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Antimicrobial resistance in eight US hospitals along the US–Mexico border, 2000–2006

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SUMMARY

Antimicrobial resistance (AR) is a growing problem worldwide and international travel, cross-border migration, and antimicrobial use may contribute to the introduction or emergence of AR. We examined AR rates and trends along the US–Mexico border by analysing microbiology data from eight US hospitals in three states bordering Mexico. Microbiology data were ascertained for the years 2000–2006 and for select healthcare and community pathogens including, three Gram-negative (*Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae*) and three Gram-positive (*Staphylococcus aureus, Enterococcus, Streptococcus pneumoniae*) pathogens and 10 antimicrobial–pathogen combinations. Resistance was highest in *S. aureus* (oxacillin resistance 45·7%), *P. aeruginosa* (quinolone resistance 22·3%), and *E. coli* (quinolone resistance 15·6%); six (60%) of the 10 antimicrobial–pathogen combinations studied had a significantly increasing trend in resistance over the study period. Potential contributing factors in the hospital and community such as infection control practices and antimicrobial use (prescription and non-prescription) should be explored further in the US–Mexico border region.

Key words: Antimicrobial resistance, US–Mexico border.

INTRODUCTION

Antimicrobial resistance (AR) is a growing problem worldwide and is associated with increased healthcare utilization, costs, morbidity, and mortality [1–3]. A number of healthcare and societal factors have contributed to the emergence of AR globally, including injudicious antimicrobial use, ineffective infection control precautions, travel (including medical tourism), and cross-border migrations [4–6]. Emerging resistance in any specific region can have widespread public health implications for a country [7].

The US–Mexico border is one of the world's busiest international boundaries with over 225 000 000 crossings annually [8]. The US–Mexico border consists of a 2000-mile stretch of land bordering four US states. The region is one of the poorest in the USA and suffers from high rates of infectious diseases [9]. Utilization of healthcare services in this region is unique due to lower cost options on the Mexico side of the border. Studies show that large portions of

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the population residing on the US side of the border commonly seek medical services in Mexico [10, 11]. Pharmaceutical purchasing is the most common type of service utilized and antimicrobials are the most common medication purchased [10, 11]. Cross-border healthcare utilization, however, is not unidirectional. Many patients on the Mexico side of the border are transferred to US hospitals for treatment, especially emergency services, due to a lack of access on the Mexico side of the border in some areas [12]. Because of potential differences in patient characteristics, healthcare utilization, and antimicrobial utilization in border and non-border populations, resistance patterns for some common pathogens may differ along the border compared to other parts of the USA and therefore should undergo special study.

Some small studies have investigated AR in US–Mexico border cities [13, 14] but these have largely focused on a single pathogen and have represented a single healthcare facility. To our knowledge, none have examined AR trends for multiple pathogens from differing geographical locations along the border. In this report, we present AR rates and trends for several clinically important healthcare and community pathogens from eight US hospitals bordering Mexico.

METHODS

Study population

The study was conducted at eight hospitals in six US cities that participated in the Centers for Disease Control and Prevention's (CDC) Border Infectious Disease Surveillance (BIDS) Program [15]. All major hospitals participating in BIDS, that serve border crossing and indigent Latino populations, were asked to participate and all agreed. The eight study hospitals were located in three of the four border states that represent over 90% of the land area of the US–Mexico border. The study hospitals represented a mix of large academic centres and community hospitals; all were located within 100 km of the US–Mexico border as defined by the La Paz Agreement. This study was determined to be non-research by the institutional review board at CDC.

Antimicrobial–pathogen combinations

To determine the prevalence and trends in antimicrobial-resistant pathogens in the study hospitals, we focused on three Gram-negative (*Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae*) pathogens, three Gram-positive (*Staphylococcus aureus, Enterococcus, Streptococcus* (*Str.*) *pneumoniae*) pathogens, and 10 antimicrobial–pathogen combinations because of their clinical importance, frequency, and likelihood of emerging resistance. The combinations examined were third-generation cephalosporin (cef3) and quinolone-resistant *E. coli*; ceftazidime, imipenem, piperacillin, and quinolone-resistant *P. aeruginosa*; cef3-resistant *K. pneumonia*; oxacillin- or methicillin-resistant *S. aureus* (MRSA); vancomycin-resistant enterococci (VRE); and penicillin-resistant *Str. pneumoniae*.

Data collection

Microbiology data for the targeted pathogens were obtained from the study hospitals' laboratory information systems (LIS). Seven of the eight hospitals opted to create datasets from their LIS. One hospital preferred CDC staff to extract the laboratory data onsite from the laboratory instrument. Susceptibility results provided to CDC were recorded as resistant, susceptible, intermediate, or not tested. The methods used for pathogen identification and susceptibility testing may have varied between study hospitals, but all laboratories were Clinical Laboratory Improvement Amendments (CLIA) and College of American Pathologists (CAP) accredited. Data were collected and analysed for the years 2000–2006.

In addition to pathogen and susceptibility data, we collected a unique patient identifier (de-identified), patient age and sex, specimen source and collection date, and patient-care area at the time of specimen collection. Specimen sources were classified as blood, respiratory, skin and soft tissue (SST), urine, and other or unknown. For example, 'bronchial', 'lung', and 'broncheoalveolar lavage' were placed in the respiratory category; 'urine', 'urostomy', and 'foley' were placed in the urine category. Patient-care area at the time of specimen collection was classified as intensive care unit (ICU), other inpatient setting, emergency department (ED), outpatient, nursing home, or unknown. We excluded isolates obtained from environmental/non-clinical sources and duplicate isolates (i.e. same pathogen from the same patient and specimen site with the same resistance profile within 14 days). When duplicates were present, the earliest/first specimen was included in the analysis.

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Analysis

We used the 2006 American Hospital Association (AHA) database to determine the characteristics of the study hospitals, including facility type, bed size, services, and utilization to allow comparisons to other general medical/surgical US hospitals in the border region (i.e. within 100 km of the border) and medical/surgical hospitals nationally. The border region was defined by selecting zip codes within 100 km of the US–Mexico border using Arc GIS software. To compare characteristics of study hospitals to those of other US hospitals, we used Wilcoxon rank-sum tests. We examined the distribution of antimicrobial-resistant pathogens by year overall, by patient-care area, and by specimen source. To determine the magnitude of resistance for each antimicrobial–pathogen combination, we calculated the percentage of isolates resistant to antimicrobial agents by pooling data from all study hospitals for the period 2000–2006 stratified by patient-care area and specimen source. The numerator consisted of the number of resistant isolates for that particular antimicrobial–pathogen combination and the denominator included the total number of isolates tested for that combination. We assessed the trends in resistance by year by graphing and applying the Cochran–Armitage test for trend.

RESULTS

Demographics of study hospitals

The eight study hospitals represented 7·5% of the 106 hospitals listed in the 2006 AHA database in the US–Mexico border region. All study hospitals were general medical/surgical hospitals and four were affiliated with medical schools. The characteristics of the study hospitals are summarized in Table 1. Compared to general medical/surgical border hospitals and medical/surgical hospitals nationwide, the study facilities had a larger bed size and average daily census, higher Medicare and Medicaid inpatient utilization, and a higher total number of surgeries and ED visits ($P<0·05$) (Table 1).

Distribution of isolates by hospital, patient, and specimen characteristics

Antimicrobial susceptibility data for the six pathogens totalled 140 475 non-duplicate clinical isolates (representing 94 254 unique patients) during the period 2000–2006. Of the 140 475 isolates, 68 315(48·6%) were *E. coli*; 31 308(22·3%) *S. aureus*; 14 698(10·5%) enterococci; 12 369(8·8%) *P. aeruginosa*; 11 808(8·4%) *K. pneumoniae*; and 1977 (1·4%) *Str. pneumoniae*. The volume of antimicrobial susceptibility data provided by each hospital varied, ranging from a low of 4981 isolates to a high of 32 118 isolates. The largest proportion of isolates were from females (60·9%), the 20–49 years age group (31·7%), and non-ICU inpatient areas (30·9%); the most common specimen source was urine (57·8%).

Prevalence rates and temporal trends in AR

Gram-negative pathogens

Among the three Gram-negative pathogens studied, the overall prevalence of resistance ranged from 1·7% (cef3-resistant *E. coli* and *K. pneumoniae*) to 22·3% (quinolone-resistant *P. aeruginosa*); the prevalence of quinolone-resistant *P. aeruginosa* ranged from 13·7% to 30·7% in the study hospitals. With the exception of ceftazidime-, imipenem-, and piperacillin-resistant *P. aeruginosa*, all other Gram-negative antimicrobial–pathogen combinations studied showed an increasing trend over the 7-year period (Fig. 1, Table 2). Quinolone-resistant *E. coli* was most notable, increasing from 7·8% to 23·8% ($P<0·0001$) over the study period (Fig. 1*a*, Table 2). Each of the resistant Gram-negative pathogens (*E. coli, K. pneumoniae, P. aeruginosa*) was more prevalent in the ICU and other inpatient settings than in the ED and outpatient settings (Supplementary Table S1, available online).

The distribution of resistant Gram-negative pathogens also varied by body site, with resistant pathogens being most frequently isolated from respiratory specimens despite urine being the most common specimen source (Supplementary Table S2). Among urinary isolates, quinolone-resistant *E. coli* increased about threefold in outpatient (5·2% in 2000 to 18·8% in 2006, $P<0·0001$) and inpatient (11·5 to 31·9%, $P<0·0001$) settings (Fig. 1*a*). For quinolone-resistant *E. coli* specimens, all specimen source/patient-care area combinations showed an increasing trend.

Gram-positive pathogens

Among the three Gram-positive pathogens studied, the overall prevalence of resistance ranged from 9·3% (penicillin-resistant *Str. pneumoniae*) to 45·7% (MRSA), with the prevalence of MRSA ranging

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Table 1. *Characteristics of study hospitals, American Hospital Association (AHA) general medical/surgical border hospitals, and all general medical/surgical AHA hospitals**

	Border study hospitals ($N=8$)†	AHA general medical/ surgical border hospitals ($N=76$)	All general medical/ surgical AHA hospitals ($N=4831$)
Hospital type			
General medical/surgical	100%	100%	100%
Medical school affiliation, %	57·1	21·1	24·5
Median (range) number of beds	326 (165–651)	135 (8–664)	107 (1–2205)
Services, %			
Medical/surgical intensive care beds	100	75·4¶	75·7¶
Other intensive care beds‡	100	58·5¶	41·8¶
Obstetrics	100	70·8¶	68·8¶
Paediatrics	71·4	53·9¶	53·1¶
Haemodialysis	57·1	44·6¶	31·7¶
Oncology	71·4	50·8¶	59·9¶
Burn care	0	3·1¶	4·6¶
Transplant§	28·6	13·9¶	8·8¶
Median (range) annual daily census	278 (75–391)	92 (2–408)	63 (0–1867)
Median (range) annual Medicare inpatient days	27 872 (8613–53 163)	11 415 (0–66 116)	8585 (0–255 644)
Median (range) annual Medicaid inpatient days	26 645 (5709–43 907)	6198 (0–54 143)	3318 (0–235 800)
Median (range) annual total number of surgeries	6831 (4322–19 809)	4221 (0–29 993)	3474 (0–104 910)
Median (range) annual total number of emergency department visits	45 534 (24 748–89 319)	19 858 (0–89 319)	17 759 (0–352 275)
Median (range) annual total number of outpatient visits	76 661 (18 322–489 625)	47 945 (2277–1 071 251)	48 789 (0–3 047 938)

* Data is from 2006 AHA database and border is defined as general medical/surgical hospitals within 100 km of the US–Mexico border.
† Two of the study hospitals are reported as one (hospital A) in AHA because they are part of the same hospital system.
‡ Includes cardiac, neonatal, or paediatric intensive care beds.
§ Includes bone marrow, heart, kidney, liver, lung, tissue, or other transplants.
¶ Proportions based on non-missing data.

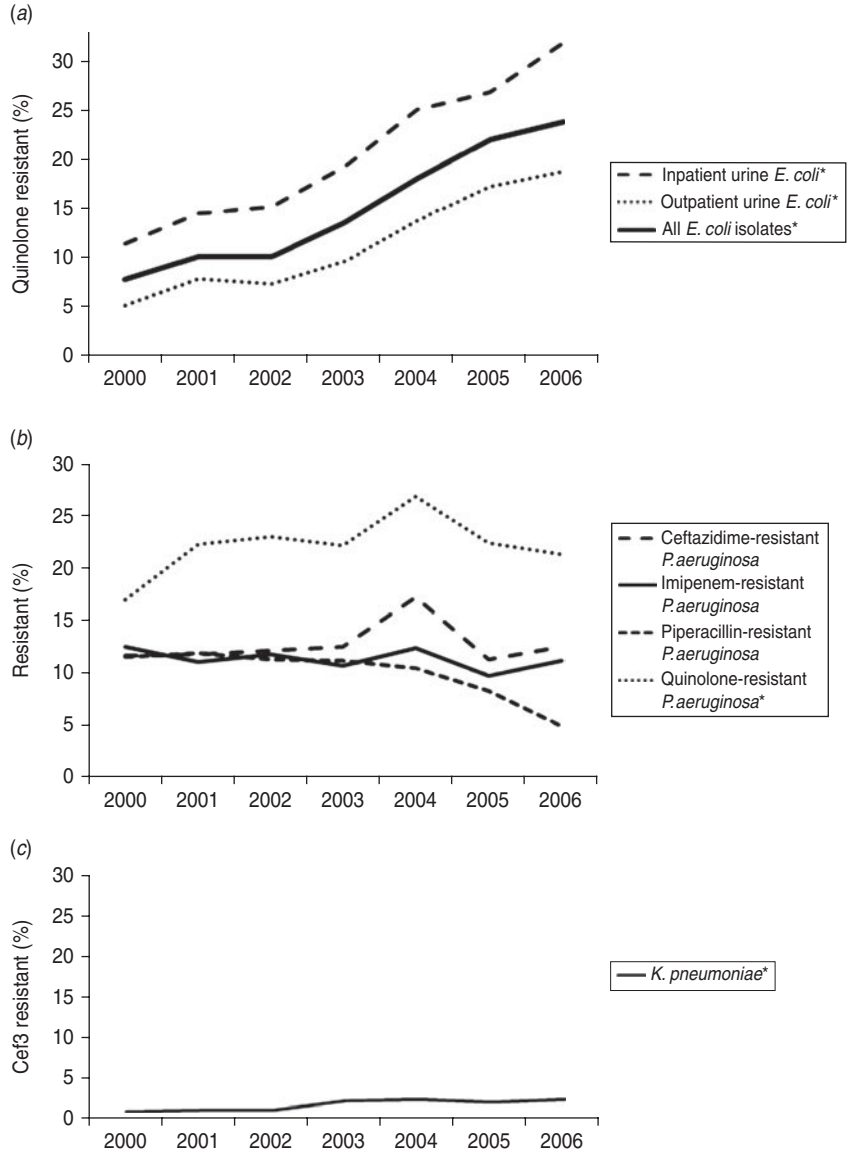

Fig. 1. Trends in Gram-negative pathogens by year (2000–2006) for eight US–Mexico border hospitals. (*a*) Quinolone-resistant *Escherichia coli* pathogens in urine and all body sites; (*b*) *Pseudomonas aeruginosa*-resistant pathogens in all body sites and all patient care areas; (*c*) Cef3-resistant *Klebsiella pneumoniae* pathogens in all body sites and all patient care areas. Inpatient = Intensive care unit and other inpatient areas; outpatient = emergency department and ambulatory care settings; Cef3 = third-generation cephalosporin. * Significant increasing trend at $P < 0{\cdot}005$

from 33·1% to 55·1% in the study hospitals. SST specimens had the highest proportion of MRSA isolates, but no specimen source had less than 38·2% of *S. aureus* isolates that were MRSA (Supplementary Table S2). Over the 7-year period, MRSA increased from 27·6% to 56·5% ($P < 0{\cdot}0001$) (Fig. 2*a*, Table 2). The sharpest increase was in outpatient SST infections which increased more than fourfold, from 14·0% to 65·6%. However, MRSA bloodstream infections (BSIs) in the inpatient setting also increased significantly (Fig. 2*a*) as well as the trend for all other specimen source/patient-care area combinations (with the exception of respiratory infection and BSI in the ICU).

For enterococcal species, the prevalence of VRE ranged from 1·0% to 25·8% in the study hospitals. Overall, blood isolates had the highest proportion of VRE (14·7%) but not significantly higher than other specimen sources (Supplementary Table S2). During the study period, the prevalence of VRE more than doubled (8·4% *vs.* 19·3%, $P < 0{\cdot}0001$) (Fig. 2*b*, Table 2).

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Table 2. *Selected antimicrobial resistance pathogens by year, border hospitals, 2000–2006**

Pathogen, antimicrobial	No. of isolates tested (% resistant)							
	2000	2001	2002	2003	2004	2005	2006	Total
Escherichia coli								
CTX, CRO, or CAZ	7139 (1·1)	8974 (0·8)	9086 (1·2)	10 260 (1·0)	11 687 (1·8)	13 588 (2·6)	7579 (2·9)	68 313 (1·7)
CIP or OFX	7139 (7·8)	8974 (10·1)	9086 (10·1)	10 258 (13·5)	11 688 (18·0)	13 586 (22·0)	7579 (23·8)	68 310 (15·6)
Pseudomonas aeruginosa								
CAZ	1340 (11·6)	1550 (11·7)	1464 (12·0)	1578 (12·4)	1676 (17·1)	2576 (11·2)	1562 (12·4)	11 746 (12·6)
IMI	1325 (12·4)	1486 (11·0)	1446 (11·7)	1616 (10·6)	1759 (12·3)	2628 (9·6)	1562 (11·1)	11 822 (11·1)
PIP	1343 (11·4)†	1137 (11·8)†	968 (11·2)†	1194 (11·1)†	1314 (10·4)†	2021 (8·2)†	875 (4·8)†	8852 (9·9)†
CIP or OFX	1440 (16·9)	1605 (22·2)	1464 (22·9)	1617 (22·0)	1967 (26·7)	2694 (22·3)	1565 (21·2)	12 352 (22·3)
Klebsiella pneumoniae								
CTX, CRO, or CAZ	1192 (0·8)	1498 (1·0)	1362 (1·0)	1689 (2·1)	2019 (2·2)	2536 (2·0)	1513 (2·2)	11 808 (1·7)
Staphylococcus aureus								
OXA	2642 (27·6)	3196 (30·8)	3435 (36·3)	4149 (42·2)	5398 (50·8)	7874 (53·9)	4614 (56·5)	31 308 (45·7)
Enterococcus spp.								
VAN	1292 (8·4)‡	1599 (5·8)‡	1595 (7·4)‡	1664 (8·2)‡	2066 (15·0)‡	3857 (14·6)‡	2625 (19·3)‡	14 698 (12·5)‡
Streptococcus pneumoniae								
PEN	328 (14·6)†	395 (8·1)†	265 (7·2)†	300 (6·0)†	252 (7·1)†	304 (10·9)†	133 (11·3)†	1977 (9·3)†

CTX, Cefotaxime; CRO, ceftriaxone; CAZ, ceftazidime; CIP, ciprofloxacin; OFX, ofloxacin; IMI, imipenem; PIP, piperacillin; OXA, oxacillin; VAN, vancomycin; PEN, penicillin.

* Unless indicated otherwise all eight hospitals contributed data and no hospital had 0% resistance.

† Not all hospitals contributed data.

‡ $\geqslant$1 hospital had 0% resistance.

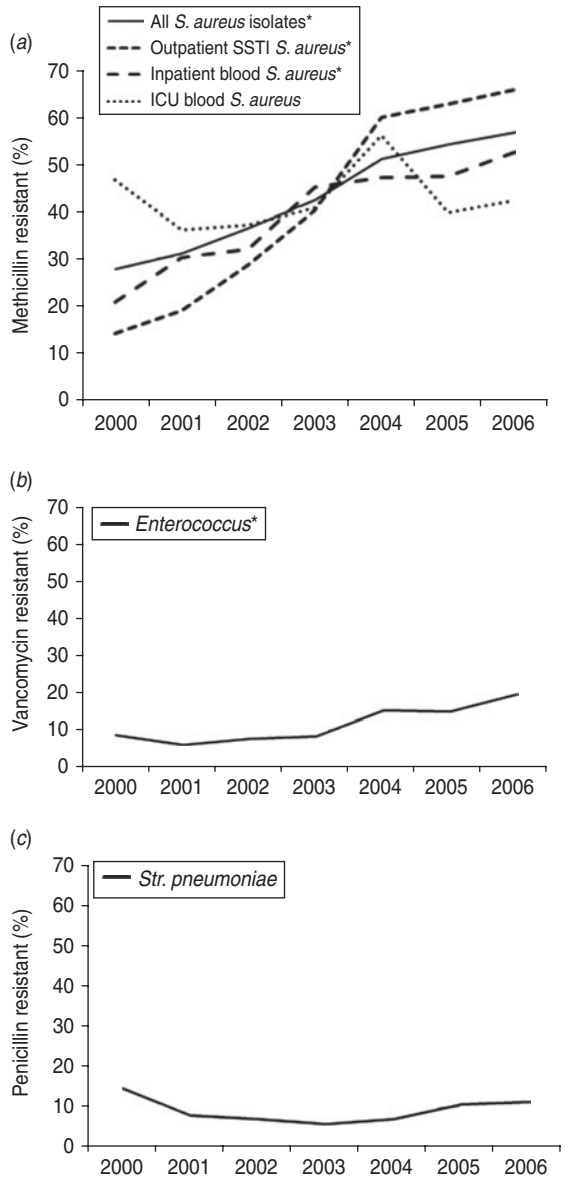

Fig. 2. Trends in Gram-positive pathogens by year (2000–2006) for eight US–Mexico border hospitals. (*a*) Methicillin-resistant *Staphylococcus aureus* pathogens in blood and all body sites; (*b*) vancomycin-resistant *Enterococcus* pathogens in all body sites and all patient care areas; (*c*) penicillin-resistant *Streptococcus pneumoniae* pathogens in all body sites and all patient care areas. SSTI, Skin and soft tissue infection; ICU = intensive care unit; inpatient = non-ICU inpatient care areas; outpatient = emergency department and ambulatory care settings. * Significant increasing trend at $P < 0{\cdot}0001$.

Overall, 9·3% of *Str. pneumoniae* isolates were penicillin resistant (range 3·1–25·0% per hospital); the prevalence of penicillin-resistant *Str. pneumoniae* was similar across patient-care areas and specimen sources (Supplementary Tables S1 and S2). However, the overall prevalence decreased by 50% between 2000 and 2004 (14·3–7·1%) and then rose to 11·3% in 2006 (Fig. 2*c*, Table 2).

DISCUSSION

We examined the frequency of AR in clinical isolates from eight US hospitals in six cities along the US–Mexico border during 2000–2006. Of the six pathogens studied, resistance was highest in *S. aureus* (oxacillin resistance 45·7%), *P. aeruginosa* (quinolone resistance 22·3%), and *E. coli* (quinolone resistance 15·6%). Over the 7-year period, six (60%) of the 10 antimicrobial–pathogen combinations studied had a significantly increasing trend in resistance, ranging from 25% (quinolone-resistant *P. aeruginosa*) to 205% (quinolone-resistant *E. coli*) increases; the two resistant pathogens with the most notable increases were quinolone-resistant *E. coli* (threefold) and MRSA (twofold).

Multidrug-resistant Gram-negative bacteria (e.g. extended-spectrum beta-lactamases and carbapenem-resistant Enterobacteriaceae (CRE)) are a growing threat in healthcare settings and the community [16]. We found substantial increases in quinolone resistance in *E. coli* urinary isolates in both outpatient and inpatient settings. In the Surveillance Network (TSN), a laboratory-based surveillance system consisting of over 200 institutions in the USA, a similar trend was found in outpatient quinolone-resistant *E. coli* urine isolates, but resistance rates were lower than observed in the border hospitals in our study (3·0% in 2000 to 12·2% in 2006) [17]. Similarly, at a large urban healthcare system in Denver, the emergence of quninolone-resistant *E. coli* was documented (1·0% in 1999 to 9·4% in 2005) after switching to levofloxacin as initial therapy for community urinary tract infections (UTIs) [18]. In inpatient settings, we found the overall prevalence of quinolone-resistant *E. coli* was 3·6 and 2·6 times higher in ICU and other inpatient areas, respectively, compared to findings from the CDC's National Nosocomial Infections Surveillance (NNIS) system [currently the National Healthcare Safety Network (NHSN)] during similar years as our study [19, 20].

In the current study, *P. aeruginosa*'s resistance profile varied by antimicrobial ranging from 9·9% (piperacillin) to 22·3% (quinolones). The prevalence of resistance to imipenem, piperacillin, and quinolones in *P. aeruginosa* isolates were comparable to those in NNIS hospitals. However, the prevalence of

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ceftazidime-resistant *P. aeruginosa* was higher than in NNIS, irrespective of patient-care area [19]. The prevalence of cef3-resistant *K. pneumoniae* in the border hospitals increased over the study period, but was low (1·7%) compared to the prevalence in NNIS [19].

Nearly 50% of *S. aureus* isolates were MRSA, most commonly found among SST infections. In outpatient settings, the proportion of SST specimens from which MRSA was isolated increased more than fourfold from 14·0% in 2000 to 65·6% in 2006. These findings are consistent with the documented emergence of community-associated MRSA in the USA [21] and the concomitant rise in outpatient visits and hospitalizations for SST infections [22]. As community-associated MRSA emerged, it became a source of healthcare-associated infections, including BSIs [23]. The percent of central line-associated BSIs that were due to MRSA increased from 47·9% in 2000 to 64·5% in 2007 in NNIS and NHSN ICUs [24], although the overall incidence of BSIs declined. In the border hospitals, the percent of *S. aureus* BSIs that were MRSA rose steadily in the inpatient setting but varied in ICUs (Fig. 2*a*).

A small bi-national study in the El Paso region found a similar overall prevalence of MRSA to our data and found a higher prevalence of MRSA on the US side of the border [13]. The investigators hypothesized that the observed differences may be explained by higher use of broad-spectrum antimicrobials, such as quinolones, on the US side, purchased in Mexico but consumed in the USA. More recent evidence in the Department of Defense population has shown a decline in the rates of hospital- and community-onset MRSA bacteraemia and the proportion of SST infections due to MRSA [25].

The VRE prevalence detected in these border hospitals was higher than previously reported to NNIS [19] or detected in other hospitals [26]. However, more recent NHSN data from 2006 and 2007 demonstrated an increased overall VRE resistance of 33·3%, 2·7 times higher than the pooled rate seen in the border hospitals [27]. The prevalence of VRE from the border hospitals in 2006 was 19·3% suggesting that VRE rates did not increase as much as in NHSN facilities.

The prevalence of penicillin-resistant *Str. pneumoniae* was lower than that reported from NNIS hospitals. Kyaw *et al*. found that with the introduction of the 7-valent pneumococcal conjugate vaccine (PCV7) in 2000, penicillin resistance decreased [28]. We also found this trend with decreased resistance to penicillin from 2000 to 2003 and then a steady increase in resistance to 2006 (Fig. 2*c*). Although PCV7 has reduced invasive pneumococcal disease, non-PCV7 strains have increased in prevalence and resistance [29]. We do not have serotype data and thus we cannot determine whether these resistant isolates are due to PCV7 or non-PCV7 strains.

There are a number of factors that may account for the resistance patterns and trends that we observed in these border hospitals. Overuse of antimicrobials in ambulatory settings in both the USA and Mexico has been well documented [30, 31]. The US–Mexico border region is distinct because patients cross the border frequently to receive medical care and purchase antimicrobials often without prescription [10, 11]. Quinolones are the most common antimicrobial used to treat uncomplicated UTIs in the USA [32] and the development of quinolone-resistant *E. coli* is directly related to volume of quinolone use [18, 33]. The marked higher prevalence of quinolone-resistant *E. coli* urine isolates that we observed in the border region may partially be explained by prescribing or consumption patterns (e.g. non-prescription use), and/or simply appropriate use in an area of high UTI burden. Future studies should attempt to examine these prescribing and consumption patterns.

Antimicrobial use, however, is just one of many factors that may have contributed to the resistance we observed in the border hospitals. The high prevalence of resistance in inpatient settings may be due to inadequate infection control practices, antimicrobial utilization in the inpatient setting, and the underlying characteristics of the patient population [4]. Additionally, the bidirectional movement of patients across the US–Mexico border contributes to the introduction of resistant organisms into the region and the facilities serving these mobile populations [10–12, 34]. Infection control practices and device utilization are highly variable and patients receiving medical care outside of their country of residence may become colonized or infected with resistant organisms and transmit these infections upon returning to their country of residence [5, 6, 35].

This study was subject to a number of limitations. Making head-to-head comparisons between our study findings and those from other studies and surveillance systems is difficult due to differences in study periods, type of facilities, and potential differences in patient mix. In addition, we lacked data on factors such as antimicrobial use, prescribing

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behaviours, and infection control practices; all of which may contribute to the resistance rates and trends that we observed in both the inpatient and outpatient settings. We also lacked denominator data such as patient-days to calculate disease incidence which would give a more complete picture of AR burden. Finally, the eight study hospitals were neither representative of all border hospitals nor other US hospitals, study hospitals did not contribute equal amounts of data, and no central laboratory was used so variations in test results may exist between laboratories. The study hospitals, however, were a mix of large academic and community hospitals serving border crossing and indigent Latino populations in three of the four states bordering Mexico, representing 7·5% of all border health facilities and 9·2% of all border general medical/surgical hospitals.

Despite these limitations, to our knowledge, this is the first report of AR rates over time for multiple community- and hospital-based pathogens from US hospitals in various geographical locations along the US–Mexico border. In response to the growing problem of AR, public health officials and professional societies in Mexico and the USA have developed multimodal strategies aimed at preventing and controlling emerging AR, including educational campaigns targeting providers and patients [36, 37], strengthening surveillance capacity, and issuing clinical practice and infection control guidelines [4, 16]. The Mexican government has also initiated new policy to enforce prescription-only purchase of antimicrobials [38]. Additionally, the WHO has issued guidance on strategic approaches to combating AR globally [39]. Future AR studies in this region should examine patient-, provider-, community-, and institution-level factors that may contribute to AR in this region such as antimicrobial use and infection control practices as well as exploring emerging multidrug-resistant Gram-negative pathogens such as CRE and *Acinetobacter*. The implementation of health information technology and adoption of uniform data standards will improve the feasibility of monitoring AR along the border and the ability to make meaningful comparisons across institutions and geographical regions.

SUPPLEMENTARY MATERIAL

For supplementary material accompanying this paper visit http://dx.doi.org/10·1017/S095026881300318X.

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DECLARATION OF INTEREST

None.

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