Isolation frequency and susceptibility pattern of non-O1 and non-O139 *Vibrio cholerae* in a tertiary health care laboratory, 1999–2012

S. Irfan,¹ N. Fasih,¹ N.K. Ghanchi¹ and E. Khan¹

ABSTRACT In the past decade the importance of non-O1 and non-O139 strains of *Vibrio cholerae* has been highlighted globally. This study aimed to evaluate the frequency and antimicrobial susceptibility profile of non-O1 and non-O139 *V. cholerae* in Pakistan. Data of stool specimens yielding growth of non-O1 and non-O139 *V. cholerae* isolated at a national referral laboratory from 1999 to 2012 were retrospectively analysed and evaluated for resistance to ampicillin, tetracycline, chloramphenicol, co-trimoxazole and ofloxacin. A total of 95 800 stool samples submitted over 1999–2012 yielded 3668 strains of *V. cholerae*, of which 6% were non-O1 and non-O139 *V. cholerae*. A high isolation rate was found in the summer season, with a peak in the year 2003. Antimicrobial susceptibility data revealed increasing resistance to co-trimoxazole and ampicillin, but strains remained highly susceptible to ofloxacin. Active surveillance of serotypes and antimicrobial susceptibility is essential to predict future epidemics and define measures to curtail the disease.

Fréquence d’isolation et profil de sensibilité de *Vibrio cholerae* non-O1 et non-O139 dans un laboratoire de soins de santé tertiaires, 1999-2012

RÉSUMÉ Au cours des dix dernières années, l’importance des souches de *Vibrio cholerae* non-O1 et non-O139 a été mise en avant à l’échelle mondiale. La présente étude visait à évaluer la fréquence de l’isolation des souches de *V. cholerae* non-O1 et non-O139 et leur profil de sensibilité aux antimicrobiens au Pakistan. Les données d’échantillons de selles ayant permis la croissance de *V. cholerae* non-O1 et non-O139 isolés dans un laboratoire national spécialisé entre 1999 et 2012 ont été analysées et évaluées rétrospectivement pour leur résistance à l’ampicilline, la tétracycline, le chloramphénicol, co-trimoxazole et ofloxacine. A total of 95 800 stool samples submitted over 1999–2012 yielded 3668 strains of *V. cholerae*, of which 6% were non-O1 and non-O139 *V. cholerae*. A high isolation rate was found in the summer season, with a peak in the year 2003. Antimicrobial susceptibility data revealed increasing resistance to co-trimoxazole and ampicillin, but strains remained highly susceptible to ofloxacin. Active surveillance of serotypes and antimicrobial susceptibility is essential to predict future epidemics and define measures to curtail the disease.
Introduction

Food- and water-borne illnesses are leading public health problems around the world. Although in developed countries the predominant bacterial causes of diarrhoea include pathogens such as Salmonella and Campylobacter spp. (1), in developing countries Vibrio cholerae still remains the top cause of watery diarrhoea (2). V. cholerae is classified to over 200 serotypes on the basis of variations in the lipopolysaccharide somatic antigen (3). V. cholerae belonging to serogroups O1 and O139 has been associated with epidemics and pandemics of cholera due to production of cholera toxin (2–5). Other serotypes are collectively known as non-O1 and non-O139 or non-typeable V. cholerae. A majority of these strains are usually responsible for sporadic cases of diarrhoea (6–8). However, the pathogenic potential of non-O1 and non-O139 V. cholerae should not be underestimated as some strains are clearly pathogenic, due either to cholera toxin production or to other virulence factors such as heat-stable enterotoxin, haemolysin, repeats-in-toxin and type 3 secretion systems (7). Occasionally, these strains are responsible for outbreaks of cholera (9–11). According to the United States Centers for Disease Control and Prevention (CDC), non-O1 and non-O139 V. cholerae are the third most commonly reported group of Vibrio spp., and since the year 2000 they accounted for around 40 cases of diarrhoea per year reported to the CDC (12). Moreover, in immunocompromised people these bacteria have been associated with a severe form of disease that may lead to sepsis and other life-threatening conditions (13–15). The susceptibility pattern of these reported isolates are diverse, showing a varying prevalence of different serovars in different regions.

In Pakistan V. cholerae O1 is one of the commonest organisms responsible for diarrhoeal outbreaks (16). An outbreak of O139 was also reported in 2002 (5). However, data on the isolation rate and antibiotic susceptibility pattern of non-O1 and non-O139 V. cholerae are lacking. Such data are valuable for the empirical treatment of patients in special circumstances and to compare with reports from other countries. This study therefore aimed to evaluate the frequency and antimicrobial profile of non-O1 and non-O139 V. cholerae in Pakistan from stool samples over the years 1999–2012.

Method

Study design and setting

This was a retrospective analysis of antimicrobial resistance among non-O1 and non-O139 V. cholerae strains isolated at the clinical microbiology laboratory of Aga Khan University hospital in Karachi, Pakistan, for diagnostic purposes. This laboratory caters for inpatients as well as outside referrals from other hospitals, clinics and general practitioners across the country. All 95 800 stool samples submitted to the laboratory for analysis from the years 1999 to 2012 were included in the study.

The study protocol and consent procedures were approved by the ethics review committee of the Aga Khan University Hospital. Specific verbal or written consent from patients was not required as the data used were obtained from laboratory records and used anonymously.

Data collection

All stool samples for culture and susceptibility testing were processed according to standard practice and were inoculated on the following media: MacConkey, Salmonella-Shigella, Campylobacter and tellurite taurocholate gelatin agar (TTGA) (Oxoid). Stool samples were also inoculated in selenite F broth and alkaline-peptone water and sub-cultured on solid media after overnight incubation. Suspected colonies from TTGA were biochemically confirmed using analytical profile index 20 Enterobacteriaceae (API 20 E) (BioMerieux). V. cholerae O1 serogroups were performed using polyvalent O1 antisera, for Ogawa and Inaba strains (Murex Diagnostic) and serogroup O139 (Dienka Sieken). Non-O1 and non-O139 V. cholerae were reported when an isolate had a biochemical profile (using API 20 E) of V. cholerae but failed to agglutinate by V. cholerae antisera O1 and O139.

Antimicrobial drug susceptibility assay was performed by the disk diffusion method using commercially available disks (Becton Dickinson; Sparks Glencoe). The antibiotics tested were: ampicillin (10 µg), tetracycline (30 µg), co-trimoxazole (1.25/23.75 µg), chloramphenicol (30 µg) and ofloxacin (5 µg). Since there were no interpretive breakpoints for V. cholerae available in the Clinical and Laboratory Standard Institute guidelines, breakpoints for Enterobacteriaceae were adopted for V. cholerae (17). Escherichia coli (ATCC 25922) strain was used as a quality control.

Data management and statistical analysis

Data extracted from the computerized information system of the hospital were transferred to the statistical software SPSS, version 19.0. Frequencies with percentages for age, seasonal distribution and isolation rate were analysed. The resistance pattern of non-O1 and non-O139 V. cholerae was evaluated among different age groups.

Results

During the study period (1999–2012), a total of 95 800 stool samples for culture and susceptibility testing were processed at the Aga Khan University
Hospital laboratory. The yield of positive samples (isolation of at least 1 diarrhoea-causing bacterial pathogen including Salmonella spp., Shigella spp., V. cholerae, Campylobacter spp. and Aeromonas spp.) was 20 125 (21%). Out of these positive cultures 3668 isolates (18%) were V. cholerae group (Table 1). Throughout the study period (1999–2012) V. cholerae O1 serogroups remained the predominant strain but a changing trend from serotype Ogawa to Inaba was seen in the years 2005–6 and 2012 respectively and again from Inaba to Ogawa was seen in 2007 (Table 1). V. cholerae O139 serogroup emerged only in the years 2000–2002.

Of the total V. cholerae isolates, 233 (6%) failed to show agglutination by O1 (Ogawa, Inaba) and O139 antisera. These isolates were confirmed as V. cholerae by API 20E, and reported as non-O1 and non-O139 V. cholerae. Table 1 shows the annual rate of isolation of non-O1 and non-O139 V. cholerae over the study period; the highest number of cases were seen in the year 2003.

The majority of stool cultures yielding non-O1 and non-O139 V. cholerae (98%) were submitted from different locations of Karachi city. From other locations 1% were isolated from Hyderabad and 0.7% and 0.3% were from Mir Pur Khas and Jacobabad respectively. Demographic data showed that 122 cases (52%) of non-O1 and non-O139 V. cholerae were in children aged ≤ 14 years and 111 (48%) in those aged > 14 years old, and more cases were in males (135, 58%) than females (98, 42%). Seasonal variations in isolation frequency were observed, with the few or no isolates during winter and a maximum rate during summer with peaks from May to August each year (Figure 1).

The annual trend of antimicrobial susceptibility data revealed increasing resistance to antibiotics such as co-trimoxazole and ampicillin. The lowest rate of resistance was observed against ofloxacin, followed by tetracycline and chloramphenicol, as shown in Figure 2. Table 2 shows that for most antibiotics antimicrobial resistance rates were similar between children and older age groups, except for co-trimoxazole which showed higher resistance among children aged ≤ 14 years than adolescent/adults aged > 14 years (52% versus 33%).

**Discussion**

To the best of our knowledge this is the first study reporting the frequency of non-O1 and non-O139 V. cholerae from clinical samples tested at a diagnostic laboratory of Pakistan. We found that the rate of non-O1 and non-O139 V. cholerae remained at a low level (≤ 10%) of the total V. cholerae group throughout the study period except from 2002 to 2004 where an upsurge was observed from...
13% to 27%, with a prominent surge in the year 2003.

Our findings of a low isolation rate of non-O1 and non-O139 V. cholerae from clinical samples (overall 6% of total V. cholerae) is consistent with the sporadic form of diarrhoea caused by endemic strains of non-O1 and non-O139 V. cholerae reported from other countries in the region. A literature search showed Indian studies reporting variable isolation frequencies of non-O1 and non-O139 V. cholerae from clinical samples. For example, 4% and 5% isolation rates of non-O1 and non-O139 V. cholerae were reported from Sevagram in Maharashtra state and Delhi respectively (18,19), and higher isolation rates of 13% and 24% from Kolkata and Hubli respectively (17,20). Similarly, reports from Thailand showed a lower rate of up to 3% of non-O1 and non-O139 V. cholerae among V. cholerae isolates (21).

The increase in frequency of non-O1 and non-O139 V. cholerae noted in 2003 is suggestive of a possible outbreak in that year. Non-O1 and non-O139 V. cholerae strains detected during that period also had unique features of co-trimoxazole resistance of 100% compared with a baseline of 35–40% (Figure 2). A plausible association of this high isolation rate could be related to heavy rainfalls leading to nationwide flooding in 2003. These findings are suggestive of a possible emergence of a novel strain with a unique antibiogram, and perhaps increased pathogenicity, leading to symptomatic disease. Due to the retrospective nature of the study we were not able to perform molecular strain typing and could not retrieve clinical data to confirm the outbreak situation with the novel strain.

Interestingly a majority of non-O1 and non-O139 V. cholerae strains were isolated from stool samples received from Karachi, a coastal city which has a questionable supply of clean drinking water and high rates of enteric fever and other gastrointestinal infections in the community (22,23). Additionally a lack of proper surveillance of diarrhoeal outbreaks leads to paucity of data. Similar upsurges

<table>
<thead>
<tr>
<th>Year of culture testing</th>
<th>Stool culture performed</th>
<th>Stool culture growing diarrhoeal pathogens</th>
<th>V. cholerae among diarrhoeal pathogens</th>
<th>O1 (Ogawa)</th>
<th>O1 (Inaba)</th>
<th>O139</th>
<th>Non-O1 and non-O139</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>4 807</td>
<td>841</td>
<td>317</td>
<td>282</td>
<td>31</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2000</td>
<td>4 806</td>
<td>735</td>
<td>271</td>
<td>213</td>
<td>3</td>
<td>1</td>
<td>39</td>
</tr>
<tr>
<td>2001</td>
<td>5 587</td>
<td>1 108</td>
<td>412</td>
<td>325</td>
<td>2</td>
<td>81</td>
<td>1</td>
</tr>
<tr>
<td>2002</td>
<td>8 062</td>
<td>1 334</td>
<td>229</td>
<td>142</td>
<td>3</td>
<td>55</td>
<td>29</td>
</tr>
<tr>
<td>2003</td>
<td>9 943</td>
<td>2 063</td>
<td>262</td>
<td>182</td>
<td>9</td>
<td>2</td>
<td>69</td>
</tr>
<tr>
<td>2004</td>
<td>4 700</td>
<td>851</td>
<td>98</td>
<td>64</td>
<td>19</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>2005</td>
<td>5 556</td>
<td>2 473</td>
<td>738</td>
<td>2</td>
<td>721</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>2006</td>
<td>6 103</td>
<td>1 441</td>
<td>188</td>
<td>0</td>
<td>181</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2007</td>
<td>6 365</td>
<td>1 084</td>
<td>286</td>
<td>149</td>
<td>122</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>2008</td>
<td>8 267</td>
<td>1 884</td>
<td>238</td>
<td>219</td>
<td>3</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>2009</td>
<td>9 999</td>
<td>2 667</td>
<td>248</td>
<td>223</td>
<td>5</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>2010</td>
<td>7 224</td>
<td>1 343</td>
<td>155</td>
<td>143</td>
<td>3</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>2011</td>
<td>7 597</td>
<td>1 294</td>
<td>152</td>
<td>136</td>
<td>10</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>2012</td>
<td>6 784</td>
<td>1 007</td>
<td>74</td>
<td>15</td>
<td>52</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>95 800</td>
<td>20 124</td>
<td>3668</td>
<td>2095</td>
<td>1162</td>
<td>178</td>
<td>233</td>
</tr>
</tbody>
</table>
in the isolation rate of non-O1 and non-O139 *V. cholerae* have been reported from India during the period 2002–04, showing replacement of predominant *V. cholerae* O1 serotypes (20). These findings suggest the possibility of a regional outbreak with novel serotypes and emphasizes the need for continuous surveillance and monitoring of regional diarrhoeal strains.

Throughout the duration of the current study (1999–2012) *V. cholerae* O1 serogroups remained the predominant serotype. Another interesting finding of our study is related to *V. cholerae* O139. It seems that a new serotype with a different antibiogram (S) had emerged in the year 2000–02. This is comparable with the similar trend reported from India (19). Further comparison of previously published antimicrobial susceptibility data of *V. cholerae* O139 from Pakistan (S) is comparable with India (19) and strains from both regions had a similar susceptibility pattern to reported antimicrobials including co-trimoxazole (S,19).

This again highlights the likelihood of circulation of particular type of *V. cholerae* O139 in the Indian subcontinent during that period. Non-O1 and non-O139 *V. cholerae* were likely to be the origin of the new virulence gene, as emergence of the O139 serovar resulted due to horizontal gene transfer between *V. cholerae* O1 and O22 (24,25). Therefore, continuous monitoring of these serovars will provide valuable information on mechanisms of virulence.

Finally, the current data showed a fluctuating pattern of susceptibility from year to year of non-O1 and non-O139 *V. cholerae* isolates to the antibiotics commonly used against cholera. Low resistance to tetracycline was seen except in the year 2012. Resistance to co-trimoxazole peaked in 2003 and 2012. Therefore with empirical use of World Health Organization recommended drugs such as tetracycline and doxycycline intended for treatment of cholera, continuous monitoring of antimicrobial resistance surveillance should be maintained.

**Conclusion**

In conclusion, this study found that, despite annual fluctuations, the rate of non-O1 and non-O139 *V. cholerae* remained a significant cause of diarrhoeal illness in Pakistan, as it is in neighbouring regions, with the possibility of emergence of novel pathogenic strains. These findings emphasize the need for continuous surveillance of serotypes and monitoring of antimicrobial resistance of regional diarrhoeal strains to predict future epidemics and define measures to curtail the disease. Surveillance data will also provide baseline information to develop empirical antibiotic choice, effective vaccines and preventive strategies.

**Acknowledgements**

We thank the faculty and staff of the department of clinical microbiology of the Aga Khan University Hospital, Karachi, for their support in this study.

**Funding:** None.

**Competing interests:** None declared.
References


