SPECIAL ARTICLE

Nurse Staffing and Inpatient Hospital Mortality

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ABSTRACT

BACKGROUND

Cross-sectional studies of hospital-level administrative data have shown an association between lower levels of staffing of registered nurses (RNs) and increased patient mortality. However, such studies have been criticized because they have not shown a direct link between the level of staffing and individual patient experiences and have not included sufficient statistical controls.

METHODS

We used data from a large tertiary academic medical center involving 197,961 admissions and 176,696 nursing shifts of 8 hours each in 43 hospital units to examine the association between mortality and patient exposure to nursing shifts during which staffing by RNs was 8 hours or more below the staffing target. We also examined the association between mortality and high patient turnover owing to admissions, transfers, and discharges. We used Cox proportional-hazards models in the analyses with adjustment for characteristics of patients and hospital units.

RESULTS

Staffing by RNs was within 8 hours of the target level for 84% of shifts, and patient turnover was within 1 SD of the day-shift mean for 93% of shifts. Overall mortality was 61% of the expected rate for similar patients on the basis of modified diagnosis-related groups. There was a significant association between increased mortality and increased exposure to unit shifts during which staffing by RNs was 8 hours or more below the target level (hazard ratio per shift 8 hours or more below target, 1.02; 95% confidence interval [CI], 1.01 to 1.03; P<0.001). The association between increased mortality and high patient turnover was also significant (hazard ratio per high-turnover shift, 1.04; 95% CI, 1.02 to 1.06; P<0.001).

CONCLUSIONS

In this retrospective observational study, staffing of RNs below target levels was associated with increased mortality, which reinforces the need to match staffing with patients' needs for nursing care. (Funded by the Agency for Healthcare Research and Quality.)

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EVIDENCE FROM AN INCREASING NUMBER of studies has shown an association between the level of in-hospital staffing by registered nurses (RNs) and patient mortality,[1-5] adverse patient outcomes,[1,5-12] and other quality measures.[13-16] Quality measures that are related to nurse staffing have been adopted by the National Quality Forum,[17] the Agency for Healthcare Research and Quality (AHRQ),[18] and the Joint Commission.[19] Some private payers have followed the lead of the Centers for Medicare and Medicaid Services in no longer paying hospitals for the costs associated with certain nursing-sensitive, hospital-acquired "never" events, such as pressure ulcers and catheter-associated infections.[20]

The strength of the evidence underpinning the association between nurse staffing and patient outcomes has been challenged because studies are typically cross-sectional in design, use hospital-level administrative data that imprecisely allocate staffing to individual patients, and do not account for differences in patients' requirements for nursing care.[21,22] Other observers have asked whether differences in mortality are linked not to nursing but to unmeasured variables correlated with nurse staffing.[23] In this study, we address these concerns by examining the association between mortality and day-to-day, shift-to-shift variations in staffing at the unit level in a single institution that has lower-than-expected mortality and high average nurse staffing levels and has been recognized for high quality by the Dartmouth Atlas, rankings in *U.S. News and World Report*, and Magnet hospital designation. In addition, our analysis includes extensive controls for potential sources of an increased risk of death other than nurse staffing.

METHODS

STUDY OVERSIGHT

The study, which was funded by the AHRQ, was designed by the research team and approved by the institutional review board at each collaborating institution. Data were obtained from a tertiary academic medical center with trained local data specialists who constructed the analytic data set. Members of the research team jointly provided direction and oversight of the analysis, wrote the manuscript, and made the decision to submit the manuscript for publication.

DATA AND POPULATION

We retrieved data for 2003 through 2006 from electronic data systems of the medical center. We excluded pediatric, labor and delivery, behavioral health, and inpatient rehabilitation units. We classified the remaining 43 hospital units according to unit type (intensive care, step-down care [i.e., with monitored beds but not intensive care], and general care) and service type (medical or surgical). For each unit, we obtained data on patient census, admissions, transfers, and discharges and on staffing levels for each nursing shift.

We excluded data for patients who declined to authorize the use of their data for research purposes (3.1% of patients). The final sample included 197,961 admissions. We obtained data about patients from electronic discharge abstracts. On a shift-by-shift basis, we identified the unit on which each patient was located and then merged unit characteristics and staffing data for the shift with the patient data. This process resulted in 3,227,457 separate records with information for each patient for each shift during which they were hospitalized (which we have called patient unit-shifts); these records included measures of patient-level and unit-level characteristics, nurse staffing, and other shift-specific measures. When we considered only the first admission of possibly multiple admissions for any specific patient during the study period, there were 1,897,424 unit-shifts for patients.

MEASURES

Inpatient Mortality

Death at hospital discharge was coded on patient discharge abstracts. Data for each hospitalization were retrieved from the hospital's administrative data support system.

RN Staffing per Unit-Shift

Studies involving RN staffing have shown that when the nursing workload is high, nurses' surveillance of patients is impaired, and the risk of adverse events increases. To measure patients' exposure to high-workload shifts, we constructed measures of below-target staffing and high turnover, each of which increases the workload for nurses.

RN staffing was normalized to 8-hour blocks of time that correspond to common notions of shifts. We obtained target RN hours for each unit and shift, which were generated by a well-calibrated and audited commercial patient-classification system. Patients may be reassessed multiple times during a shift and target staffing may be revised, so we used the last estimate of target staffing for each shift. We adjusted the target hours for each shift to account for the time that patients spent away from the unit for anesthesia-related procedures (but not for procedures, such as dialysis, that do not require anesthesia). We calculated the difference between target RN hours for the shift and actual hours worked on the unit in direct patient care, and we set a flag for below-target staffing when actual staffing was 8 hours or more below the adjusted target.

Patient Turnover

Because demands on nursing staff increase as the numbers of admissions, transfers, or discharges increase,[24,25] we constructed a measure of patient turnover for each shift that was equal to the sum of unit admissions, transfers, and discharges (excluding deaths) and the adjusted or start-of-shift census so that complete patient turnover would equal 100%. A shift was defined as having a high turnover if the rate was greater than or equal to the mean plus 1 SD for the day-shift turnover for that unit, and a dummy variable for high turnover was merged into the patients' unit-shift record.

Other Unit and Shift Measures

To account for mortality-associated differences across units, our models included an indicator of the unit to which the patient was initially admitted. We included unit service type and indicators for day, evening, and night shifts as time-varying covariates for each shift. To adjust for possible confounding between measures of below-target staffing and mortality, the models included start-of-shift census and target staffing for the shift.

Patient-Level Measures

We used patient-level measures to adjust for the risk of death, including age, sex, payment source, type of admission, whether the patient was a local resident or out-of-area referral, and the 29 coexisting conditions included in the Elixhauser algorithm.[26] (A list of these conditions is provided in the Supplementary Appendix, available with the full text of this article at NEJM.org.) In addition, each patient was assigned a predicted in-hospital mortality value on the basis of the patient's diagnosis-related group (DRG). This value was constructed for each DRG for each year from the 2003–2006 AHRQ Hospital Cost and Utilization Project National Inpatient Samples by estimating the average annual in-hospital rate of death for each AHRQ-modified DRG, with a single pooled value for low-volume modified DRGs. AHRQ-modified DRGs are used in AHRQ risk-adjustment models to decrease the possibility that hospital-acquired complications influence estimates of risk adjustment.[27] To adjust for possible confounding from measures of staffing and hospitalization in an intensive care unit (ICU), we included as a time-varying covariate the cumulative number of shifts during which the patient had been in an ICU.

STATISTICAL ANALYSIS

To assess the association between mortality and nurse staffing, we conducted a survival analysis using Cox proportional-hazards regression models with the time from hospital admission as the time scale and in-hospital death as the outcome. We summarized the characteristics of patients, units, and shifts with the use of means and standard deviations for continuously scaled variables and counts and percentages for nominal variables. We calculated the proportion of shifts with actual staffing levels that were 8 hours or more below target and examined the distribution of below-target shifts according to unit shift and shift time. We calculated means and standard deviations for patient turnover and the proportion of shifts with high turnover. By aggregating data across all hospital stays and using the in-hospital rates of death from the national inpatient samples for each DRG, we calculated a standardized mortality ratio and 95% confidence interval to compare observed mortality with predicted in-hospital mortality.

We analyzed associations between mortality, levels of RN staffing, and other variables using Cox proportional-hazards regression models. We used the time elapsed during the hospital admission, accounting for the date of the admission in order to adjust for potential temporal differences in mortality, as the time scale. Follow-up for all patients was stopped after 90 shifts (approximately 30 days) because 99.9% of patients were discharged within 90 shifts. Unit-shift and patient-level variables were included in the models to account for differences in the risk of death. When values for unit- and patient-level variables changed (e.g., changes to the unit census), they were treated as time-varying covariates. Cox models included cumulative time-varying measures of each patient's exposure to shifts with staffing levels of 8 hours or more below target and high-turnover shifts.

Because patients with longer lengths of hospital stay have increased opportunities to be exposed to below-target and high-turnover shifts, we performed several secondary analyses to check the robustness of the findings. These analyses included counting below-target and high-turnover shifts occurring only within the first 5 days of each stay, the inclusion of patients who had stayed only on general units, and the inclusion of exposure to below-target and high-turnover shifts in a rolling window of six shifts (2 days) before the current shift.

We used regression models that included these variables to estimate hazard ratios and 95% confidence intervals. Hazard ratios were tested for significance with the use of two-sided Wald tests. A P value of less than 0.05 was considered to indicate statistical significance. All statistical analyses were conducted with the use of SAS software, version 9.1.

RESULTS

CHARACTERISTICS OF PATIENTS, UNITS, AND STAFFING

Of the 197,961 patients who were included in the study, 51.4% were men (Table 1). The mean age was 60.2 years. Although we excluded pediatric units, pediatric patients who were treated on adult units were included in the analysis, and 4443 admissions (2.2%) were for patients below the age of 21 years. Eighty percent of patients were from outside the local area, reflecting the institution's substantial referral practice. Medicare was the most frequent payer. The average predicted mortality was 3.1%, whereas actual mortality was substantially lower (1.9%) (standardized mortality ratio, 0.61; 95% confidence interval [CI], 0.59 to 0.63).

During the study period, there were 176,696 staffed unit-shifts; two thirds were in general care units, with the remainder split between critical care and step-down units. Patient turnover across shifts averaged 10.4% but was highly variable (SD 13.5%); 6.9% of shifts were categorized as having a high turnover.

The target staffing for RNs in ICUs was quite consistent across day, evening, and night shifts, whereas step-down and general care units had higher levels of staffing in the daytime and lower levels at night (Table 2). On average, actual staffing was close to target across all units; however, 15.9% of all shifts had actual staffing levels that were 8 hours or more below target. Nearly one fifth (19.4%) of critical care units had staffing levels that were 8 hours or more below target, with night shifts most likely to fall below target. On general care units, 14.0% of shifts had staffing levels that were 8 hours or more below target, with day and evening shifts more likely to be below target. On step-down units, 18.7% of shifts had staffing levels that were 8 or more hours below target, with day and evening shifts more likely than night shifts to be below target staffing. The proportion of shifts with high turnover was consistent across units: 14.9% on day shifts, 5.6% on evening shifts, and 0.2% on night shifts.

BELOW-TARGET STAFFING, HIGH TURNOVER, AND MORTALITY

Of all the patients who were evaluated during the first 30 days after admission, 31.9% stayed in units in which no shifts had actual staffing levels that were 8 hours or more below target, whereas 34.6% stayed in units that had three or more shifts with below-target staffing; 39.7% of patients were not exposed to any high-turnover shifts, whereas 12.6% were exposed to three or more shifts with high turnover (Table 3).

In survival models with adjustments for measures of patient, unit, and shift risk, there was a significant association between mortality and exposure to below-target or high-turnover shifts (Table 4). For all hospital admissions, the risk of death increased with exposure to an increased number of below-target shifts (hazard ratio per below-target shift, 1.02; 95% CI, 1.01 to 1.03; $P<0.001$). When counts of below-target shifts were restricted to those in the first 5 days after admission, the hazard ratio increased to 1.03 (95% CI, 1.02 to 1.05; $P<0.001$). When the exposure was specified only in a sliding window of the previous six shifts, the hazard ratio was 1.05 (95% CI, 1.02 to 1.07; $P=0.001$). When the analysis was restricted to patients with no exposure

Table 1. Characteristics of the Patients, Units, and Nursing Shifts.*

Variable	Value
Patients	
No. of admissions	197,961
Deaths — no. (%)	3,681 (1.9)
Age — yr	
Mean	60.2±18.0
Range	0–105.0
Male sex — no. (%)	101,694 (51.4)
Payer — no. (%)	
Medicare	95,779 (48.4)
Commercial	84,743 (42.8)
Other government	12,224 (6.2)
No insurance	5,215 (2.6)
Admission type — no. (%)	
Routine	117,991 (59.6)
Emergency	65,522 (33.1)
Urgent	14,384 (7.3)
No. of ICU shifts per admission	
Mean	2.3±9.6
Range	0–510.0
Local residence — no. (%)	38,449 (19.4)
Predicted mortality on the basis of modified diagnosis-related group — %	
Mean	3.1±4.1
Range	0–31.6
Units	
No. of units	43
Type of unit — no. (%)	
ICU	8 (18.6)
Step-down care	7 (16.3)
General care	28 (65.1)
Medical units — no. (%)	20 (46.5)
Shifts	
No. of patient unit-shifts	3,227,457
Type of unit per shift — no. (%)	
Intensive care	459,054 (14.2)
Step-down care	682,607 (21.1)
General care	2,085,796 (64.6)
Type of service per shift — no. (%)	
Medical	1,392,404 (43.1)
Surgical	1,835,053 (56.9)
Patient turnover per shift — %	
Mean	0.09±0.15
Range	0–0.14
High-turnover shifts — no. (%)†	12,242 (6.9)

* Plus–minus values are means ±SD. In addition to the listed variables, for each patient, a dummy variable was created for each of the 29 coexisting conditions in the Elixhauser algorithm. The percentage of patients with each condition ranged from approximately 0% for peptic ulcer disease with bleeding and for the acquired immunodeficiency syndrome to 43% for hypertension. ICU denotes intensive care unit.

† This percentage is based on 176,696 shifts that were staffed on all units during the study.

Table 2. Levels of RN Staffing and Patient Turnover, According to Type of Unit and Shift.*

Variable	ICUs	Step-Down Units	General Care Units	All Units
Day shift				
No. of shifts	11,663	10,183	37,141	58,987
No. of target hours	92.6±41.1	76.4±25.9	56.3±21.9	67.0±31.1
No. of actual hours	89.0±35.6	72.2±23.7	54.6±20.5	64.4±28.3
Shifts with actual staffing level 8 hr or more below target (%)	13.7	20.4	15.6	16.1
Shifts with high turnover (%)	15.1	15.3	14.8	14.9
Evening shift				
No. of shifts	11,660	10,179	37,048	58,887
No. of target hours	90.7±43.2	73.3±26.3	54.5±23.3	64.9±32.3
No. of actual hours	88.5±37.7	70.1±23.7	51.4±20.3	62.0±29.3
Shifts with actual staffing level 8 hr or more below target (%)	14.8	21.5	19.7	19.0
Shifts with high turnover (%)	5.4	4.4	6.1	5.6
Night shift				
No. of shifts	11,650	10,172	37,000	58,822
No. of target hours	89.3±39.2	45.9±17.0	30.5±12.8	44.8±31.3
No. of actual hours	85.7±34.2	46.3±15.0	32.7±12.2	45.5±28.1
Shifts with actual staffing level 8 hr or more below target (%)	29.7	14.2	6.8	12.6
Shifts with high turnover (%)	0.1	<0.1	0.3	0.2
All shifts				
No. of shifts	34,973	30,534	111,189	176,696
No. of target hours	90.9±41.2	65.2±27.2	47.1±23.1	58.9±33.1
No. of actual hours	87.8±35.9	62.9±24.2	46.2±20.5	57.3±29.8
Shifts with actual staffing level 8 hr or more below target (%)	19.4	18.7	14.0	15.9
Shifts with high turnover (%)	6.9	6.6	7.0	6.9

* Plus–minus values are means ±SD. ICU denotes intensive care unit.

to shifts in an ICU, the estimates were similar to those for all patients, with higher hazard ratios when counts of below-target shifts were restricted to those during the first 5 days after admission. The results were similar for other sensitivity checks (i.e., restricting the sample to patients admitted to general units but including patients transferred to the ICU, restricting the sample to first admissions, and changing the sliding window to 30 shifts).

Exposure to high-turnover shifts was also significantly associated with an increased risk of death. For the analyses that included all hospital admissions and counted cumulative exposure during the first 30 days, the hazard ratio per high-turnover shift was 1.04 (95% CI, 1.02 to 1.06; P<0.001). When counts of high-turnover shifts were restricted to those in the first 5 days, the hazard ratio increased to 1.07 (95% CI, 1.03 to 1.10; P<0.001). A similar pattern was found in the sensitivity checks that considered patients with no admission to an ICU or that restricted the sample to first admissions and patients with initial admissions to general care units. The exception to this pattern occurred when exposure was specified as a time-varying rolling window of the previous six shifts, for which the hazard ratio was close to 1.0 and was not significant (Table 4).

ASSOCIATION BETWEEN OTHER VARIABLES AND MORTALITY

In the survival analysis, units were analyzed as fixed effects to account for any mortality-associated differences across units. Of the variables that were included in all analyses (Table 1), sex was the only variable that was not significantly associated with mortality in all four models. (De-

Table 3. Exposure of 197,961 Patients to Shifts with an Actual Staffing Level 8 Hours or More below Target and with a High Turnover of Patients, According to the Number of Shifts and Days after Admission.*

Number of Shifts	Exposure during First 30 Days after Admission		Exposure during First 5 Days after Admission	
	Below Staffing Target	High Patient Turnover	Below Staffing Target	High Patient Turnover
	number of patients (percent)			
0	63,145 (31.9)	78,533 (39.7)	67,915 (34.3)	88,905 (44.9)
1	39,033 (19.7)	63,781 (32.2)	42,337 (21.4)	68,464 (34.6)
2	27,082 (13.7)	30,669 (15.5)	29,533 (14.9)	28,631 (14.5)
3	18,168 (9.2)	12,335 (6.2)	19,651 (9.9)	8,496 (4.3)
4	12,143 (6.1)	5,761 (2.9)	12,958 (6.5)	2,541 (1.3)
5	8,419 (4.3)	2,771 (1.4)	8,788 (4.4)	700 (0.4)
6	6,118 (3.1)	1,682 (0.8)	5,985 (3.0)	176 (0.1)
7	4,635 (2.3)	930 (0.5)	4,068 (2.1)	38 (<0.1)
8	3,502 (1.8)	595 (0.3)	2,574 (1.3)	8 (<0.1)
9	2,702 (1.4)	303 (0.2)	1,730 (0.9)	2 (<0.1)
10–14	7,316 (3.7)	526 (0.3)	2,362 (1.2)	0
15–19	2,791 (1.4)	71 (<0.1)	60 (<0.1)	0
20–24	1,333 (0.7)	4 (<0.1)	NA	NA
25–29	763 (0.4)	0	NA	NA
30 or more	811 (0.4)	0	NA	NA

* NA denotes not applicable.

tails are provided in the Supplementary Appendix.) The patient census at the beginning of the shift, target staffing, and the cumulative number of shifts in an ICU were significantly associated with mortality in all four models. However, the exclusion of these variables did not substantively change the hazard ratios, which reinforces the robustness of the findings of an association between an increased risk of death and below-target staffing and high patient turnover. Results were similar when the sample was restricted to first admissions for patients with multiple hospitalizations.

DISCUSSION

In an institution with a history of success in meeting staffing levels and with a level of patient mortality that was substantially below that predicted by its case mix, we found that the risk of death increased with increasing exposure to shifts in which RN hours were 8 hours or more below target staffing levels or there was high turnover. We estimate that the risk of death increased by 2% for each below-target shift and 4% for each high-turnover shift to which a patient was exposed. In our analyses, we addressed many of the criticisms of previous research, since our findings were adjusted for many patient-specific and unit-specific factors associated with mortality and included direct measurement of individual patients' exposure to staffing levels.

For hospitals that generally succeed in maintaining RN staffing levels that are consistent with each patient's requirements for nursing care, this study underscores the importance of flexible staffing practices that consistently match staffing to need throughout each patient's stay. For hospitals that do not maintain nurse staffing levels consistent with each patient's nursing care requirements, our findings underscore the need to use systems for tracking such requirements and the patient census and to implement practices that improve the match between staffing and patients' needs. Our findings suggest that nurse staffing models that facilitate shift-to-shift decisions on the basis of an alignment of staffing with patients' needs and the census are an important component of the delivery of care.

We also found that the risk of death among patients increased with increasing exposure to shifts with high turnover of patients. Staffing

Table 4. Risk of Death Associated with Exposure to a Shift with an Actual RN Staffing Level 8 Hours or More below Target, High Patient Turnover, and Other Variables.*

Variable	Hazard Ratio (95% CI)	P Value
Total of 197,961 patients		
Each shift with RN staffing level below target or high turnover during first 30 days after admission		
Shift with RN staffing level 8 hr or more below target	1.02 (1.01–1.03)	<0.001
Shift with high patient turnover	1.04 (1.02–1.06)	<0.001
Each shift with RN staffing level below target or high turnover during first 5 days after admission		
Shift with RN staffing level 8 hr or more below target	1.03 (1.02–1.05)	<0.001
Shift with high patient turnover	1.07 (1.03–1.10)	<0.001
Each shift with RN staffing level below target or high turnover during the previous six shifts		
Shift with RN staffing level 8 hr or more below target	1.05 (1.02–1.07)	0.001
Shift with high patient turnover	0.98 (0.93–1.04)	0.55
Total of 171,041 patients with no shifts in an ICU		
Each shift with RN staffing level below target or high turnover during first 30 days after admission		
Shift with RN staffing level 8 hr or more below target	1.04 (1.03–1.06)	<0.001
Shift with high patient turnover	1.07 (1.02–1.13)	0.006
Each shift with RN staffing level below target or high turnover during first 5 days after admission		
Shift with RN staffing level 8 hr or more below target	1.12 (1.08–1.16)	<0.001
Shift with high patient turnover	1.15 (1.07–1.24)	0.001

* Listed are results from four separate Cox proportional-hazard regressions for mortality within the first 90 shifts (approximately 30 days) after admission. All regressions include 197,961 patients and 3,227,457 unique observations of patient unit-shifts. Descriptions of regression models specify the measure of understaffing included in the analysis. All regressions include measures of patients' age, sex, local residence or referral, type of payer, type of admission, rate of death as predicted by AHRQ national inpatient data for the modified diagnosis-related group, 29 coexisting conditions included in the Elixhauser algorithm, type of current unit (intensive care, general, or step-down), medical or surgical service of current unit, dummy variable for the unit of initial admission, target RN hours for current shift, unit census, and number of shifts in an intensive care unit (ICU).

projection models rarely account for the effect on workload of admissions, discharges, and transfers. Our results suggest that both target and actual staffing should be adjusted to account for the effect of turnover. In light of the potential importance of turnover on patient outcomes, research is needed to improve the management of turnover and institute workflows that mitigate the effect of this fluctuation.[28]

Our study has several limitations. As in any observational study, confounding is a concern. We did not explicitly include information on care delivery models, the availability of staff members aside from RNs, or differences in physical characteristics of units, although the inclusion of unit fixed effects implicitly controlled for many of these differences. Although we studied the risk of death through the first 90 shifts (approximately 30 days) after admission, we did not study factors influencing mortality after this time or outside the hospital. Our data did not allow us to identify patients who had do-not-resuscitate orders, a factor that influences the interpretation of overall mortality and may influence staffing decisions. Additional research is needed to understand the complex interplay among nurse staffing, patient preferences, and other factors, including staffing levels for physicians and other non-nursing personnel, technology, work processes, and clinical outcomes.

Efforts to reform the delivery and financing of health care, including new payment mechanisms designed to increase accountability and efficiency and to bundle services,[29] mean that the costs and outcomes of nursing care will be under increasing scrutiny in the years ahead. Our finding that below-target nurse staffing and high patient turnover are independently associated with the risk of death among patients suggests that hospitals, payers, and those concerned with the quality of care should pay increased attention to assessing the frequency with which actual staffing matches patients' needs for nursing care. The results of our study can be used to shift the national dialogue from questions about whether nurse staffing levels have a significant effect on patient outcomes to a focus on how current and emerging payment systems can reward hospitals' efforts to ensure adequate staffing. In addition, providing sufficient resources to ensure that staffing is adequate and paying close attention to patient transfers and other factors that have a major effect on workload should become an active part of daily conversations among nurses, physicians, and hospital leaders in planning for the care of their patients.

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