What have we learned about antimicrobial use and the risks for *Clostridium difficile*-associated diarrhoea?

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*Clostridium difficile* is recognized as a major cause of antibiotic-associated diarrhoea and colitis. Antimicrobial agents have been repeatedly recognized as a causative risk for *C. difficile*-associated diarrhoea (CDAD) and more recently fluoroquinolones have been particularly implicated. Unfortunately, not all reports of antimicrobial associations with CDAD have excluded variables other than antimicrobial use. Prevention of CDAD usually involves infection control interventions and antimicrobial restriction policies may not be fully substantiated by currently available data; however, antimicrobial drug restriction seems prudent in outbreak situations.

Keywords: antibiotics, hospital-acquired CDAD, anaerobes

Introduction

*Clostridium difficile* is an anaerobic Gram-positive spore-forming bacillus. It persists for an extended duration in the environment and may colonize humans without clinical disease. As an opportunistic pathogen, *C. difficile* is the major cause of antibiotic-associated diarrhoea and colitis.1 The prevalence and epidemiology of *C. difficile*-associated colitis is global. The incidence varies considerably but is increasing worldwide due to broad-spectrum antimicrobial use.2 Oldfield3 estimated that annually in the USA, there were an estimated 3 million cases of *C. difficile*-associated diarrhoea (CDAD) costing ~1 billion dollars in healthcare expenses. CDAD is a recognized cause of hospital-acquired infectious diarrhoea; however, many cases of hospital-acquired diarrhoea do not have an established aetiology. Patel1 indicated that the financial consequences of CDAD are considerable and in the UK in 2005, CDAD is thought to have cost the National Health Service £200 million and resulted in the need for 1 million extra bed-days. Risk factors associated with hospital-acquired *C. difficile*-associated colitis include: antimicrobial use; advanced age (>65 years); laxative use; proton pump inhibitors; anti-neoplastic chemotherapeutic use; renal insufficiency; gastrointestinal surgery/procedures; severity of underlying disease; nasogastric intubation; gastric acid suppressants; duration of hospital stay; duration of antibiotic course; multiple antibiotics; and prolonged hospital stay.4–8

*C. difficile* is estimated to colonize 3% of healthy adults and 15% to 25% of hospitalized patients.9–12 The incidence of CDAD ranges from 1 to 30 cases per 1000 hospital discharges.13 Raveh et al.14 commented that for *C. difficile* to colonize the gut of a normal individual, the resident normal flora must be altered.15 Anaerobic gut flora are thought to be crucial to ‘colonization resistance’; however, the precise components involved have not yet been clearly defined. Raveh et al.14 evaluated the risk factors for *C. difficile* toxin-positive nosocomial diarrhoea. They compared parameters from over 530 patients of whom 17% had positive toxin tests and 83% negative toxin tests. Patients who were toxin positive: were older (*P* < 0.001), more often from nursing homes (*P* < 0.05), had higher leucocyte counts (*P* < 0.001), had higher blood urea nitrogen (*P* < 0.01), lower serum albumin (*P* < 0.01), more often received diuretics (*P* < 0.01) and received clindamycin (*P* < 0.05). By logistic regression analysis, previous antibiotic-associated diarrhoea was the most significant risk factor for toxin-positive diarrhoea (*P* < 0.001) followed by clindamycin therapy (*P* < 0.005), diuretics (*P* < 0.005) and older age (*P* < 0.05). Macrolides (*P* < 0.05) were also shown to contribute to the development of hospital-acquired diarrhoea.
Pathogenesis

Elliott et al.\textsuperscript{16} indicated that disruptions of normal colonic flora appear to be essential to the pathogenesis of \textit{C. difficile} infection. Colonization resistance is the term for the mechanism by which indigenous flora controls colonization by \textit{C. difficile}\.\textsuperscript{17} As such, colonization resistance may be compromised by antimicrobial compounds, illness or by therapeutic procedures.

The pathogenesis of infections with \textit{C. difficile} clearly begins with the ingestion of either vegetative organisms or with spores. Spores are non-vegetative forms that persist in the environment for extended periods and are difficult to eradicate. Spores survive gastric acidity, germinate in the colon to vegetative organisms and toxin-producing strains subsequently produce toxin. Toxins A and B lead to tumour necrosis factor production, pro-inflammatory interleukins and increased vascular permeability. This results in colitis, pseudomembrane formation and watery diarrhoea.\textsuperscript{18,19} Toxin production is associated with clinical disease in ‘infected’ patients. Clinical symptoms include diarrhoea, fever, faecal leucocytes, cramping and dehydration. Potentially significant complications include hypoalbuminaemia, toxic megacolon, colonic perforation and pseudomembranous colitis. According to Poutanen and Simor,\textsuperscript{19} severe cases of toxic megacolon may be associated with mortality rates of 24% to 38%. The factors impacting patients being asymptomatically colonized may include:\textsuperscript{20}

- organism virulence,
- degree of disruption to the host’s normal flora,
- host factors (i.e. immune response)

Two studies, published several years ago, suggested that IgG antibody against toxin A was more commonly seen in asymptomatic carriers than those with CDAD ($P < 0.001$) and that high IgM antibody levels to surface layer proteins of \textit{C. difficile} were associated with protection against recurrent CDAD.\textsuperscript{21,22}

Antimicrobial use and CDAD

Antimicrobial use and the association with CDAD remains a significant issue and Oldfield\textsuperscript{3} indicated it was more commonly associated with ampicillin, clindamycin and cephalosporins.

Akbar \textit{et al.}\textsuperscript{23} reported on a case of pseudomembranous colitis 3 months after the start of rifampicin therapy for tuberculous abdominal lymphadenopathy and suggested that clinicians should be aware of this serious complication of rifampicin therapy.

According to data reviewed and summarized by Elliott \textit{et al.}\textsuperscript{16} and Tedesco \textit{et al.},\textsuperscript{24} they showed the association between clindamycin and pseudomembranous colitis and this agent was the highest risk agent in the 1970s; a subsequent decline in use reduced attributable risk.\textsuperscript{25} Throughout the 1980–1990s, third-generation cephalosporins were associated with the highest relative risk and continue as a significant risk today.\textsuperscript{25}

The role of fluoroquinolone use and the risks for CDAD have emerged in numerous peer-reviewed reports.\textsuperscript{26–31} As ‘newer’ fluoroquinolones (i.e. moxifloxacin and previously gatifloxacin) exhibit better \textit{in vitro} activity against anaerobic organisms than do the older quinolone compounds,\textsuperscript{32} there was some suggestion that these agents may have different effects on intestinal flora and, therefore, have a greater likelihood for CDAD.\textsuperscript{30} Preliminary data from three studies appeared to support this hypothesis.\textsuperscript{30,33,34}

Initially, a study by Yip \textit{et al.}\textsuperscript{26} identified an association between ciprofloxacin use and CDAD and another report by Gaynes \textit{et al.}\textsuperscript{30} reported on an outbreak of CDAD in a long-term care facility that was associated with a formulary change from levofloxacin to gatifloxacin.

Barbut \textit{et al.}\textsuperscript{35} investigated CDAD in a 760 bed teaching hospital in Paris. Of 151 cases, 147 cases could be reviewed and 131 bacterial strains were studied. The overall incidence of CDAD was 1.1 cases/1000 patients admitted. A total of 28 patients had community-acquired diarrhoea. For patients with healthcare-associated diarrhoea, transmission of a strain from patient to patient was demonstrated in 12 cases.

Cherifi \textit{et al.}\textsuperscript{36} described a nosocomial outbreak of CDAD in a geriatric department of a tertiary care teaching hospital in 2003. The incidence of CDAD increased from 27 cases/100 000 patient days to 99/100 000 patient days during the outbreak. A total of 21/92 patients in four geriatric wards—two geographically distinct sites that were staffed by the same medical team—were involved. A total of 5/21 patients had community-acquired diarrhoea and secondary hospital transmission resulted in three clusters involving 16 patients: 16/19 isolates were the same serotype. Management of the outbreak involved reinforcement of contact isolation precautions for patients with diarrhoea, cohorting of infected patients in the same ward and promotion of hand hygiene; antimicrobial restriction and changes in antimicrobial use were not implemented; however, the authors suggested that as past exposure of antimicrobials was a major risk factor for CDAD, active surveillance of antibiotic consumption will be left in place to limit duration of therapy and promote early switch from intravenous to oral treatment. In this study, only 4/21 patients had received quinolone antimicrobials alone and 5/21 had received quinolone antimicrobials in combination with other antimicrobial agents; 15–21 patients had received either a β-lactam alone or in combination with other antimicrobial compounds. This outbreak did not appear to be related to any change in antimicrobial use but may have been related to organizational changes in the geriatric wards. As well, sharing of common rooms, toilets and showers was more common in elderly geriatric wards than in other wards.

Yam and Smith\textsuperscript{18} commented on the selection of antimicrobial compounds for orthopaedic patients and the increasing incidence of \textit{C. difficile} infections. They suggested that prolonged therapy with broad-spectrum antimicrobials results in unavoidable collateral damage. The primary culprits for \textit{C. difficile} infection were clindamycin, cephalosporins and extended-spectrum penicillin.

Biller \textit{et al.}\textsuperscript{37} reported on moxifloxacin therapy as a risk factor for \textit{C. difficile}-associated disease during an outbreak at an acute care, non-teaching, community hospital in central Pennsylvania. The outbreak began after a hospital formulary substitution from levofloxacin to moxifloxacin for the treatment of respiratory tract infections. By univariate analysis, the following were identified as significant risk factors in \textit{C. difficile} cases ($n = 50$) versus controls ($n = 100$): deficiency anaemia ($P = 0.021$), fluid and electrolyte disorders ($P = 0.04$), uncomplicated diabetes ($P = 0.02$), hospitalization within 6 months of admission ($P \leq 0.001$), moxifloxacin use ($P = 0.004$) and type II histamine antagonistic or proton pump inhibitor use showing a tendency towards significance ($P = 0.06$). By multivariate analysis, hospitalization within the previous 6 months ($P < 0.001$), moxifloxacin exposure ($P = 0.01$) and uncomplicated diabetes ($P = 0.02$) were independently associated with CDAD.
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while the use of any cephalosporin, fluoroquinolone, macrolide or penicillin or the use of cefazolin, ciprofloxacin, clindamycin, ceftriaxone, levofloxacin or vancomycin were identified as risks. Specific histories of drug use in the 20 patients receiving moxi-
floxacin were not given—particularly in the period leading up to the outbreak. The authors indicated that switching from moxi-
floxacin to levofloxacin failed to control the outbreak and that this may relate to increased levofloxacin use during the interven-
tion period. Indeed, all antimicrobial use increased in the pre-
outbreak period (just over 800 DDD/1000 to ∼1100 DDD/1000 patient days—estimated from graph) with intermittent fluctua-
tions. The increase in the monthly CDAD rates between January and February 2005 was preceded by a spike in overall antimicrobial use from September—October 2004 to November—
December 2004 (∼1000 DDD/1000 to ∼1300 DDD/1000 patient days). The precise role of any fluoroquinolone in this outbreak
remains unclear and further data evaluations—if available—may be necessary to resolve this point. The authors in conclusion noted that further research was necessary to determine the role of specific antimicrobial intervention in controlling outbreaks. The authors also noted that ‘recommended enhanced infection control measures’ should be implemented during outbreaks.5,38 Finally, Biller et al.37 suggested that an assessment of ‘all antimicrobial exposures’ among CDAD patients and reviews of specific antimicrobial classes may be useful to reduce unnecessary use. Muto et al.39 reported that exposure to levofloxacin was an independent risk factor for CDAD and appeared to contribute substantially to an outbreak at a teaching hospital and that restriction in levofloxacin use (and other implicated antimicrobials—i.e. clindamycin) may be necessary to control the outbreak.

Recently, Dhalla et al.31 asked ‘Are broad-spectrum fluoro-
quinolones more likely to cause Clostridium difficile-associated disease?’ To address this question, the authors utilized a population-based case-controlled study of outpatients prescribed fluoroquinolones—the first such study conducted. Over a 3 year period, 96 individuals hospitalized with CDAD within 1 month of outpatient treatment with a fluoroquinolone were compared with 941 matched controls that had received fluoroquinolone therapy but were not hospitalized. No statistically significant increased risk of CDAD was seen among patients prescribed gatifloxacin or moxifloxacin when compared with levofloxacin. The authors concluded that this large population-based investiga-
tion of outpatients prescribed fluoroquinolones showed that there was no increased risk of CDAD in patients receiving gati-
floxacin or moxifloxacin when compared with levofloxacin. In a discussion of their findings, the authors noted that their results differed from those of Loo et al.34 that reported gatifloxacin and moxifloxacin were collectively almost six times more likely than levofloxacin to be associated with CDAD. Dhalla et al.31 argued that a single, predominantly clonal outbreak was in no way the same observation as a 3 year population-based outpatient study. Dhalla et al.31 noted that the study of Gaynes et al.,30 reporting an increased risk of CDAD with gatifloxacin use, was uncon-
trolled and prone to multiple temporally confounding influences.

McDonald et al.40 reported on an epidemic, toxin gene
variant strain of C. difficile. In this study, 187 C. difficile isolates were collected from eight healthcare facilities in six states where outbreaks (2000–2003) of CDAD were reported. This same strain was associated with outbreaks in Canada and Europe.34,41 Bacterial strains were analysed by pulsed-field gel electro-
phoresis (PFGE), restriction-endonuclease analysis (REA) and

Prevention of CDAD

Oldfield3 suggested that to prevent CDAD, education and better compliance with isolation, use of gloves and hand washing were necessary. Control appears to be based on initiation or

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reinforcement of infection control practices rather than drug restrictions. Accordingly, efforts to prevent CDAD include education, better compliance with isolation, use of gloves and hand washing. McFarland et al.33 showed that 20/34 hospital staff members caring for patients with CDAD had C. difficile on their hands. As well, environmental contamination is considered to be an important factor for nosocomial infection.33,44 Kuiper et al.45 commented that ‘hospital hygiene/infection control department plays a central role in the prevention of nosocomial infections and thus a major role in the prevention of CDAD by ensuring adequate isolation of affected patients, institution of precautions and formulation of practice guidelines’. Appropriate and adequate cleaning of the hospital environment is important for prevention of CDAD, especially as Kuiper et al.45 indicated that 30% to 60% of sites in hospital wards were contaminated with C. difficile spores. Kuiper et al.45 also indicated that up to 50% of all antibiotic usage in hospitals is inappropriate; however, proof of this was not provided. Reducing antimicrobial use arguably would reduce antimicrobial-resistant organisms—a desirable goal. Clearly, hand decontamination through proper hand washing and glove utilization may impact on controlling C. difficile transmission within healthcare environments.

Conclusions

What do we now know about CDAD? Ingestion of vegetative organisms or spores is important for pathogenesis; however, only patients with identified risks have CDAD. These organisms are acquired from the environment and from healthcare providers. Clearly, CDAD is an important infectious complication associated with antimicrobial therapy of both inpatients and outpatients and is associated with substantial morbidity and mortality. As summarized, many predisposing factors contribute to ‘at risk’ patients. Antimicrobial therapy and the risks for CDAD is a ‘hot’ topic and most recently, fluoroquinolone use is being closely scrutinized. Thomas et al.46 conducted a systematic review of antimicrobial use and CDAD and reported that 41 of 48 studies that found an increased risk of CDAD with antimicrobial exposure had major weaknesses. The two studies that had ‘less serious threats to validity’ were by McFarland et al.43 and Chang and Nelson.47 The report of McFarland et al.43 found an increased risk for CDAD after cephalosporin exposure for up to 1 week and penicillin exposure for up to 2 weeks. Chang and Nelson47 ‘provided precise estimates of the effect of clindamycin and increased numbers of antibiotics adjusted for age, length of stay and proximity to patients with CDAD’, however, adjustments for co-morbidities were not done. Thomas et al.46 concluded that despite a large number of published studies supporting the association of various antimicrobial agents with hospital-acquired CDAD, well-designed epidemiological studies are lacking.

Inappropriate antimicrobial use is of concern, but not easily fixed as empirical use is common, based on clinical impressions and often without decision-influencing data such as the results of laboratory investigations. As with all pharmaceutical products, use is based on a ‘risk–benefit’ ratio and if the perceived or known benefit is such that the product is utilized, risks associated with the product use are accepted as part of the patient management. While CDAD is recognized as a potential risk following antimicrobial exposure, so is the potential for secondary infection (nosocomial?) with drug-resistant organisms, fungal infections and drug-associated side effects.

There remains little doubt that antimicrobial use increases the risks for CDAD and that certain compounds or classes of compounds are potentially associated with an increased risk. However, the exact role (risk) of each compound or class remains unresolved due to a lack of well-designed prospective studies. Ongoing investigation and outbreak reports may further resolve this point. Antimicrobials and the risks for CDAD remain very topical and undoubtedly there is more to follow with well-designed prospective studies. Until such time and likely after the completion of well designed and controlled studies, the role of infection control initiatives cannot be overstated.

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