ORIGINAL ARTICLE

Quantifying Interhospital Patient Sharing as a Mechanism for Infectious Disease Spread

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BACKGROUND. Assessments of infectious disease spread in hospitals seldom account for interfacility patient sharing. This is particularly important for pathogens with prolonged incubation periods or carrier states.

METHODS. We quantified patient sharing among all 32 hospitals in Orange County (OC), California, using hospital discharge data. Same-day transfers between hospitals were considered "direct" transfers, and events in which patients were shared between hospitals after an intervening stay at home or elsewhere were considered "indirect" patient-sharing events. We assessed the frequency of readmissions to another OC hospital within various time points from discharge and examined interhospital sharing of patients with *Clostridium difficile* infection.

RESULTS. In 2005, OC hospitals had 319,918 admissions. Twenty-nine percent of patients were admitted at least twice, with a median interval between discharge and readmission of 53 days. Of the patients with 2 or more admissions, 75% were admitted to more than 1 hospital. Ninety-four percent of interhospital patient sharing occurred indirectly. When we used 10 shared patients as a measure of potential interhospital exposure, 6 (19%) of 32 hospitals "exposed" more than 50% of all OC hospitals within 6 months, and 17 (53%) exposed more than 50% within 12 months. Hospitals shared 1 or more patient with a median of 28 other hospitals. When we evaluated patients with *C. difficile* infection, 25% were readmitted within 12 weeks; 41% were readmitted to different hospitals, and less than 30% of these readmissions were direct transfers.

CONCLUSIONS. In a large metropolitan county, interhospital patient sharing was a potential avenue for transmission of infectious agents. Indirect sharing with an intervening stay at home or elsewhere composed the bulk of potential exposures and occurred unbeknownst to hospitals.

Infect Control Hosp Epidemiol 2010; 31(11):1160-1169

Hospitals are reservoirs for infectious diseases, because patients are admitted with infections and because hospitalized patients are more susceptible to acquiring infections. Patients may acquire an infectious disease in one hospital and then transmit the disease to others when hospitalized in another facility. Several examples of multiple-hospital and regional outbreaks exist,[1-4] as do examples of successful regional control efforts.[1,3] Mathematical models of infectious diseases also involve assumptions related to interhospital transmission.[5,6] As national efforts seek to reduce healthcare-associated infections, it is important to ascertain whether interhospital patient sharing is an important avenue for the spread of transmissible pathogens. Understanding patterns of hospital transfer and readmission to the same or different facilities can inform continuity of care, quantify the role that direct communication between facilities may have on the risk of disease spread, and improve public health strategies in response to hospital outbreaks.

Little is known about interfacility patient sharing. To our knowledge, no studies have tracked the movements of pa-

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 0899-823X/2010/3111-0010$15.00. DOI: 10.1086/656747
Received February 14, 2010; accepted May 21, 2010; electronically published September 28, 2010.

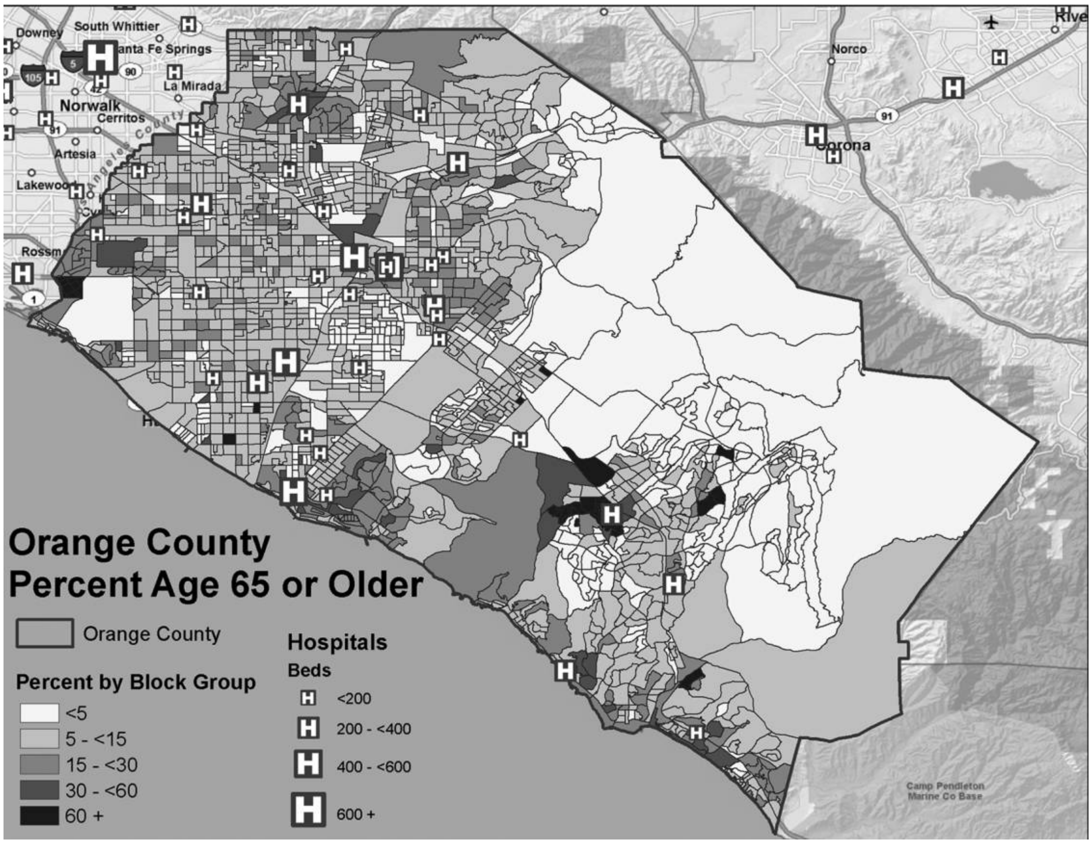

FIGURE 1. Map depicting size and location of Orange County hospitals on background of the fraction of block group residents aged more than 65 years, based on 2007 US Census data.

tients from facility to facility over time. Although physicians admitting patients may discover that a patient has been recently hospitalized, relevant dates and locations are subject to patient recall and desire to inform. In addition, even if patients report recent hospitalizations, these data are not reliably captured or stored.

There is reason to believe that interfacility patient sharing in the United States may be substantial. With increasing capitation of hospitalization fees, there is a strong financial pressure to reduce the length of the hospital stay. Repeated hospitalization may be more common as complex medical care becomes increasingly delivered through home health, rehabilitation centers, and skilled nursing facilities.

In addition, although the structure of healthcare in some European nations requires patients to seek medical care in an assigned local hospital, the US healthcare system allows hospitalization location to be influenced by choice. Other factors that influence hospital selection may include location at time of illness, ambulance instructions to avoid hospitals at maximum capacity, changes in health coverage, allegiance to medical providers who change hospitals, and private payer reimbursement alliances that favor delivery of care in select hospitals.

We evaluated the frequency of repeated hospitalizations and the degree to which patients are shared across multiple facilities in a large California county of approximately 3 million people. We also examined interfacility sharing among patients with *Clostridium difficile* infection as an example of the potential role of patient sharing in spreading contagious pathogens.

METHODS

We performed a retrospective cohort study of all patients hospitalized in any of 32 hospitals in Orange County (OC), California, in 2005, and we evaluated their risk for readmission within the 365 days after discharge. We used a mandatory hospital discharge dataset from the California Office of Statewide Health Planning and Development comprising line-item hospitalization data from every acute care facility in the county. Data included hospitalization dates; demographic information; residential zip code; diagnostic and procedure codes from *The International Classification of Diseases, Ninth Revision (ICD-9);* location category before and after admission (eg, home, rehabilitation center, nursing home, assisted living facility, or jail or homeless status); and an irreversibly encrypted identifier based on Social Security number that enables the tracking of patients across different hospitals (rec-

TABLE 1. Characteristics of Orange County Admissions with Unique Identifier, 2005

Characteristic	All admissions countywide (n = 238,505)	Adult admissions (n = 228,754)	Pediatric admissions (n = 9,751)	Patients with 1 admission (n = 123,470)	Patients with ≥2 admissions (n = 49,473)	P [a]
Age, years, median	55	58	8	48	66	<.001
Male sex	39	39	50	34	44	<.001
Race						<.001
White	79	79	79	77	82	
Black	3	3	4	2	3	
Asian	10	10	9	11	8	
Other	7	7	7	8	6	
Unknown	1	1	0.4	1	1	
Hispanic ethnicity	17	16	45	19	15	<.001
Length of hospital stay, days, mean	5.7	5.7	5.7	4.7	7.1	<.001
Insurer type						<.001
Medicare	39	41	0.2	26	52	
Medicaid	13	11	51	14	11	
Private coverage	41	41	44	52	31	
Location prior to admission						<.001
Home	90	90	91	95	93	
Other acute care hospital	5	5	3	2	2	
Skilled nursing facility	2	2	0.04	1	2	
Residential care	1	1	0.1	1	2	
Location or status after discharge						<.001
Home	71	70	95	83	61	
Acute care transfer	2	2	2	1	5	
Skilled nursing facility	10	10	0.3	5	12	
Residential care	1	1	0.3	1	2	
Died	2	2	0.3	2	0.01	
Home health service	9	9	2	6	10	
Comorbidities						
Diabetes	18	18	2	11	22	<.001
Renal disease	3	3	1	1	4	<.001
Liver disease	2	2	0.4	1	3	<.001
Solid cancer	8	8	5	5	10	<.001
AIDS	0.2	0.2	0.03	0.1	0.2	<.001
Surgical procedure[b]	30	30	21	37	28	<.001

NOTE. Data are percentage of admissions, unless otherwise indicated.
[a] Comparison of characteristics between patients with 1 versus ≥2 admissions.
[b] On the basis of *The International Classification of Diseases, Ninth Revision,* procedure codes.

ord linking number [RLN]). This study was approved by the institutional review boards of the University of California Regents and the California Health and Human Services Agency.

OC was the fifth most populated US county in the 2000 census. It encompasses 790 square miles (approximately 2046 km^2) of land and has a population of approximately 3 million people. Its geographic isolation on 3 sides—the ocean on the west, forest to the east, and miles of undeveloped land to the south—makes it a good candidate for assessing patient sharing within a region. Traffic is a significant barrier to driving north into Los Angeles County for routine healthcare. In addition, it is racially and ethnically diverse (48% non-Hispanic white, 34% Hispanic white, 16% Asian, 2% black, and 15% other persons). There is broad economic diversity across the county, with 10% of the population falling below the poverty line.

Orange County has 32 hospitals, including 1 academic medical center and 3 dedicated children's hospitals. Six of the acute care facilities are long-term acute care (LTAC) facilities that provide hospital-level medical care to those requiring long-term hospitalization, such as patients undergoing long-term ventilation. One LTAC facility provides pediatric care.

For descriptive purposes, we calculated hospital-level characteristics on the basis of the proportion of hospitalized patients with selected characteristics. Patient characteristics were summarized for all patients admitted in 2005 countywide. Characteristics were compared between unique patients experiencing 1 admission in 2005 and those experiencing more

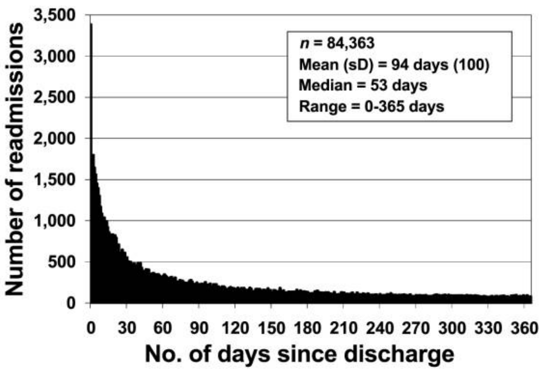

FIGURE 2. Time in days to next admission for Orange County patients hospitalized in 2005 who are readmitted within 365 days from discharge. Other than direct transfers, all readmissions, including readmission to the same facility, are included. SD, standard deviation.

than 1 admission within 365 days after discharge using the χ^2 test for categorical variables and the Student *t* test for continuous variables. The interval (in days) between sequential admissions occurring in 2005 was also evaluated.

Among patients with multiple admissions to OC hospitals, readmissions were categorized as direct transfers or indirect patient-sharing events with respect to prior admission locations. Direct transfers occurred when one hospital transferred a patient directly to another hospital. This was identified when a unique patient (ie, with the same RLN) was discharged from one hospital within 1 calendar day of admission to another hospital. The discharging location was required to specify that an acute care hospital transfer was arranged. If a patient went home or to any other nonhospital location (eg, to a nursing home, rehabilitation center, or assisted living center) before being readmitted, then the readmission was considered an indirect patient-sharing event from that facility to each subsequent hospital where that patient was admitted. This directional assessment was intended to assess the potential risk of transferring contagious pathogens from one facility to another. Counts of direct transfers and indirect patient-sharing events within 365, 84, 30, and 14 days after discharge were assessed for all pairs of facilities.

In addition, we evaluated patient sharing within 84 days (12 weeks), 30 days, and 14 days after discharge using the example of patients hospitalized with *C. difficile* infection (*ICD-9* code 008.45 within the first 3 diagnostic positions). The choice of 12 weeks for *C. difficile* infection reflects the epidemiology that relapse, recurrence, and infectious shedding are common during that time frame.[7]

Finally, to assess the speed at which any OC hospital shared patients, directly or indirectly, with other OC facilities, we evaluated the amount of time required for each facility to share a threshold number of patients with a cumulative percentage of all OC hospitals. We specifically evaluated thresholds of 10 and 50 patients to assess the potential for spread of infectious diseases through patient sharing. Thresholds were selected to reflect the estimated discharge prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) carriage (approximately 10%)[8-11] and *C. difficile* infection (approximately 2%)[7,12,13] in US hospitals. In addition, we assessed the speed at which any OC hospital discharged patients to OC zip codes. This was also assessed using thresholds of 10 and 50 patients.

RESULTS

Among the 32 OC hospitals (including LTAC facilities), the median number of licensed beds was 178 (hospital range, 24–453). The median number of annual admissions was 985 (range, 47–4,591) among LTAC facilities and 10,766 (hospital range, 2,173–29,737) among all other acute care hospitals. Among hospitals, the percentage of admissions for nonwhite persons ranged from 7% to 85%, and the percentage of admissions for Medicaid-insured persons ranged from 2% to 66%. Hospital locations are shown in Figure 1.

In 2005, there were a total of 319,918 admissions in OC hospitals after 971 (less than 1%) admissions with implausible admission and discharge dates were removed (eg, because of a discharge date before the admission date). This included 249,495 admissions for adults (78%) and 70,423 pediatric admissions (22%). Among all hospitalizations, 238,505 patients (75%) had an RLN, including 92% of adult patients and 14% of pediatric patients. Reasons for the lack of an RLN were not available. However, among the 81,413 patients without an RLN, 51,539 (63%) were less than 6 months of age. Of the remainder, 16,616 (56%) were insured by Medicaid, and 38 (less than 1%) were homeless. Characteristics of countywide hospitalizations with an RLN are provided in Table 1.

Among the 172,943 unique patients with an RLN who were hospitalized in 2005, 49,473 (29%) had multiple admissions within 365 days. Fourteen percent of patients had 2 admissions, 4% had 3 admissions, and 2% had 4 admissions. Characteristics of patients with 1 versus 2 or more admissions are also provided in Table 1. Patients admitted multiple times were more likely to be older, to be insured via Medicare, to reside in a nursing home, and to have comorbidities. Among those who were readmitted within 365 days after discharge, the interval (in days) to the next admission is shown in Figure 2. More than one-third (39%) of all readmissions occurred within 1 month after discharge (median interval, 53 days). A total of 3,372 (4%) of all hospital readmissions occurred on the exact same day as discharge. Direct transfers were not included as readmissions.

When provided as a proportion of annual admissions at each of the 32 OC hospitals, a median of 19% (range, 2%–49%) of annual admissions involved patients who were eventually admitted to another OC facility within 365 days after discharge. This was slightly higher for LTAC hospitals (median, 34%; range, 17%–49%) than for all other acute care hospitals (median, 18%; range, 3%–43%). The number of

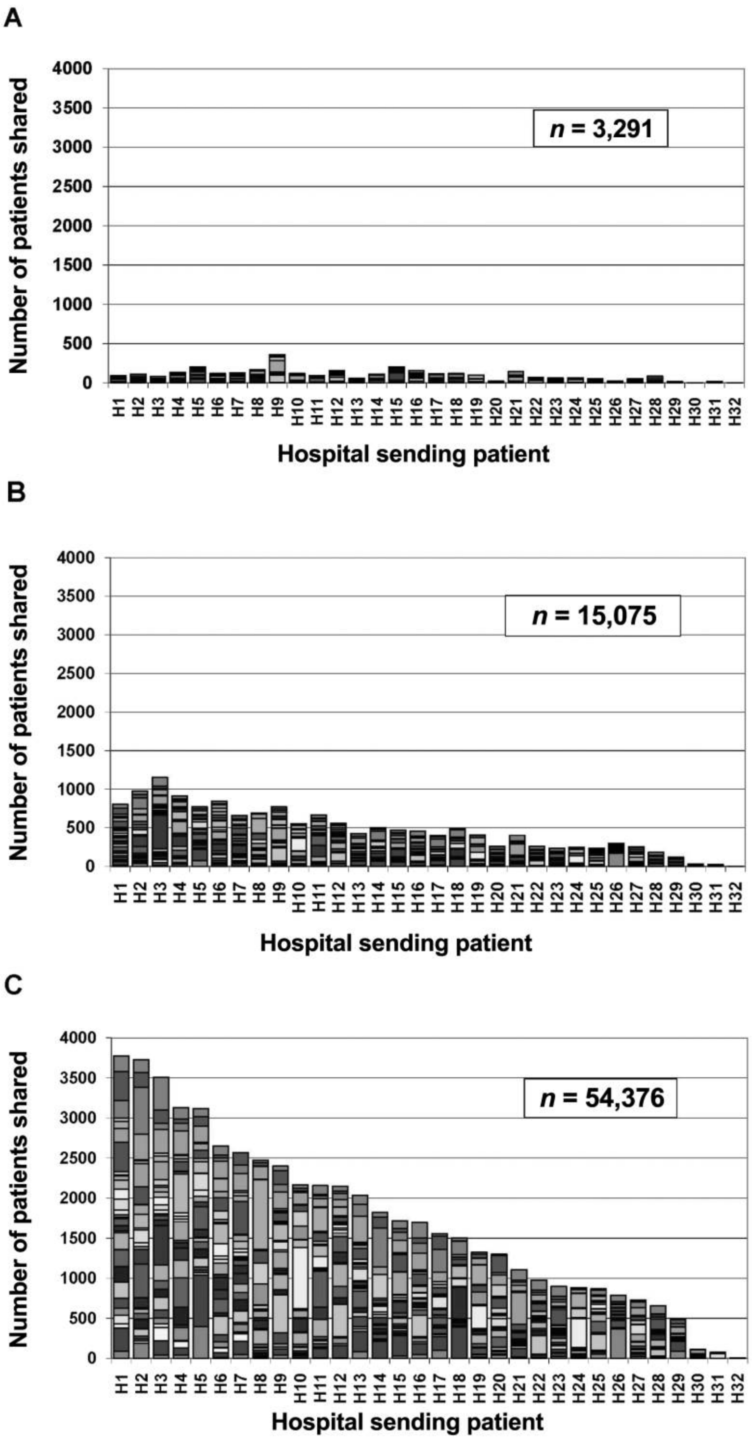

FIGURE 3. Comparison of interfacility patient sharing when evaluating direct patient transfers (*A*) versus both direct transfers and indirect patient sharing events within 30 days (*B*) and 365 days (*C*) after discharge from a 2005 admission to an Orange County hospital. Bar graphs depict volume of patients shared between one hospital (*x* axis) and all other Orange County hospitals. Each hospital (H) is assigned a unique color (see online color version). Direct transfers refer to patients transferred directly from one hospital to another within one calendar day, while the combination of direct transfers and indirect patient sharing events include patient sharing between institutions despite an intervening stay at home or at another nonhospital facility. Graphs do not include readmissions to the same facility.

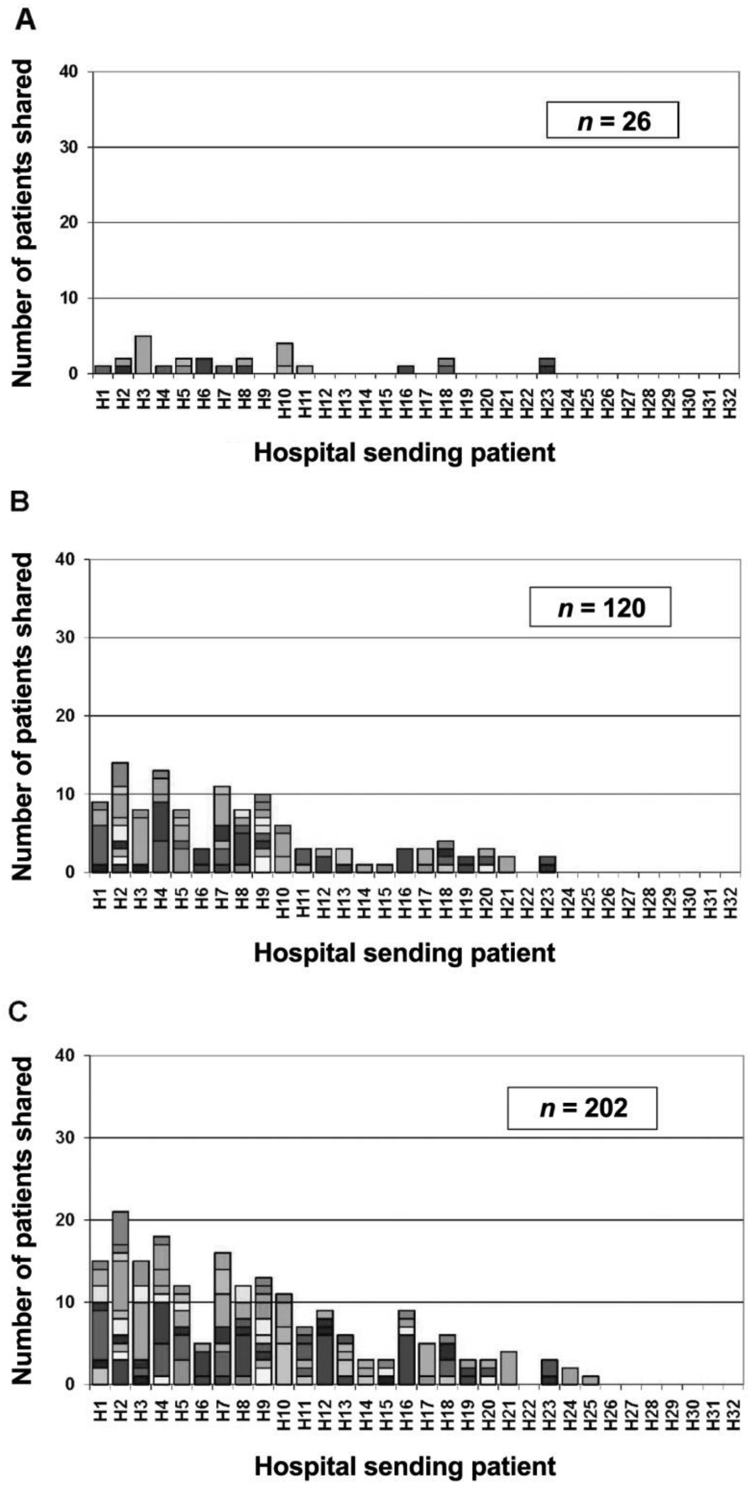

FIGURE 4. Comparison of interfacility sharing of patients with *Clostridium difficile* infection within 12 weeks after hospitalization. Figure shows direct patient transfers (*A*), as well as direct transfers and indirect patient sharing events within 30 days (*B*) and 12 weeks (84 days; *C*) after discharge from a 2005 admission with *C. difficile* infection. Bar graphs depict volume of patients shared between one hospital (*x* axis) and all other Orange County hospitals. Each hospital (H) is assigned a unique color (see the color version, which appears only in the electronic version of the journal). Direct transfers refer to patients transferred directly from one hospital to another within 1 calendar day, while the combination of direct transfers and indirect patient sharing events include patient sharing between institutions despite an intervening stay at home or at another non-hospital facility. Graphs do not include readmissions to the same facility.

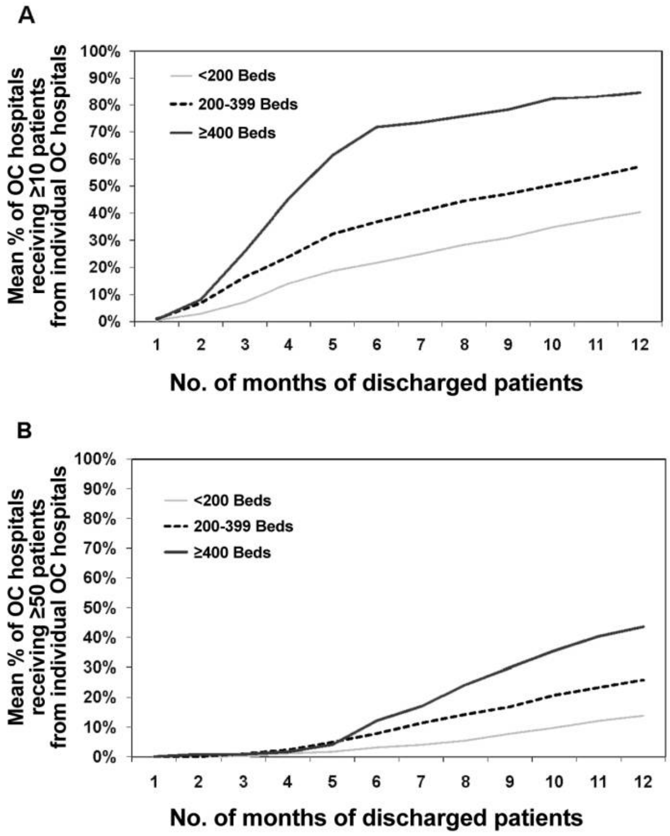

FIGURE 5. Mean percent of Orange County (OC) hospitals receiving a threshold of 10 patients (*A*) and 50 patients (*B*) from individual OC hospitals. Patient sharing is defined as both direct transfers and indirect patient sharing events in 2005. Lines are stratified by the bed sizes of sending hospitals.

admissions seen elsewhere varied with hospital size. Larger hospitals (ie, those with 200 or more beds) shared a median of 14% of admissions (range, 3%–28%) with other OC hospitals, compared with 24% (range, 7%–49%) of admissions at smaller hospitals (ie, those with less than 200 beds).

Interfacility patient sharing was common. Among readmissions within 365 days after discharge, the very next admission was to the same hospital 69% of the time and was to another hospital in the county 31% of the time. Overall, 75% of patients with multiple admissions were admitted to more than 1 hospital. Hospitals shared 1 or more patient with a median of 28 other hospitals.

When excluding readmissions to the same facility, there were 54,376 interhospital patient-sharing events within 365 days after discharge. Only 3,291 (6%) were direct transfers between hospital facilities, suggesting that indirect patient sharing accounted for 16 times the amount of direct transfers within 1 year after discharge (Figure 3). For 66% of OC hospitals, the hospital with which they received the most direct transfers was not the same hospital with which they received the most patients, when direct transfers plus indirect patient-sharing events were considered. In 22% of hospitals, the top 3 hospitals, as ranked by direct transfers, were different from all of the top 3 hospitals based on direct-plus-indirect patient sharing. Among interhospital patient-sharing events occurring within 365 days after discharge, 24,261 events (45%) occurred within 84 days (12 weeks) after discharge, 15,075 (28%) occurred within 30 days after discharge, and 11,184 (21%) occurred within 14 days after discharge.

As an example of interhospital sharing of patients harboring infectious diseases, we identified 1,102 admissions (among 907 patients) with *C. difficile* infection in OC hospitals (only the first 3 *ICD-9* diagnoses were used; 47% were the primary diagnoses). Readmissions (for any reason) occurred among 49% of patients within 12 weeks after discharge. The very next admission was to the same hospital 74% of the time and to another hospital in the county 26% of the time. When we excluded readmissions to the same facility, there were 202 interhospital patient-sharing events within 12 weeks after discharge. Only 26 (6%) were direct transfers, suggesting that the majority of shared patients with *C. difficile* infection were associated with indirect patient-sharing events (Figure 4). Among the 202 interhospital patient-sharing events, 120 (59%) occurred within 30 days after discharge, and 87 (43%) occurred within 14 days after discharge.

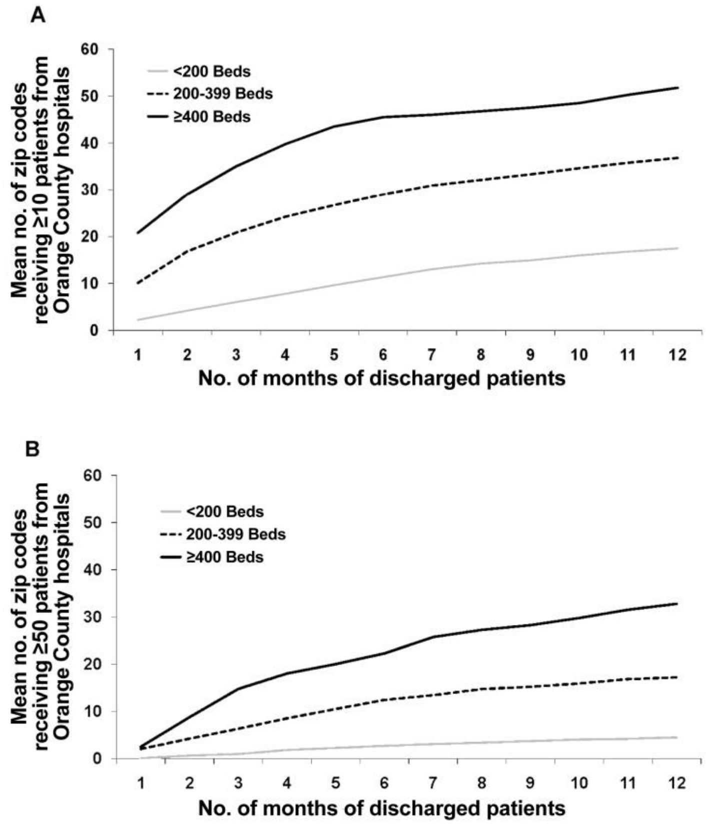

FIGURE 6. Mean number of Orange County zip codes receiving a threshold of 10 patients (*A*) and 50 patients (*B*) from each of 32 Orange County hospitals. Lines are stratified by the bed sizes of sending hospitals.

When quantifying the rate at which patient sharing occurred, we found that 6 OC hospitals (19%) sent 10 or more patients to one-half of all OC hospitals within 6 months, 12 hospitals (38%) did so within 9 months, and 17 hospitals (53%) did so within 12 months (Figure 5*A*). When the threshold was increased to 50 patients, only 1 hospital transferred 50 patients to one-half of OC hospitals within 365 days. Nevertheless, 20 hospitals (65%) transferred 50 patients to 5 or more other OC hospitals within 12 months (Figure 5*B*).

Similarly, when quantifying the speed at which patients were discharged to the various 148 OC zip codes, we found that 15 OC hospitals (47%) sent 10 or more patients to 20 OC zip codes within 6 months, 19 hospitals (59%) did so within 9 months, and 21 hospitals (66%) did so within 12 months (Figure 6*A*). When the threshold was increased to 50 patients, the fraction of hospitals transferring 50 or more patients to 20 OC zip codes was 3 (9%) within 6 months, 5 (16%) within 9 months, and 7 (22%) within 12 months (Figure 6*C*).

DISCUSSION

To our knowledge, this is the first in-depth study of interhospital patient sharing across an entire county. Nearly all hospitals shared large numbers of patients with other facilities without knowing it. In fact, more than 90% of patient sharing occurred indirectly, with patients being discharged from one facility and sent home or to other nonhospital facilities before being readmitted.

Surprisingly, this high degree of patient sharing was not limited to large or academic hospitals but was seen across all types of hospitals. This suggests that not all patient sharing is referral based. Although the reasons for extensive patient sharing were not studied, there are several possible additional causes. Patients may be exercising their freedom to choose different facilities and physicians. Some may be constrained by changes to or loss of health insurance. In addition, hospital choice may be affected by a patient's current location when immediate medical care is needed. We found that nearly 75% of readmitted patients sought care in more than 1 hospital.

This previously unreported degree of patient sharing has important implications for handling the potential spread of infectious diseases among acute care facilities. Patient sharing could be an important avenue of transmission for major outbreaks of disease,[1-4] including *C. difficile* infection,[14,15] and persistently harbored pathogens, such as MRSA or vancomycin-resistant enterococci.[1]

Among shared patients, the fact that so few are transferred directly from one hospital to the next magnifies the risk that infectious agents can be transmitted between hospitals without interfacility disclosure. Thus, even perfect compliance with customary hospital-to-hospital disclosure, such as relaying the MRSA or vancomycin-resistant enterococci status of a transferring patient, is unlikely to have a large impact in containing these organisms. This supports either the need for a highly protected—but universally accessible—electronic medical record or the need for patients to be educated and empowered to be effective owners of their medical history.

We emphasize not only the magnitude of patient sharing but the rate at which patients were shared across hospitals within a large county. The bulk of repeated hospitalizations occurred within 2 months after discharge. This rapid readmission rate leaves considerable room for interhospital transmission of pathogens, including those with incubation periods of days to weeks, such as *C. difficile,* for which 49% of patients hospitalized with *C. difficile* infection were readmitted for any reason within 12 weeks.

This research has practical applications in states where mandatory hospital reporting enables a routine and comprehensive assessment of the facilities where patients seek inpatient medical care. Although there is no expectation that patient behavior will change with regard to seeking care in multiple hospitals, knowledge of patient-sharing patterns has the potential to impact public health response.[3] In the event of a major public health problem, being aware of which hospitals share the most patients with other hospitals can guide decisions on whom to alert and where to intervene first. This may be particularly useful in pandemic planning, including table-top drills simulating regional response to highly contagious organisms.

There are several limitations to this study. First, numbers reported are likely underestimates of the actual amount of patient sharing. Only patients who reported their Social Security numbers to the state could be tracked between institutions. Although the majority of patients who lacked Social Security numbers were children aged less than 6 months, the lack of data on 10% of older children and adults likely led to an underestimation of interhospital patient sharing. Also, this study did not include the interaction of hospitals with skilled nursing homes, psychiatric hospitals, or rehabilitation facilities.

Second, these findings may not be generalizable to other regions due to different healthcare systems. Counties with a single dominant healthcare system comprising multiple facilities may share much more among the facilities within its system. Facilities in sparsely populated areas may have relatively little sharing. Facilities in very densely populated areas with numerous facilities may have extensive sharing. Patient options and choice will be affected by the proximity of local and regional hospitals and by economic constraints that limit access to care. Additional studies are needed to confirm whether these results are typical of large urban counties.

Third, these findings are subject to interpretation in the context of specific infectious disease agents. The impact of patient sharing on spread of contagion will be heavily dependent on pathogen and host factors, including incubation period, presence of a carrier state, susceptibility of the patient population, and the transmissibility of the agent in question.

Finally, this study raises several additional questions that we did not attempt to address. The high frequency of readmission coupled with the fact that patients seek inpatient care in a variety of hospitals raises questions about the continuity of medical care when it is delivered across disparate hospitals. The high rate of readmission during the first 2 months after discharge, compared with subsequent months, raises necessary questions about the quality of posthospitalization medical care, the stability of patients at discharge in an era of reduced hospital-length-of-stay, or both.

In conclusion, we show that the patient populations of all 32 hospitals in a single metropolitan county heavily overlap with one another. Specifically, patients are shared frequently and in high numbers. This has important implications for the spread and containment of infectious diseases and should be evaluated further as a mechanism for epidemic and endemic spread of pathogens.

ACKNOWLEDGMENTS

Financial support. The Models of Infectious Disease Agent Study (MIDAS) consortium grants U01 GM76672 (to R.P.), U01GM070708 (to D.S.B.), U01 GM070698 (to D. Wagener, Research Triangle Institute), U01 GM076499 (to R.M.B.), U01GM076497 (to M.L.), and U01GM070694 (to S.E.) from the National Institutes of Health and research funds from the University of California Irvine. R.P. has received research grants from Sanofi-Aventis, GlaxoSmithKline, Pfizer, and TAP Pharmaceuticals in the past 2 years.

Potential conflicts of interest. M.L. has received consulting income and/or honoraria from Novartis and Pfizer and has had research funded by Roche. All other authors report no conflicts of interest relevant to this article.

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