Clinical outcomes of campylobacteriosis: a case series analysis of hospitalisations associated with the Havelock North *Campylobacter* outbreak

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ABSTRACT

AIM: In August 2016, a large waterborne campylobacteriosis outbreak occurred in Havelock North, New Zealand. This analysis describes the clinical complications of cases admitted to hospital as a result of acute infection, identifies risk factors for hospitalisation and compares deaths between hospitalised and non-hospitalised cases. Hospital admissions with post-infectious sequelae were excluded as they are the subject of a separate analysis.

METHODS: A case series analysis was undertaken by reviewing the electronic medical records of 933 residents of Hawke's Bay District Health Board with probable and confirmed campylobacteriosis linked to the Havelock North *Campylobacter* outbreak.

RESULTS: A total of 67 hospital admissions, among 58 individuals, are described. Pre-existing comorbidity and advanced age were significant risk factors for hospital admission in univariate analysis. Dehydration (74.1%), electrolyte imbalance (35.8%) and acute kidney injury (27.6%) were common among hospitalised cases. The proportion of hospitalised cases that died within one year was significantly higher when compared to deaths among non-hospitalised cases (OR 5.0, 95% CI: 2.3–10.7), although this trend was not statistically significant after adjusting for age and comorbidity (OR 2.3, 95% CI: 0.96–5.3).

CONCLUSIONS: This study highlights the serious health impacts that occurred from a campylobacteriosis outbreak of this magnitude.

Campylobacter infection is a major cause of enteric illness (campylobacteriosis) worldwide. In developed countries, it remains the leading cause of culture-confirmed bacterial gastroenteritis,[1] and although campylobacteriosis is a self-limiting illness for most, serious complications, including haemorrhagic colitis and bacteraemia, are known to occur.[1]

The association between campylobacteriosis and post-infectious sequelae, including Guillain–Barré syndrome, have been widely described in the literature, including in New Zealand.[2] However, studies that focus on short- and medium-term clinical outcomes associated with campylobacteriosis are often limited by small sample size or rely on diagnostic information coded within routinely collected administrative health datasets.[3–6]

In August 2016, a large waterborne *Campylobacter* outbreak occurred following contamination of the reticulated, unchlorinated water supply in Havelock North, a town of approximately 14,000 residents in the Hawke's Bay Region. *Campylobacter jejuni* was implicated through epidemiological and microbiological investigation.[7] The Havelock North *Campylobacter* outbreak

(HNCO) has been described in detail elsewhere.[7,8] In brief, contamination of the ground water supply likely arose following a heavy rainfall event that resulted in infiltration of sheep faecal matter into the Heretaunga Plains aquifer from an agricultural field adjacent to the twin bore heads that supplied drinking water for the Havelock North township.

It is estimated that the HNCO resulted in between 6,260 and 8,320 people becoming unwell with symptoms of campylobacteriosis, including 953 residents or visitors to the area who had physician- or laboratory-confirmed illness. At the time of the outbreak, 42 hospitalisations were reported to the Hawke's Bay public health unit (HBPHU) linked to the outbreak.

This retrospective case series aims to (1) describe the clinical complications related to acute infection that resulted in hospitalisation and were attributable to the HNCO, (2) identify risk factors for hospitalisation among campylobacteriosis cases and (3) investigate the association between hospitalisation and all-cause mortality at both eight weeks and one year.

Methods

Case identification

As campylobacteriosis is a notifiable disease in New Zealand, physicians and laboratories are required by law to report all cases to the public health unit (PHU) responsible for the geographical location of the case. Standardised demographic and clinical information from all reported cases, including whether cases are linked to a known outbreak, are stored in the national notifiable disease surveillance database (EpiSurv). The Hawke's Bay District Health Board (HBDHB) is responsible for providing or funding the public healthcare services for the approximately 165,000 residents of Hawke's Bay and has a PHU responsible for the same population.

Consistent with the case definitions used in other studies of the HNCO, probable cases were defined as individuals who reported exposure to the Havelock North reticulated water supply during the likely period of *Campylobacter* contamination (5–12 August 2016) and subsequently developed onset of clinician-confirmed diarrhoea during the outbreak period (7–24 August 2016). In addition to these criteria, confirmed cases were required to have a faecal specimen that was positive for *Campylobacter*. The methodology for defining the outbreak period and case definitions for the HNCO has been described in more detail elsewhere.[7]

Individuals included in this case series were identified in two ways. Firstly, all probable and confirmed cases of campylobacteriosis that had a residential address within the HBPHU area and were linked to the HNCO were extracted from EpiSurv. This process identified 930 individuals for inclusion in this case series. Twenty three of the 953 cases linked to the HNCO in EpiSurv were excluded because their usual residential addresses were outside of the HBPHU area.

In addition to these 930 included cases, active case finding identified a further three probable cases to form a case series of 933 individuals (204 confirmed cases and 729 probable cases). Active case finding was undertaken to identify any hospitalised cases that were not notified to HBPHU at the time of the outbreak and therefore not captured by EpiSurv. This search was done by manually reviewing all inpatient admissions to HBDHB healthcare facilities between 7–31 August 2016 that listed *Campylobacter* enteritis, or a related complication, as the primary reason for admission based on International Classification of Disease (ICD) coding. A list of ICD codes used for active case finding is available in the supplementary material.

Clinical data extraction

A qualified research nurse reviewed the electronic medical records of all 933 individuals in this case series. This review included all available hospital discharge summaries, specialist outpatient clinic letters, referrals to specialist services and laboratory results. Records from general practice visits are not held by HBDHB and were not reviewed.

Age, sex, ethnicity and Charlson Comorbidity Index (CCI) were manually extracted for all cases. The date of death of those who were deceased at the time of review was also extracted. Prioritised ethnicity was used to categorise cases into one of three groups,

Māori, Pacific Peoples or New Zealand European and Other, according to the Ministry of Health Ethnicity Data Protocols. CCI is a standardised measure of comorbidity based on ICD coding and produces a comorbidity score that has been validated to predict mortality across a range of health research settings.[8] A score of 0 indicates no comorbidity and scores above 0 correlate with higher predicted mortality risk. CCI scoring in this study was based on a review of documented comorbid diagnoses in hospitalisation and outpatient clinic records using a 10-year review period, from August 2007 to August 2016, with weightings assigned as outlined by Sundararajan et al.[8]

Hospital-based electronic medical records for admissions among cases that occurred within the approximate eight-week period following the HNCO (7 August–31 September 2016) were then reviewed in detail to identify those relating to campylobacteriosis. Hospital admissions were defined as emergency department or inpatient service events that lasted for more than three hours.

All hospital admissions that listed symptoms or complications of campylobacteriosis as the primary reason for admission were classified as attributable to the HNCO. Admissions were considered partially attributable if symptoms or infective complications were present but not the primary reason for admission. Post-infectious sequelae (eg, Guillain–Barré, reactive arthritis) were excluded as they are the subject of a separate analysis. Two confirmed cases had hospital admissions (one admission each) that were deemed not attributable to the HNCO and were excluded from analysis as they had systemically recovered from their acute infection at the time of admission and there was clear documentation within their clinical notes that the reason for admission was not related to their recent acute infection.

For all attributable and partially attributable hospital admissions the following information was collected: date of admission, primary and secondary reasons for admission (ICD coded), length of stay (days) and prevalence of the following complications (yes/no): dehydration, electrolyte disorders, acute kidney injury, bacteraemia, acute lower-gastrointestinal bleeding, colitis and requirement for intensive care unit (ICU) support. The research criteria used to define these conditions are included in supplementary material.

Statistical analysis

Risk factors for hospitalisation were first investigated with univariate analysis using Pearson chi-square statistic. To account for interaction between risk factors, adjusted odds ratios (OR) were calculated using a multivariable logistic regression model. Risk factors that were significant in univariate analysis were included, with age (categorical) and CCI (categorical) included in the final model.

The proportion of hospitalised cases that experienced specific complications (eg, dehydration) were calculated on a per-case rather than per-admission basis, meaning cases that were admitted twice with the same complication counted once in the numerator. Confidence intervals (CI) around proportions were calculated using the two-sided exact (Clopper–Pearson) binomial method.

Multivariate logistic regression, adjusted for the confounding effects of age and CCI, was used to investigate whether hospitalisation from campylobacteriosis was associated with all-cause deaths at eight weeks and one year post outbreak.

Interaction terms were initially included in all multivariate models but did not substantially alter the pattern of model outputs, so they were removed. Data analysis was undertaken using IBM SPSS Statistics 22. Statistical significance for all tests were set at the ≤0.05 level.

Ethics

This study was approved by the New Zealand Health and Disability Ethics Committee (18/NTA/155) with locality approval granted by HBDHB.

Results

Risk factors for hospitalisation

Of the 933 individuals included in this case series, 58 patients were admitted to Hawke's Bay hospital with complications of acute infection that were attributable or partially attributable to the HNCO. This number equates to a risk of hospitalisation with acute illness among reported cases of

6.2% (95% CI: 4.8–8.0). Table 1 compares the demographic characteristics of hospitalised and non-hospitalised cases. Hospitalised cases were significantly older with a higher level of comorbidity, when compared with non-hospitalised cases.

Age and CCI were both highly associated with the risk of hospitalisation in univariate analysis. Using multivariate analysis to adjust for the effect of age demonstrated that, in comparison to those with a CCI of 0, the risk of hospitalisation was approximately 2.9-times higher in those with a CCI of 1 or 2 and approximately 4.7-times higher in those with a CCI of 3 or more (Table 2). There was also a trend towards increased risk of hospitalisation with advanced age, although after adjustments for CCI in multivariate analysis, this association was not statistically significant.

Acute complications requiring hospitalisation

Dehydration (74.1%), electrolyte disorders (35.8%) and acute kidney injury (23.9%) were common complications among cases admitted to hospital (Table 3).

Based on Kidney Disease: Improving Global Outcomes (KDIGO) scoring, seven of the 16 cases that were hospitalised with an acute kidney injury were classified as stage 1, three were classified as stage 2 and six were classified as stage 3. Two cases, one with pre-existing chronic kidney disease, required renal replacement therapy with dialysis.

Five cases were admitted with lower gastrointestinal bleeding, one of which was classified as severe (haemoglobin drop of >30gm/L); all resolved without endoscopic or surgical intervention. Of the cases that developed bacteraemia (n=5), none experienced serious end-organ sequelae (eg, endocarditis).

Two patients required support within ICU, which equates to a probability of needing ICU support if hospitalised of 3.4% (95% CI: 0.4%–11.9%). There was one inpatient death as a result of an acute stroke event which occurred 10 days into an admission for the management of diarrhoea, dehydration and frailty.

Hospitalisation events

A total of 67 hospitalisation events were attributable (n=55) or partially attributable (n=12) to acute infectious complications of campylobacteriosis related to the HNCO. This total included nine re-admission events. Figure 1 shows the date of admission for all hospitalisations, with the majority (85.1%) occurring within the outbreak period, 7–24 August.

Length of stay varied significantly; of the 55 hospital admissions that lasted over 24 hours, the median length of stay was three days (interquartile range: four days). The longest hospital admission was 111 days, with the prolonged length of stay driven by multiple complications following pancolitis and multi-organ failure.

Deaths

HBPHU received reports of four deaths in which campylobacteriosis was found to be a contributing cause of death (two in hospitalised cases, two in non-hospitalised cases). Unadjusted all-cause deaths were higher among hospitalised cases when compared to non-hospitalised cases; although this was not statistically significant at eight weeks (OR 3.9, 95% CI: 0.8–18.7), it was at one year (OR 5.0, 95% CI: 2.3–10.7).

After adjustments for the confounding effects of age and CCI, this trend remained, although it was not statistically significant at either eight weeks (OR 1.5, 95% CI: 0.28–7.8) or one year (OR 2.3, 95% CI: 0.96–5.3).

Discussion

We describe 58 individuals who required hospitalisation due to acute illness in a case series of 933 people with probable or confirmed campylobacteriosis arising from a large waterborne outbreak. Key findings of this study include that age and comorbidity were significant risk factors for hospitalisation; dehydration and associated acute kidney injury were common among hospitalised cases; and unadjusted all-cause deaths were higher at eight weeks and one year among hospitalised cases compared to non-hospitalised cases.

Our finding of 58 individuals hospitalised is an increased estimate from previous publications about the HNCO, which report 42 people hospitalised.[7] Although not directly comparable as our analysis only includes HBDHB residents and includes both attributable and partially attributable hospitalisations, it is likely that the reliance

Table 1: Demographic characteristics of hospitalised cases, compared to non-hospitalised cases, in a series of 933 probable and confirmed campylobacteriosis cases.

	Hospitalised cases, n (% of row total)	Non-hospitalised cases, n (% of row total)	Total cohort, n
Sex			
Female	25 (5.1)	464 (94.9)	489
Male	33 (7.4)	411 (92.6)	444
Ethnicity			
Māori	6 (6.0)	94 (94.0)	100
Pacific peoples	1 (7.1)	13 (92.9)	14
New Zealand European and Other	51 (6.2)	768 (93.8)	819
Age*			
<5	1 (1.7)	59 (98.3)	60
5–14	2 (1.9)	102 (98.1)	104
15–34	6 (3.3)	174 (96.7)	180
35–64	15 (5.9)	240 (94.1)	255
65–84	20 (8.4)	217 (91.6)	237
85+	14 (14.4)	83 (85.6)	97
Charlson Comorbidity Index*			
0	27 (3.8)	691 (96.2)	718
1-2	17 (12.2)	122 (87.8)	139
3+	14 (18.4)	62 (81.6)	76
Total	**58 (6.2)**	**875 (93.8)**	**933**

*Age and Charlson Comorbidity Index were both associated with hospitalisation (Chi-square test of association p=0.001).

Table 2: Risk factors for hospitalisation in series of 933 probable and confirmed campylobacteriosis cases.

	Adjusted OR for hospitalisation, OR (95% CI)**
Charlson Comorbidity Index	
CCI=0	Reference
CCI=1–2	2.9 (1.4–5.9)
CCI=3+	4.7 (2.0–10.7)
Age	
0–34 years	Reference
35–64 years	1.9 (0.8–4.4)
65–84 years	1.8 (0.7–4.4)
85+	2.3 (0.8–6.6)

**CCI adjusted for age, and age adjusted for CCI.

Table 3: Proportion of cases and admissions with specific complications in a series 58 hospitalised campylobacteriosis cases.

	Number of hospitalised cases	**Number of admissions**	**Proportion of hospitalised cases affected, % (95%CI)**
Dehydration	43	45	74.1 (61.0–84.7)
Electrolyte disorders	21	24	35.8 (24.5–48.5)
Acute kidney injury	16	16	27.6 (16.7–40.9)
Bacteraemia	5	5	8.6 (2.9–19.0)
Acute lower-gastrointestinal bleeding	5	5	8.6 (2.9–19.0)
Colitis	3	3	5.2 (1.1–14.4)
Total	**58**	**67**	

Figure 1: Hospitalisations (N=67) attributable or partially attributable to HNCO, showing date of admission or readmission, 7 August–30 September 2016.

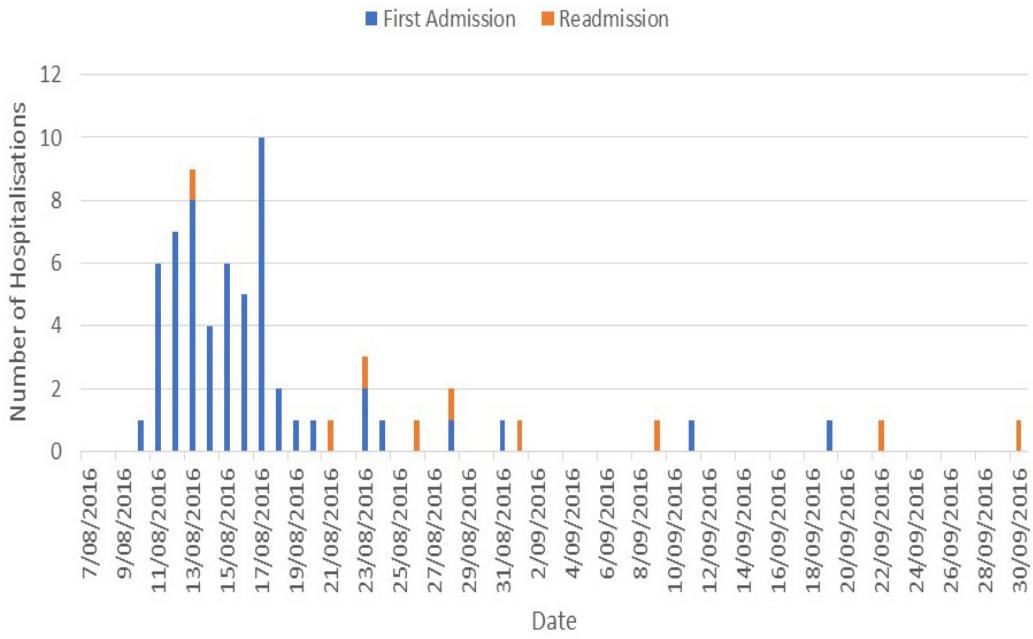

Table 4: All-cause deaths at eight weeks and one year in series of 933 probable and confirmed campylobacteriosis cases.

Hospitalised	Died within eight weeks	Died within one year***
Yes (n=58)	2 (3.4)	10 (17.2)
No (n=875)	8 (0.9)	35 (4.0)
Total (n=933)	**10 (1.1)**	**45 (4.8)**

*** Includes those who died within eight weeks.

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on passive notification data in previous publications have underestimated the burden of hospitalisations associated with the outbreak.[7,9]

A unique feature of this waterborne outbreak is that the majority of the outbreak cohort are likely to have been exposed to *Campylobacter* in their drinking water supply over several days prior to chlorination of the water supply and the issuing of a boil water notice.[10] However, the proportion of cases hospitalised in this outbreak cohort (6.2%) is broadly similar to the 5.4% of cases that were reported as hospitalised in a national analysis of notified campylobacteriosis cases in New Zealand between 1999 and 2003.[11]

Patient comorbidity was a strong predictor of hospitalisation in this study. Those with a CCI score of three or more were approximately five-times more likely to be hospitalised in comparison to those with a CCI score of 0. Older age was also a strong predictor of hospitalisation, although the effect size is potentially underestimated in this analysis given active case finding was undertaken in residential care facilities during the HNCO, meaning it is possible that more complete case finding and a greater proportion of mild illness was captured in the over 65 cohort. A large Swedish study of notified sporadic *Campylobacter jejuni* cases found that those over 60 years of age had approximately double the risk of hospitalisation and that underlying patient comorbidity increased the risk by approximately four times.[6]

Of note was the relatively low proportion of hospitalisations among children in this outbreak (1.8% of those <15 years were hospitalised). This proportion is half of that reported in a previous population study of campylobacteriosis notifications in New Zealand between 1997 and 2015 (which found that 3.6% of cases in children <15 years were hospitalised).[12] It is unclear whether this disparity relates to differences in case notification procedures, better access to primary care treatment or less-severe clinical disease among children during this well-publicised outbreak.

The complications and hospitalisations described in this analysis confirm that campylobacteriosis can result in serious illness. Approximately one quarter (27.6%) of hospitalised patients had an acute kidney injury on admission, with dehydration being a significant underlying factor in most cases. This finding emphasises the importance of proactive fluid management of medically vulnerable individuals as part of campylobacteriosis outbreak response measures. During the HNCO, general practices serving the Havelock North population initiated phone triaging services for those experiencing gastroenteritis symptoms.[9] Data manually collected during the outbreak indicated that gastroenteritis-related general practice consultations (phone and in-person) peaked early in the outbreak, at 289 consultations per day, before rapidly declining over the first week.[9] General practices were able to provide intravenous fluid rehydration for those more seriously affected, and it is likely that without the significant response from both general practices and community pharmacies the number of individuals requiring hospitalisation would have been higher.[9,13]

We estimate *Campylobacter* bacteraemia occurred in 7.5% of hospitalised cases (0.5% of total reported cases), although this may well be an underestimate given that not all cases received blood cultures. This proportion compares to crude estimates of between 0.4% and 1% of notified cases in Sweden, 0.3% in Finland and 0.4% in Denmark.[14–16] Although traditionally associated with individuals who are elderly or immunocompromised, bacteraemia is known to occur in otherwise healthy individuals.[1,16] In our cohort, all patients with diagnosed bacteraemia were over 80 years of age.

To our knowledge, this is the first publication to compare all-cause deaths among cases hospitalised with campylobacteriosis to non-hospitalised cases at eight weeks and one year. Hospitalisation in this context is a proxy for severity of illness, although it is also heavily influenced by factors such as age and comorbidity, which were found to significantly affect the risk of hospitalisation.

In this cohort, the unadjusted risk of death at one year among hospitalised cases was approximately five times that of non-hospitalised cases. Although the trend towards excess deaths in hospitalised cases remained

after adjustments for age and CCI score, this trend was not statistically significant. However, utilising hospitalisation as a proxy for severity of infection in this analysis likely underestimated the true effect difference, given there were a small number of deaths that were directly attributable to campylobacter infection in individuals who died without being hospitalised (two deaths in non-hospitalised cases occurred in residential care settings).

These findings raise the possibility that campylobacteriosis, traditionally thought of as a self-limiting illness, can have persisting impacts on mortality in medically vulnerable populations. There are biologically plausible mechanisms, such as increased frailty following acute illness, that may mediate poorer medium-term survival following severe systemic infection.[18] Increased all-cause mortality has been described among domestically acquired campylobacteriosis cases in Sweden, compared to the general population at one month post notification (SMR 2.9, 95% CI: 1.9–4.0), although this effect decreased over time and no significant differences were apparent in mortality rates at one year (SMR 1.0, 95% CI: 0.9–1.1).[19]

Strengths and limitations

This study was able to follow a cohort of outbreak-associated cases of campylobacteriosis to generate a robust estimate of the acute infectious complications that arose. Strengths include the large, well-defined outbreak cohort and utilising a comprehensive review of electronic hospital records to estimate the frequency of complications rather than relying on diagnostic coding in administrative health datasets. The design of the case series is a key limitation. Ideally, analysis of deaths would have been undertaken by comparing cases and controls, rather than comparing hospitalised and non-hospitalised cases. In addition, health records for admissions in private hospitals or public hospitals outside HBDHB were not able to be reviewed. Although the impact of this has been minimised by limiting this case series to HBDHB residents (who are less likely to seek healthcare outside of HBDHB), it is possible some hospital admissions may have been missed.

It would be useful to investigate the long-term consequences of campylobacteriosis in more detail using New Zealand's large datasets of notified and hospitalised cases. This analysis could generate suitable comparison populations to better quantify the population health impact of this common enteric pathogen. Such an analysis would allow the health and economic benefits of investing in improved safety of the water and food supply to be further quantified.

Conclusion

This study provides a comprehensive analysis of the acute infectious complications that resulted in hospitalisation attributable from a large campylobacteriosis outbreak. It demonstrates the serious health impact that campylobacteriosis can have in medically vulnerable individuals and highlights the importance of public health measures to prevent exposure to this organism.

Supplementary Material

Supplementary Table 1: ICD-10-AM codes used to search for non-notified cases of campylobacteriosis associated with the HNCO that were hospitalised, based on hospital admissions 7–31 August 2016.

Gastroenteritis
A04.5 Campylobacter enteritis
A04.9 Bacterial intestinal infection
A09* Other gastroenteritis and colitis of infectious and unspecified origin
A08.4 Viral intestinal infection, unspecified
A08.5 Other specified intestinal infections
Potential complications of gastroenteritis
E86 Volume depletion
N17* Acute kidney injury
J69.0 Aspiration pneumonia
R50* Fever of unknown origin
K59.3 Megacolon
A41.9 Sepsis, unspecified.
R57.2 Septic shock.
O60* Premature labour
Known post-infectious sequelae of campylobacteriosis
M02 Reactive arthritis
G61.0 Guillain-Barre syndrome
K58 Irritable bowel syndrome

Supplementary Table 2: Research definitions.

Condition	Extent of audit	Research criteria:
Acute lower gastrointestinal bleeding	Review of clinical notes and endoscopy results	Documented clinical diagnosis of lower gastrointestinal bleed within four weeks of symptoms of active infection (ie, diarrhoea). All bleeds in setting of confirmed acute infection, irrespective of potential underlying chronic pathology such as haemorrhoids or diverticulosis were included.
Severe lower gastrointestinal bleeding	Review of clinical notes and endoscopy results	A subset of those with a documented clinical diagnosis of lower gastrointestinal bleeding, which also had a haemoglobin drop of >30gm/L (either from baseline level or between admission haemoglobin and lowest haemoglobin during admission).
Colitis	Review of imaging and/or endoscopy result and/or histology	Documented clinical diagnosis of colitis or Endoscopy report documenting presence of mucosal inflammation with or without compatible histology or abdominal imaging consistent with colonic inflammation.
Toxic mega colon	Review of imaging and clinical notes	Documented clinical diagnosis of toxic mega colon or non-obstructive colonic dilation greater than 6cm reported on AXR or CT imaging with signs of systemic toxicity.
Dehydration	Review of clinical notes	A clinical diagnosis of dehydration at admission or discharge or documentation that intravenous fluid bolus was given on admission.
Electrolyte disorders on admission	Review of laboratory results	Hypokalaemia <3.5mmol/L Hyponatremia <135mmol/L Hypernatremia >145mmol/L

Supplementary Table 2: Research definitions (continued).

Condition	Extent of audit	Research criteria:
Acute kidney injury	Review of laboratory results	Acute kidney injury definition: KDIGO's serum creatinine criteria for acute kidney injury: Stage 1: Increase in SCr of ≥0.3mg/dL (26.52umol/L) within 48 hours or increase in SCr 1.5 to 1.9 times baseline which is known or presumed to have occurred in the prior seven days Stage 2: Increase in SCr to 1.0 to 2.9 times baseline Stage 3: Increase in SCr to 3.0 times baseline or increase in serum creatinine to ≥4.0mg/dl (≥353.6umol/l) or Initiation of renal replacement therapy *Operational definition of baseline creatinine:* The baseline Cr is an *outpatient* reading within 365 days of the current admission date; if multiple pre-hospitalization values are available, the one closest to the date of hospital admission will be used. If an outpatient pre-hospitalization value is not available during the 365 days prior to admission date, the lowest Cr value obtained during the current hospitalization should be taken as the baseline.
Bacteraemia	Review of laboratory results	*Campylobacter* species isolated from blood culture

Competing interests:
Nil.
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