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## Residential proximity to high-density poultry operations associated with campylobacteriosis and infectious diarrhea

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### Abstract

Poultry carry zoonotic bacteria that can cause gastroenteritis in humans. Environmental transmission of pathogens from poultry operations may increase gastrointestinal infection risk in surrounding communities. To evaluate associations between residential proximity to high-density poultry operations and individual-level diarrheal illnesses, we conducted a nested case-control study among 514,488 patients in Pennsylvania (2006–2015). Using electronic health records, we identified cases of five gastrointestinal outcomes: three pathogen-specific infections, including *Escherichia coli* (n = 1425), *Campylobacter* (n = 567), and *Salmonella* (n = 781); infectious diarrhea (n = 781); and non-specific diarrhea (2012–2015; n = 28,201). We estimated an inverse-distance squared activity metric for poultry operations based on farm and patient addresses. Patients in the second and fourth (versus first) quartiles of the poultry operation activity metric had increased odds of *Campylobacter* (AOR [CI], Q2: 1.36 [1.01, 1.82]; Q3: 1.38 [0.98, 1.96]; Q4: 1.75 [1.31, 2.33]). Patients in the second, third, and fourth quartiles had increased odds of infectious diarrhea (Q2: 1.76 [1.29, 2.39]; Q3: 1.76 [1.09, 2.85]; Q4: 1.60 [1.12, 2.30]). Stratification revealed stronger relations of fourth quartile and both *Campylobacter* and infectious diarrhea in townships, the most rural community type in the study geography. Increasing extreme rainfall in the week prior to diagnosis strengthened fourth quartile *Campylobacter* associations. The poultry operation activity metric was largely unassociated with *E. coli*, *Salmonella*, and non-specific diarrhea. Findings suggest high-density poultry operations may be associated with campylobacteriosis and infectious diarrhea in nearby communities, highlighting additional public health concerns of industrial agriculture.

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### Introduction

Poultry are reservoirs of several zoonotic bacteria that cause acute gastroenteritis in humans, including *Campylobacter*, *Salmonella*, *Escherichia coli*, and *Listeria* (Berghaus et al., 2012; Blaak et al., 2015; Dahshan et al., 2016; Lee et al., 2016; Sahin et al., 2015). Among the most common causes of foodborne illness in the U.S., these pathogens cause significant morbidity and mortality, with serious sequelae such as Guillain-Barré syndrome (*Campylobacter*), reactive arthritis and irritable bowel syndrome (*Campylobacter* and *Salmonella*), end-stage renal disease (*E. coli*), and pre-term labor and fetal infection (*Listeria*) (Humphrey et al., 2007; Scallan et al., 2015). The risk of illness due to foodborne transmission of pathogenic bacteria from poultry meat is well documented (Batz et al., 2012). Environmental transmission of these pathogens from poultry operations to humans presents an additional, though far less-studied risk.

Research has previously linked industrial food animal production (IFAP)—which is characterized by large, homogeneous, and densely packed livestock operations—to increased risk of zoonotic diseases in nearby communities (Casey et al., 2015). In terms of zoonotic bacteria associated with gastroenteritis, a case-control study conducted in counties with high cattle density found that living or working on a dairy farm was positively associated with campylobacteriosis, with strong overlap between human and bovine bacterial isolates (Davis et al., 2013). A study conducted across multiple states that linked *Campylobacter* cases with socioeconomic and environmental data by zip code found that in top poultry and dairy producing regions, campylobacteriosis incidence rates were significantly higher in zip codes with broiler operations or dairy operations compared to zip codes without operations (Rosenberg Goldstein et al., 2016). Other ecological studies using disease surveillance data have reported associations of farm animal density and *Campylobacter*, and the percent of the population living on a farm with risk of *E. coli* infection (Chang et al., 2009; Green et al., 2006). Studies have also found that rural residents living in areas with swine or dairy IFAP experience greater occurrence of diarrhea as measured by interviews with area residents (Arnold, 1999; Wing and Wolf, 2000), although these studies did not assess specific pathogens and are subject to recall bias.

While studies have shown living or working on a poultry farm and contact with live poultry to be a risk factor for *Campylobacter* and antibiotic-resistant *E. coli* infection (Davis et al., 2013; Price et al., 2007; Studahl and Andersson, 2000; Thorsteinsdottir et al., 2010; Wilson 2004), individual-level associations of poultry operations with risk of human infections in surrounding communities are largely unstudied. Environmental contamination from poultry operations has the potential to spread pathogens to nearby communities (Jonsson et al., 2010). Bacterial pathogens colonize animals at an early age and spread quickly through a flock (Blaak et al., 2015; Friese et al., 2013; Hermans et al., 2012; Sahin et al., 2015). From poultry houses, bacteria enter the community environment via aerosolized particles or in dust emitted through ventilation fans, through pests such as flies, and through land-disposal of poultry waste (Blaak et al., 2014, Blaak et al., 2015; Bull et al., 2006; Friese et al., 2013; Graham et al., 2009a, Graham et al., 2009b; Skora et al., 2016). Heavy rainfall can facilitate further transport of pathogens into surface and groundwater and is independently associated with gastrointestinal illness (Gleason and Fagliano, 2017; Levy et al., 2016).

Given the limited research related to poultry IFAP and risk of relevant human infections in surrounding communities, the aim of this study was to evaluate associations between residential proximity to poultry operations and individual-level diarrheal illnesses. We conducted a case-control study of the association between residential proximity to poultry operations and five gastrointestinal outcomes. While past research utilized gravity models to analyze zoonotic disease risk in swine and bovine operations (e.g. Casey et al.,

2013), to our knowledge this is the first study to use this geospatial method to assess infectious disease risks related to poultry IFAP and to evaluate associations of IFAP with gastrointestinal outcomes. We evaluated three pathogen-specific intestinal infection diagnoses that have been linked to poultry operations: *E. coli*, *Campylobacter*, and *Salmonella*. In addition, since the majority of patients seeking medical care for diarrhea are not tested for specific pathogens (Scallan et al., 2005), we sought to ascertain the relation of poultry operation proximity to less severe or persistent diarrheal illnesses by evaluating two other diagnoses, specifically infectious and non-specific diarrhea.

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## Section snippets

### Study population

Using electronic health record (EHR) data, we identified child and adult patients with one of five gastrointestinal outcomes from Geisinger, an integrated health system in Pennsylvania, USA. Geisinger primary care patients represent the age and sex distribution of the general population in central and northeastern Pennsylvania (Casey et al., 2016a, Casey et al., 2016b). The study area comprised 38 counties in Pennsylvania, including the health system's primary care market and bordering counties ...

### Description of cases, controls, and poultry operations

We identified 28,201 incident cases of non-specific diarrhea between 2012 and 2015, and 781 cases of infectious diarrhea, 1425 cases of *E. coli*-related intestinal infection, 567 cases of *Campylobacter*-related intestinal infection, and 293 cases of *Salmonella* gastroenteritis between 2006 and 2015 (Table 1A, Table 1B). Cases overlapped across gastrointestinal outcomes, particularly between non-specific diarrhea and other case types; between 19.8% and 42.0% of the more specific diagnoses were also ...

### Discussion

In this study evaluating patients' residential proximity to high-density poultry operations and diarrheal illnesses we found that patients who lived closer to a greater number or larger operations had a higher odds of diagnosis with campylobacteriosis and infectious diarrhea. The odds of *Campylobacter* increased further with the occurrence of more extreme precipitation events in the week prior to diagnosis. Additionally, proximity to poultry operations was more strongly associated with ...

### Conclusion

In one of the first studies to evaluate patients' residential proximity to poultry operations and diarrheal illnesses, we found an association between residing closer to more or larger poultry operations and campylobacteriosis. This association was stronger as the number of extreme precipitation events increased in the week prior to diagnosis, evidence of biologically plausible effect modification that provides further support to a causal inference that *Campylobacter* diagnoses were related to...

### Conflicts of interest

None....

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