

Michigan *Clostridium difficile* Hospital Discharges: Frequency, Mortality, and Charges, 2002–2008

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ABSTRACT

Objective. *Clostridium difficile* (*C. difficile*) causes an intestinal bacterial infection of increasing importance in Michigan residents and health-care facilities. The specific burden and health-care costs of *C. difficile* infection (CDI) were previously unknown. We evaluated the frequency, mortality, and health-care charges of CDI from Michigan hospital discharge data.

Methods. The Michigan Department of Community Health purchased discharge data from all Michigan acute care hospitals from the Michigan Health and Hospital Association. We extracted all hospital discharges from 2002 through 2008 containing the International Classification of Diseases, Ninth Revision code for intestinal infection due to *C. difficile*. Discharges were stratified by principle diagnosis and comorbidity level. Total hospitalization charges were standardized to the 2008 U.S. dollar.

Results. From 2002 through 2008, 68,686 hospital discharges with CDI occurred. The annual rate increased from 463.1 to 1096.5 CDI discharges per 100,000 discharges. CDI discharge rates were substantially higher among the elderly, females, and black people. Of all CDI discharges, 5,924 (8.6%) patients died. The mean total health-care charge for the time period was \$67,149, and the annual mean increased 35% from 2002 to 2008. Hospital charges varied significantly by race/ethnicity and age. People with Medicaid insurance accrued the highest charges.

Conclusion. Across Michigan, the CDI burden is growing substantially and affecting vulnerable populations. Surveillance utilizing hospital discharge data can illuminate trends and inform intervention targets. To reduce disease and health-care charges, increased prevention and infection-control efforts should be directed toward high-risk populations, such as the elderly.

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Clostridium difficile (*C. difficile*) causes an intestinal bacterial infection of increasing importance in Michigan hospitalized patients and health-care facilities. Patients may carry *C. difficile* asymptotically or experience infection symptoms ranging from mild diarrhea to more severe manifestations, including pseudomembranous colitis, toxic megacolon, sepsis, and even death.^{1,2} *C. difficile* is an anaerobic, toxin-producing, spore-forming bacillus found in the health-care environment³ and in the intestinal tracts of 7% of inpatients and 31% of inpatients on antibiotics.^{4,5} The bacterium may overwhelm the intestinal tract, causing disease in the absence of normal flora.^{6,7} Broad-spectrum antibiotic use may facilitate conditions for this overgrowth.^{6,8} Principle *C. difficile* infection (CDI) includes patients hospitalized primarily for CDI, while non-principle CDI includes patients hospitalized for other diagnoses who were also diagnosed or treated for CDI.^{7,9,10} The clinical presentations may not differ between non-principle and principle CDI. Risk factors for CDI include prolonged hospitalization, comorbidity, recent antibiotic use, and advanced age.^{4,11,12} The elderly experience the largest burden of disease.¹¹ Hospitalization is a key risk factor, as it can affect both *C. difficile* infection and colonization.^{4,12} The emergence of a new hypervirulent strain in 2002, B1/NAP1, has also changed the epidemiology of infection.^{13–16} B1/NAP1 is increasingly more prevalent in long-term care facilities¹⁷ and community settings.^{18,19}

CDI is the leading cause of infectious diarrhea in hospitals within developed countries^{4,20} and is the most common identifiable cause of antimicrobial drug-associated diarrhea found in the U.S.⁹ CDI has been associated with greater length of stay, rehospitalization, and additional health-care expenditures.^{21–25} Nationally, studies have estimated total CDI costs between \$1.1 billion and \$3.2 billion annually.^{10,22} Individual cases of CDI contribute an additional cost of \$2,871 to \$13,675 per hospitalization.^{10,25} The burden of disease and health-care charges associated with Michigan inpatients discharged with CDI had not been previously explored. Presently, approximately half of U.S. states have legislation for public reporting of health-care-associated infections. Of these states, only two mandate *C. difficile* reporting. Without mandatory national- or state-legislated reporting requirements, Michigan's CDI burden was previously estimated from national data, which showed increasing rates of CDI.^{26–29} The objectives of this study were to (1) characterize the frequency of CDI discharges among Michigan residents; (2) assess mortality, length of stay, and distribution of disease; and (3) analyze charges among Michigan acute care hospital CDI discharges.

METHODS

Data for *C. difficile* infections

The Michigan Health and Hospital Association (MHA) collects and maintains hospital discharge data from all Michigan acute care hospitals. The Michigan Department of Community Health (MDCH) annually purchases these data from MHA. We compiled and analyzed discharge data from 193 Michigan hospitals from January 1, 2002, through December 31, 2008. Non-Michigan residents were excluded from analysis. A subset of CDI discharges were identified; to classify CDI discharges, all records that contained the International Classification of Diseases, Ninth Revision (ICD-9) code 008.45, "Intestinal infection due to *Clostridium difficile*," were included. Each discharge event included up to 30 ICD-9 diagnosis codes. Multiple hospital admissions per year are possible; therefore, we defined the unit of analysis as a hospital CDI discharge rather than an individual patient.

Race/ethnicity was determined through self-assignment, documentation, and, for some discharges, imputation. Race/ethnicity may have been self-identified or assessed by the hospital staff and classified at patient admission. Racial/ethnic categories included white, black, Native American (including American Indian/Alaska Native), Asian, Hispanic, or other. Race/ethnicity was unknown for approximately 25% of discharges. In these instances, MDCH linked the discharge database with the Michigan Birth Registry or Michigan Death Registry, or matched multiple admissions by the same patient (identified by hospital, medical record number, ZIP code, date of birth, and gender). For approximately 13% of cases, race/ethnicity was still unknown after matching and, therefore, was imputed according to the proportion of known race/ethnicity data among discharges in the dataset by age, gender, and ZIP code. We analyzed race/ethnicity to assess any potential disparities in disease rate, mortality, or charge.

Total charges were voluntarily reported by hospitals. These total charges differed from hospital costs, as they were not adjusted with the cost-to-charge ratio. Total charges also did not account for reimbursements from the Centers for Medicare and Medicaid Services. Additionally, charges did not include doctors' fees or costs experienced by the patient, such as deductibles or copayments. Total charge was reported for 49,516 (72.1%) CDI discharges.

Data stratification and analysis

We stratified CDI hospital discharges into two groups: principle and non-principle.^{7,9,10} All diagnoses included at discharge were assessed for underlying comorbidities. We used the Deyo modification of the Charlson

index to assess and score up to 30 ICD-9 diagnosis codes per discharge event.^{30,31} The score is associated with one-year mortality and ranges from 0 = no comorbidity to ≥ 5 = severe underlying conditions.

Analysis was performed to determine rate, mortality, and health-care charges for Michigan CDI discharges. The database was maintained in Microsoft® Excel and Access 2002, and descriptive and statistical analyses were conducted with SAS® version 9.1.³² We used Chi-square tests and t-tests to analyze categorical and continuous variables. Significance was quantified using $\alpha \leq 0.05$, and statistical results were reported as *p*-values. The frequency and mortality rate of CDI discharges was calculated based on total discharges and expressed as a rate per 100,000 discharges (frequency) or per 100,000 2000 U.S. Census population (mortality). Similarly, we analyzed rates by gender and age compared with Census data. To adjust for inflation of health-care charges over time, total charges were standardized to 2008 U.S. dollars using the consumer price index.

RESULTS

Frequency and severity of *C. difficile* infection

From 2002 through 2008, there were 68,686 hospital CDI discharges among Michigan residents. The frequency and rate of CDI discharges rose significantly over the time period. In 2008, CDI was documented in more than 1% of all discharges from Michigan hospitals (Table 1). The distribution of disease varied by county, with the highest CDI rates centered in Southeast Michigan (Figure). Disease severity was assessed by mortality and length of stay (Tables 2 and 3).

The frequency of CDI discharges more than doubled from 2002 to 2008. CDI discharges varied by gender; a higher proportion of females were discharged with *C. difficile*. The rate ratios for discharge and mortality revealed significant differences. Higher rates of CDI discharges corresponded with the oldest age strata—970.5 CDI discharges per 100,000 population aged 85 years or older (approximately 1% of all people in this age strata). In addition, the CDI rate differed significantly by race/ethnicity. The mean CDI discharge rate was 22% greater among black people than white people (134.3 vs. 109.8 per 100,000 population). CDI rates among people of Native American, Asian, or Hispanic race/ethnicity were significantly lower than those among white and black people. As noted with the discharge rate, the highest mortality rate occurred in those aged 85 years and older—121.2 deaths per 100,000 population. By race/ethnicity, the highest mortality rates occurred among black people, at a rate that was 32% higher than their white counterparts. With respect to underlying conditions, higher Charlson scores corresponded with an increase in CDI mortality rate (Table 2).

Principle and non-principle CDI discharges

As shown in Table 3, the majority of CDI discharges (74.7%) had a non-principle CDI discharge diagnosis. Analysis of principle and non-principle CDI discharges revealed statistically significant differences in the variables explored. The mean length of stay for all CDI discharges was two weeks but varied by a week for principle (7.1) and non-principle (16.5) diagnoses. The mean Charlson score was 2.6 but was higher for non-principle discharges, indicating more severe

Table 1. Frequency and rate of hospital discharges containing the diagnosis of *Clostridium difficile* infection among Michigan residents, 2002–2008

Year	CDI discharges N	Total discharges N	Rate of CDI per 100,000 discharges	Rate of CDI per 100,000 population ^a
2002	6,052	1,306,763	463.1	60.9
2003	6,228	1,324,328	470.3	62.7
2004	7,696	1,334,478	576.7	77.4
2005	10,115	1,345,851	751.6	101.8
2006	10,909	1,354,747	805.2	109.8
2007	13,024	1,346,682	967.1	131.1
2008	14,662	1,337,230	1,096.5 ^b	147.5
Total	68,686	9,350,079	804.1 ^c	108.5 ^c

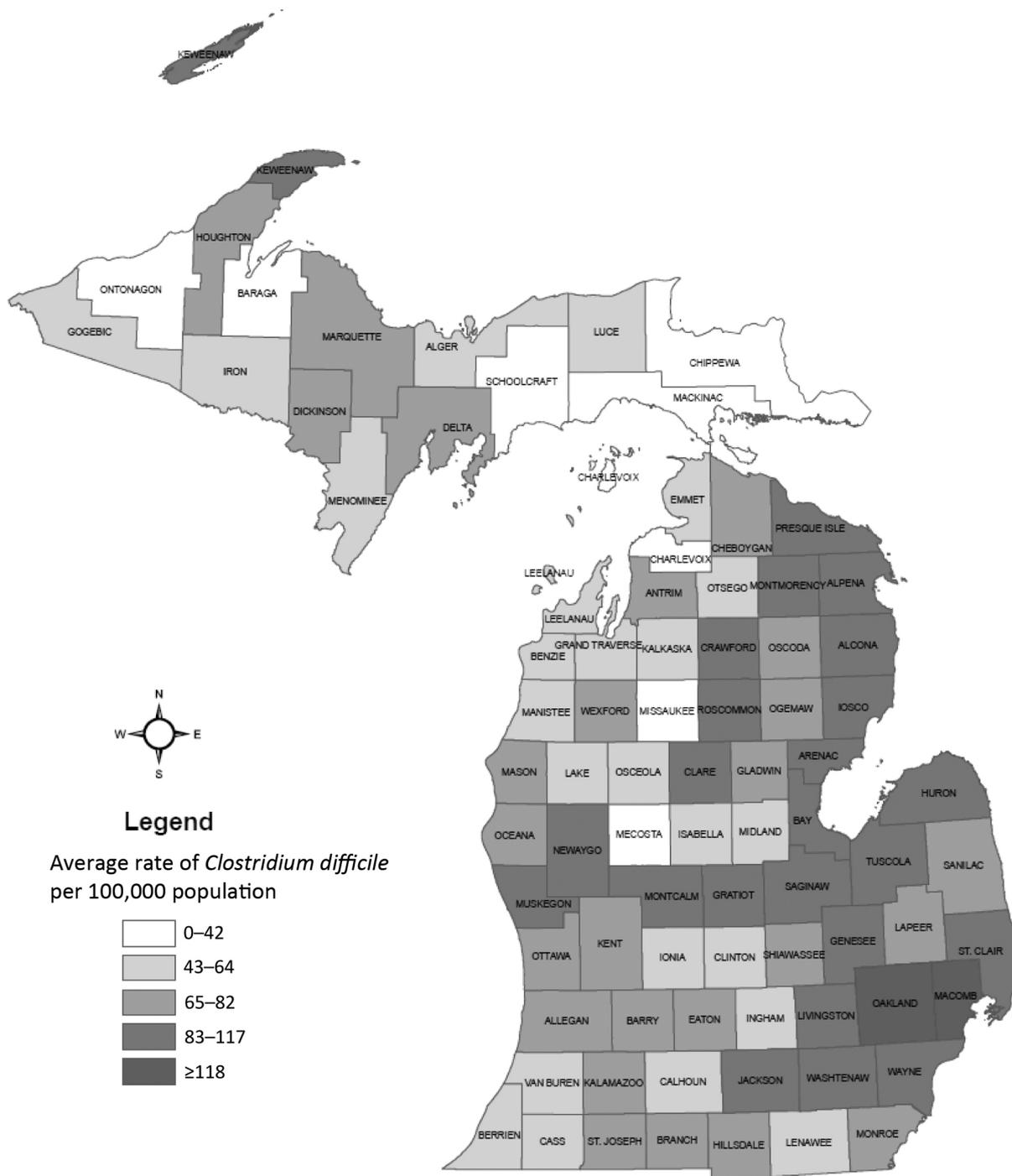
^aPopulation was calculated using 2000 U.S. Census data. Chi-square test for trend of the rate of CDI per 100,000 population: $\chi^2=6786.9$, degree of freedom = 6, $p<0.0001$

^bCDI was documented in more than 1% of all discharges in Michigan.

^cMean rate per 100,000 population

CDI = *Clostridium difficile* infection

Figure. Mean rate of hospital discharges of Michigan patients with *Clostridium difficile* infection, 2002–2008, by county



underlying conditions in these patients. Stratifying CDI by principle diagnosis greatly influenced total charges, as patients with non-principle CDI diagnoses had 3.3 times the health-care charges of those with principle

CDI diagnoses. Overall, death occurred in 5,924 (8.6%) patients diagnosed with CDI. Among patients who died, 563 (9.5%) had a principle CDI diagnosis, while 5,361 (90.5%) had a non-principle CDI diagnosis.

Table 2. Demographics of hospital discharges containing the diagnosis of *Clostridium difficile* infection among Michigan residents, 2002–2008, by discharge and mortality rate per 100,000 population (n=68,686)

Characteristic	CDI discharges		CDI mortality	
	Rate per 100,000 population ^a	RR (95% CI)	Rate per 100,000 population ^a	RR (95% CI)
Year				
2002	60.9	Ref.	5.7	Ref.
2003	62.7	1.0 (1.0, 1.1)	5.5	1.0 (0.9, 1.1)
2004	77.4	1.3 (1.2, 1.3)	6.5	1.2 (1.0, 1.3)
2005	101.8	1.7 (1.6, 1.7)	8.7	1.5 (1.4, 1.7)
2006	109.8	1.8 (1.8, 1.9)	8.9	1.6 (1.4, 1.8)
2007	131.1	2.2 (2.1, 2.2)	11.2	2.0 (1.8, 2.2)
2008	147.5	2.4 (2.4, 2.5)	13.1	2.3 (2.1, 2.6)
Age (in years)				
<5	16.8	4.2 (3.7, 4.9)	0.5	7.8 (2.3, 26.0)
≥5 and <10	3.8	Ref.	0.1	Ref.
≥10 and <15	3.9	1.2 (1.0, 1.5)	0.6	1.0 (0.2, 4.9)
≥15 and <20	8.3	2.2 (1.9, 2.5)	0.2	2.8 (0.7, 10.4)
≥20 and <25	14.4	3.8 (3.3, 4.4)	0.3	5.8 (1.7, 20.0)
≥25 and <35	16.7	4.4 (3.8, 5.0)	0.7	11.9 (3.7, 37.7)
≥35 and <45	28.3	7.3 (6.4, 8.4)	1.5	26.7 (8.5, 83.7)
≥45 and <55	62.8	16.4 (14.3, 18.7)	4.4	75.7 (24.3, 235.7)
≥55 and <60	127.2	33.1 (29.0, 37.9)	10.5	183.0 (58.8, 570.1)
≥60 and <65	180.0	47.0 (41.1, 53.8)	16.2	281.2 (90.3, 875.4)
≥65 and <75	278.9	71.0 (62.2, 81.1)	26.6	463.3 (149.2, 1,438.4)
≥75 and <85	615.6	153.1 (134.2, 174.7)	66.8	1,161.0 (374.1, 3,602.7)
≥85	970.5	250.5 (219.5, 286.0)	121.2	2,108.0 (678.9, 6,545.1)
Gender ^b				
Male	606.2	Ref.	58.7	Ref.
Female	772.7	1.28 (1.3, 1.3)	60.5	1.0 (1.0, 1.1)
Race/ethnicity ^b				
White	109.8	Ref.	9.3	Ref.
Black	134.3	1.1 (1.1, 1.2)	12.3	1.2 (1.2, 1.3)
Asian	36.7	0.3 (0.3, 0.3)	1.5	0.5 (0.4, 0.7)
Native American ^c	35.3	0.3 (0.3, 0.4)	7.5	0.6 (0.4, 1.0)
Hispanic	24.0	0.2 (0.2, 0.2)	0.3	0.0 (0.0, 0.1)
Other	12.4	0.0 (0.0, 0.0)	0.8	0.0 (0.0, 0.1)
Score ^d				
0	NC ^e	NC ^e	4,801.2	Ref.
1–2	NC ^e	NC ^e	6,268.8	1.3 (1.2, 1.4)
3–4	NC ^e	NC ^e	8,435.3	1.8 (1.6, 1.9)
≥5	NC ^e	NC ^e	13,704.1	2.9 (2.6, 3.1)

^aThe rates for year, age group, gender, and race/ethnicity were calculated based on data from the 2000 U.S. Census.

^bFor gender, calculations are based on n=68,684. For race/ethnicity, calculations are based on n=68,633.

^cIncludes American Indian/Alaska Native people

^dDeyo modification of the Charlson score (ranging from 0 = no underlying conditions noted from ICD-9 codes to ≥5 = multiple or severe comorbidities)

^eRate could not be calculated, as no underlying comorbidity using the Deyo modification of the Charlson score exists for the state of Michigan's population.

CDI = *Clostridium difficile* infection

RR = rate ratio

CI = confidence interval

Ref. = reference group

NC = not calculated

ICD-9 = International Classification of Diseases, Ninth Revision

Table 3. Analysis of hospital discharges with *Clostridium difficile* infection, principle vs. non-principle diagnoses, among Michigan residents, 2002–2008 (n=68,686)

Variable	CDI discharges			P-value
	All (n=68,686)	Principle diagnosis (n=17,413)	Non-principle diagnosis (n=51,273)	
Length of stay, in days: mean (SD)	14.2 (17.8)	7.1 (7.0)	16.5 (19.6)	<0.0001
Score: ^a mean (SD)	2.6 (2.0)	2.0 (1.9)	2.8 (1.9)	<0.0001
Charges, in U.S. dollars: ^b mean (SD)	\$67,149 (\$118,722)	\$24,850 (\$36,632)	\$81,619 (\$132,801)	<0.0001
Discharge status: ^b N (percent)				
Home	21,565 (31.4)	8,634 (40.0)	12,931 (60.0)	<0.0001
Other facility ^c	41,147 (60.0)	8,210 (20.0)	32,937 (80.0)	<0.0001
Death	5,924 (8.6)	563 (9.5)	5,361 (90.5)	<0.0001

^aDeyo modification of the Charlson score (ranging from 0 = no underlying conditions noted from ICD-9 codes to ≥ 5 = multiple or severe comorbidities)

^bFor charges in U.S. dollars, calculations are based on $n=49,516$. For discharge status, calculations are based on $n=68,636$.

^cIncludes general hospital, nursing, intermediate care, federal health-care, hospice, rehabilitation, long-term care, psychiatric hospital, critical access, or other similar facilities.

CDI = *Clostridium difficile* infection

SD = standard deviation

ICD-9 = International Classification of Diseases, Ninth Revision

Length of stay and health-care charges for *C. difficile* infection

As shown in Table 4, examination of mean length of stay revealed significant variation by gender, race/ethnicity, and age. Males, Asian people, and children younger than 5 years of age had significantly longer hospitalizations. In fact, children younger than 5 years of age were hospitalized for a mean of more than 25 days per discharge. The mean length of stay for CDI discharges (14.2 days) was significantly longer compared with all discharges (4.7 days) (data not shown).

The mean total charges associated with CDI discharges increased by \$20,041 (35%) from 2002 to 2008. Comparison of the mean CDI charge with the mean total charge of all other discharges during the same time period revealed a mean total charge for CDI discharges (\$67,149) that was three times that of all other Michigan discharges (\$21,098; $n=6,053,323$, data not shown). Among CDI deaths, the mean charges were more than double those of surviving patients: \$132,758 vs. \$61,029. The majority of CDI discharges (69.4%) had Medicare insurance, while private insurance covered 19.2% of CDI discharges. Mean charges accrued varied by insurance type. The highest charges reported were for CDI discharges with Medicaid insurance (\$103,806) and the lowest charges were for CDI discharges with Medicare insurance (\$59,136) (Table 4).

Substantial race/ethnicity and age variation in health-care charge was evident. Children younger than 5 years of age had mean charges of \$148,525, compared with \$56,796 for discharges of patients who were aged 65 years or older. By race/ethnicity, Asian people had

the highest mean health-care expenditures (\$131,432) which was 1.5 times that for black patients and double that of Native American, white, and Hispanic patients. Relative to white people, the health-care charges per CDI discharge event for black people were a mean of \$27,013 more per episode, while charges for Native American and Hispanic people were in excess of \$3,000 more per episode (Table 4). Variation in mean daily health-care charges was also noted among racial/ethnic groups—Asian people had a mean daily charge of \$5,351 compared with \$4,317 for non-Asians, a difference that was statistically significant (data not shown).

DISCUSSION

This article is the first to characterize the frequency, mortality, and health-care charges in hospital CDI discharges using discharge data in Michigan. The rise in CDI frequency and variance in mortality and health-care charges are of concern, particularly for certain subpopulations. For instance, age is a known risk factor for CDI; our data confirm previous studies showing the elevated risk that advancing age contributes to frequency and mortality rates.⁷ Further, our data show CDI frequency among Michigan hospital discharges to be similar to national studies.³³

Prevention of *C. difficile* infection

Prevention of *C. difficile* acquisition and infection can diminish CDI morbidity and mortality. Effective prevention efforts include antimicrobial stewardship³⁴ and the use of gloves and disposable thermometers.³⁵ Hand

hygiene with soap and water reduces bacterial load,³⁶ and thorough environmental cleaning using a sodium hypochlorite dilution can reduce endemic CDI rates.³⁷

The use of isolation and private rooms, and cohorting of infected patients are widely implemented measures. Other approaches for CDI reduction have included

Table 4. Mean length of stay and total charges, by characteristic, for hospital discharges of Michigan patients with *Clostridium difficile* infection, 2002–2008

Characteristic	Mean length of stay in days	P-value	Mean charge in U.S. dollars ^a	P-value
All reported	14.2	<0.0001 ^b	\$67,149	<0.0001 ^b
Year				
2002	15.8	Ref.	\$56,790	Ref.
2003	15.0	0.0161	\$60,861	0.0270
2004	14.7	0.0002	\$63,883	<0.0001
2005	13.8	<0.0001	\$64,956	<0.0001
2006	13.5	<0.0001	\$62,885	<0.0001
2007	13.6	<0.0001	\$70,184	<0.0001
2008	14.1	<0.0001	\$76,831	<0.0001
Outcome				
Died	19.0	<0.0001	\$132,758	<0.0001
Survived	13.7	Ref.	\$61,029	Ref.
Score ^c				
0	10.7	Ref.	\$42,835	Ref.
1–2	11.7	<0.0001	\$48,336	<0.0001
3–4	14.1	<0.0001	\$67,339	<0.0001
≥5	18.9	<0.0001	\$103,087	<0.0001
Payer (percent)				
Medicare (69.4)	13.4	<0.0001	\$59,136	<0.0001
Medicaid (6.0)	18.5	<0.0001	\$103,806	<0.0001
Private (19.2)	14.1	Ref.	\$81,540	Ref.
Government (1.3)	17.2	0.0004	\$97,801	0.1291
Self/other (4.1)	19.6	<0.0001	\$84,316	0.3749
Missing (0.0)	12.2	0.1696	\$71,932	0.0090
Age (in years)				
<5	25.4	<0.0001	\$148,525	<0.0001
≥5 and <18	13.2	0.9921	\$82,327	<0.0001
≥18 and <40	14.1	0.0062	\$82,568	<0.0001
≥40 and <65	15.9	<0.0001	\$85,482	<0.0001
≥65	13.2	Ref.	\$56,796	Ref.
Race/ethnicity				
White	13.5	Ref.	\$62,286	Ref.
Black	16.9	<0.0001	\$89,299	<0.0001
Asian	23.1	0.0013	\$131,432	<0.0001
Native American ^d	15.2	0.3952	\$65,635	0.7474
Hispanic	14.6	0.2259	\$65,660	0.6145
Other	21.9	0.0358	\$83,217	0.4526
Gender				
Male	15.5	<0.0001	\$78,116	<0.0001
Female	13.1	Ref.	\$58,961	Ref.

^aMean total charge reported from 49,561 (72.1%) hospitals

^bCompared with all discharges in the database from 2002 through 2008

^cDeyo modification of the Charlson score (ranging from 0 = no underlying conditions noted from ICD-9 codes to ≥5 = multiple or severe comorbidities)

^dIncludes American Indian/Alaska Native people

Ref. = reference group

ICD-9 = International Classification of Diseases, Ninth Revision

probiotics³⁸ and fecal recolonization therapy in severe recurrent cases.³⁹

C. *difficile* discharge severity in Michigan

The overall severity of CDI discharges in Michigan is similar to national estimates. Prevalence of mortality (8.6%) correlates with national statistics (8.4%)⁹ as does the mean length of stay (14 days).⁷ Differences in length of stay between principle and non-principle CDI discharges have also been previously documented.^{9,10} Instances in which death occurred were not limited to people with comorbidities; 9.5% of fatal cases occurred among principle CDI discharges. Due to a lack of strain typing data, we can only hypothesize that some of the mortality may have been due to a greater severity associated with the emergence of the B1/NAP1 hypervirulent strain.^{13–16} Further, the mortality rate increased starting at age 45 years in our study. While the traditional risk factor of age 65 years and older still holds, age-based prevention efforts could be broadened to include all people aged 45 years and older. We also found great variation in length of stay and mortality by race/ethnicity, age, and gender. These findings suggest that targeting prevention efforts toward groups with the longest hospital stays (i.e., males, children younger than 5 years of age, and Asian and black people) and elevated mortality (i.e., black and elderly people) could reduce the most severe infections.

The interaction between race/ethnicity and severity is a growing area of research that could benefit from further examination. A national study by Redelings et al. in 2007 found that white people had the highest mortality rate from 1999–2004, which was attributed to greater health-care access and antibiotic utilization.²⁸ However, a study by Ricciardi et al. in 2007 revealed a significantly elevated mortality rate among black and Hispanic people.⁷ Our study similarly found a higher mortality rate among black people but a lower rate for Hispanic people.

Health-care charges associated with *C. difficile* discharges

Our study reveals a large and growing economic burden associated with health-care charges for CDI discharges. Health-care expenditures related to CDI discharges are not evenly distributed across racial/ethnic groups in Michigan, and Asian people incur the highest total and daily charges. A driving factor for the high total charges is in part due to the length of stay Asian people experience; however, race/ethnicity-specific risk factors that would lead to this extended hospitalization stay have not been previously reported, nor have differences that would account for significantly higher daily costs.

Total charges associated with CDI discharges are also disproportionate by age, with mean charges for children younger than 5 years of age exceeding 2.5 times those aged 65 years and older. The health-care costs associated with extended stay can be burdensome. In other studies, acquiring CDI corresponded with an attributable greater length of stay of 2.9 days and 6.4 days for non-principle and principle cases, respectively,¹⁰ and 3.6 days for all cases.^{22,35} A better understanding of differences among host risk factors related to CDI and the use of targeted prevention efforts are important to decrease length of stay and health-care-associated charges.

Limitations

Barriers to determining true costs. The limitations of this study are similar to other studies using hospital discharge data. The total charge data are voluntarily reported by hospitals and do not take into consideration outpatient or indirect costs, such as loss of wages, productivity, or societal factors. These total charges were also not adjusted with the cost-to-charge ratio for hospitals, which varies among facilities. Further, the charges included in the study do not represent the reimbursable amount from the diagnosis-related group payment system or the out-of-pocket costs to the patient. Future studies to determine incremental and total costs faced by consumers would be of interest.

Microbiology and laboratory barriers. During the time period studied, possible changes in diagnostic testing done by facilities and the clinical criteria for *C. difficile* testing could not be assessed. Differences among laboratory testing practices are an important consideration for *C. difficile*, as wide variation exists in practices and test sensitivity and specificity. This variation could lead to an over- or underestimation of the true proportion of CDI cases among Michigan discharges. More accurate tests and standardized testing protocols among Michigan hospitals are needed for enhanced comparison. Due to the lack of laboratory data, this study could not take into consideration any potential variances in pathogenicity between the B1/NAP1 hypervirulent strain and other strains, which could potentially account for some of the greater frequency or higher mortality rates.

Use of discharge data. A major limitation of this study was the selection of discharges. Records were classified using an ICD-9 code, which is largely determined by the individual clinician's judgment.⁷ ICD-9 codes do not contain identifiers that would allow for validation against laboratory data, nor do they contain information

to assess antibiotic use. The determination process for coding “008.45” involves medical record review of the doctor’s diagnosis, which should be guided by a positive laboratory result. If the laboratory test was normal, the patient’s symptoms that prompted ordering the test should be coded. Uncertain or probable diagnoses should not be coded. Previous studies have validated the use of the ICD-9 *C. difficile* code compared with clinical *C. difficile* cases confirmed with microbiological data. One study found a sensitivity of 71% and a specificity of 99% for discharge data.⁴⁰ Another found a good correlation between ICD-9 and *C. difficile* toxin assay ($\kappa=0.72$) and an ICD-9 code sensitivity of 78% and specificity of 99.7%.⁴¹ Further, surveillance of CDI through the use of discharge data is not an effective method for time-sensitive responses; however, it is the most comprehensive data source currently available to understand CDI trends in Michigan.

Clinical infection. Although the CDI ICD-9 code is based on clinical information, the discharge data do not reflect symptomatology or onset dates, which would be useful for determining community or health-care onset and acquisition. Further data that would address whether the *C. difficile* bacterium was responsible for the infection or an incidental finding were not available in this present dataset. In future studies, additional data would be helpful in deepening our understanding of CDI. CDI frequency reported in this study could be an underestimate of the true incidence of CDI; milder cases might not require hospitalization. Conversely, monitoring CDI frequency through discharge data may lead to an overestimate of clinical disease, as the proportion of CDI discharges that were incidental findings could not be measured.

CONCLUSION

Prevention of CDI among patients would reduce mortality and morbidity, as well as associated health-care costs.^{15,22–29} In Michigan, prevention efforts should be focused on elderly and black patient populations, as they have the highest CDI discharge and mortality rates, and on children younger than 5 years of age and Asian patients, who have the longest length of stay and highest health-care charges. Hospitals should adopt an antibiotic stewardship program to encourage judicious antimicrobial use.³³ In addition, better adherence to established prevention measures could reduce health-care-acquired CDI. Careful hospital surveillance can help detect and ameliorate cases and inform future prevention strategies. Increased efforts in prevention can lead to reduced frequency of CDI,^{34–39} as well as reduced health-care charges.^{10,22–25}

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