality for the i^{th} magnet hospital.

$$\text{Set } \Delta X_{ij} = x_{i0} - x_{ij} \text{ and } \Delta x_{i.} = \left(\sum_{j=1}^5 \Delta x_{ij} \right) / 5.$$

Model II is a random-effects regression of Δy_{ij} on both within-block (Δx_{ij}) and compositional ($\Delta x_{i.}$) differences in predicted mortality.⁶⁰

$$(A3) \quad \Delta y_{ij} = \beta_{0i} + \beta_{1i} (\Delta x_{ij} - \Delta x_{i.}) + e_{ij},$$

$$(A4) \quad \beta_{0i} = \gamma_{00} + \gamma_{01} \Delta x_{i.} + u_{0i}, \text{ and}$$

$$(A5) \quad \beta_{1i} = \gamma_{10} = u_{1i},$$

with $\text{Var}(u_{1i})=\tau_{11}$ and $\text{Cov}(u_{0i}, u_{1i})=\tau_{10}=\tau_{01}$. We were unable to reject the hypothesis that $\tau_{11}=\tau_{10}=0$ ($\chi^2 = 3.56, 2 \text{ DF}, P > .15$), so these terms were set equal to zero for Model II, which was re-estimated as a one-way analysis-of-covariance (ANCOVA) with random effects.⁶⁰

Under Model II, estimates of both γ_{01} and γ_{10} (the effects of block-specific and within-block differences in predicted mortality on observed mortality) are

approximately equal to one. Under the assumption that they are exactly equal to one, Model II can be re-expressed as

$$(A6) (y_{i0}-x_{i0})-(y_{ij}-x_{ij})=\gamma_{00}+\text{variance components}$$

which is to say that the estimate of γ_{00} under Model II is essentially that which would obtain if "excess mortality" (observed minus predicted) in magnet hospitals were compared with excess mortality in matched controls. A variant on this is to transform the response variable so as to describe excess mortality in *percentage terms*, and estimate Model III,

$$(A7) \ln[(y_{i0}/x_{i0})/(y_{ij}/x_{ij})]=\beta_{0i}+e_{ij},$$

with reference to equation (A2).