Published in final edited form as:

Paediatr Perinat Epidemiol. 2018 July ; 32(4): 401–410. doi:10.1111/ppe.12481.

Enhanced identification of maternal hepatitis C virus infection using existing public health surveillance systems

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Abstract

Background: Hepatitis C virus (HCV) infection is under-recognized among US adults and children. Prenatal HCV screening may help close the diagnosis gap among women while also identifying at-risk infants. Current surveillance efforts for maternal HCV rely primarily on birth certificate data. We sought a more accurate assessment of HCV prevalence among pregnant women in Ohio by combining existing public health surveillance data.

Methods: Vital Statistics (VS) birth certificate data and Ohio Disease Reporting System (ODRS) HCV case data, both available through the Ohio Department of Health, were linked to determine rates of past or present HCV infection among women giving birth from 2012 to 2015 in Ohio, overall and by county. Among women with available test results, the proportion with present HCV infection indicated by detectable viraemia during pregnancy was calculated.

Results: Birth certificate data identified 4695 deliveries to women with past/present HCV infection during the study period. Linkage to ODRS revealed an additional 1778 deliveries to women with past/present infection, including 355 with confirmed viraemia during pregnancy. The prevalence of past/present HCV among pregnant women in Ohio rose from 0.82% in 2012 to 1.54% in 2015.

Conclusions: Maternal HCV infection is under-recognized and increasing in prevalence. Current case identification processes are inadequate in pregnancy, even among women with prior positive HCV testing. Alternative approaches, including enhanced risk factor-based screening or

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CONFLICTS OF INTEREST

All authors have no financial conflicts of interest to disclose.

universal prenatal screening in high prevalence settings, are needed to improve rates of HCV recognition among reproductive-aged women and newborns at risk of vertical transmission.

Keywords

data linkage; hepatitis C; pregnancy; surveillance

1 | INTRODUCTION

Hepatitis C virus (HCV) infection is often clinically silent. Without recognition and appropriate treatment, chronic HCV can lead to late-onset complications, including liver cirrhosis and hepatocellular carcinoma, in 10 to 40% of patients and accounts for up to half a million deaths worldwide yearly.^{1–3} In the US, it is estimated that less than 50% of chronically infected adults are aware of their diagnosis, and this rate is even lower for infected children.^{4–6} Current guidelines by the Centers for Disease Control and Prevention (CDC) and United States Preventive Service Task Force recommend testing individuals with specific HCV risk factors.^{7,8} However, risk-based screening in the clinical setting is inadequate due to failure to identify high-risk behaviours among patients and low engagement by at-risk persons in routine medical care.^{9–11}

Pregnancy represents a unique time during which young, otherwise healthy adults may actively engage in medical care. This includes vulnerable populations who have increasingly accessed prenatal care in recent decades due to expansion of coverage for prenatal care in US Medicaid plans.^{12,13} Thus, prenatal screening for HCV may be an effective outreach strategy to help close the diagnosis gap among adult women. Furthermore, recognition of HCV during pregnancy is critical to identify infants at risk of mother-to-child transmission (MTCT) of HCV. Birth to an infected mother carries an estimated 5.8% risk of MTCT and is the primary route of paediatric HCV infection.¹⁴ To date, national guidelines advise risk-based HCV screening rather than universal HCV screening among pregnant women due to the lack of proven strategies to prevent MTCT.^{7,8,15} This approach may miss a significant fraction of HCV-infected pregnant women. Moreover, the prevalence of HCV appears to be increasing among women of reproductive age in the US due to increased injection drug use.^{15–19} Thus, an increasing number of infants may be at risk for vertically acquired HCV and potential adverse fetal outcomes including fetal growth restriction and low birth weight. Public health approaches to better understand the magnitude of HCV infection in women of reproductive age and subsequent risk to newborns are required.

By integrating data from 2 surveillance systems routinely maintained by the Ohio Department of Health (ODH), we sought to develop a new algorithm that could more fully ascertain the prevalence of HCV infection among pregnant women in Ohio.

2 | METHODS

2.1 | Study population

We linked data from Vital Statistics (VS) records and the Ohio Disease Reporting System (ODRS), both maintained by ODH, to assess rates of past or present HCV infection among

pregnant women having livebirths in Ohio from 2012 to 2015. This study was approved by the Institutional Review Boards at Nationwide Children's Hospital and ODH.

The primary study outcome was maternal HCV status, defined as past or present HCV infection. VS birth certificate data report maternal HCV status as a dichotomous variable based on the self- report, medical history, or laboratory test results found in prenatal and labour/delivery records.

Health providers and/or laboratory personnel throughout Ohio are required by state law to report all suspected cases of HCV infection in real time to ODRS.²⁰ Based on available test results in ODRS, we assessed the primary outcome of past or present HCV infection as having: (i) anti-HCV positivity, with a signal to cut- off ratio predictive of true positive when available; or (ii) a positive HCV RNA test (including qualitative, quantitative or genotype testing). This definition has been used by the CDC as its HCV case definition since 2012. Present HCV infection, defined by detectable HCV RNA, was a secondary outcome evaluated in exploratory analyses among women with nucleic acid testing.

2.2 | Approach for identification of past/present HCV infection

We first identified all pregnant women reported as having past/present HCV infection in VS records (Method 1). We subsequently used data from ODRS to enhance identification of past/present HCV infection among pregnant women who may not have been reported as such in VS (Method 2; Figure 1).

In Method, 2 we linked women who gave birth in Ohio from 2012 to 2015 to cases of HCV infection reported to ODRS between 2003 and 2015. Women were matched between the 2 databases using Registry PlusTM Link Plus, a probabilistic record linkage program publicly available by the CDC. Using a user- specified matching algorithm, Link Plus identifies all potential matches that subsequently can be manually reviewed to derive a final list of matched records. In this study, women were linked based on matching of first name, date of birth, and 1 of the following: (i) last name or (ii) street address of residence (Appendix 1). We then excluded matches: (i) that did not meet our inclusion linkage criteria; (ii) where test results did not meet the criteria for past/present HCV infection; and (iii) where the date of first positive HCV test occurred after the infant delivery date. Of the remaining matches, we separated women who had been already identified as having past/present HCV in VS in order to determine the number of additional women with past/present HCV infection identified by linkage to ODRS.

2.3 | Data Collection

Using VS records, maternal demographic data at time of delivery were collected, including: age, race, ethnicity, education level, marital status, insurance status, and county of residence. Insurance status was categorized as enrolled in US Medicaid, private/commercial plan, or other/unknown. County of residence was classified using the 2013 National Center for Health Statistics Urban-Rural Classification Scheme for Counties. Available maternal clinical data included: pre-pregnancy body mass index (BMI), cigarette use, having a prior pregnancy, prenatal care, pre-pregnancy diabetes, and gestational diabetes. Infant clinical

characteristics recorded included low birth weight (<2500 g) and prematurity (delivery at <37 weeks gestational age).

2.4 | Data and statistical analyses

We calculated, by calendar year, the proportion of total livebirths to all women identified as having past/present HCV infection using Methods 1 and 2 to determine the prevalence of maternal HCV infection (per 1000 livebirths). To avoid presenting duplicate data on women who had multiple gestation births, we identified the total number of unique pregnancies resulting in livebirths and the proportion of pregnancies to women with past/present HCV infection. Each pregnancy of a woman who delivered in multiple years during the study period was included. To identify women who delivered multiple times between 2012 and 2015, we matched mothers who had the same first and last names as well as date of birth. For each year, we presented separately the number of pregnancies to women with past/present HCV infection identified by Method 1 and the additional women identified by Method 2.

For each county in Ohio, the proportions of livebirths occurring to women with past/present HCV infection from 2012 to 2015 were calculated, and county-specific rates for every 1000 livebirths are presented.

We compared the descriptive characteristics of women with past/present HCV infection who were identified using VS records (Method 1) to those additionally identified by linking VS and ODRS data (Method 2) by calculating point estimates and 95% confidence intervals of the difference in medians for continuous variables and of proportions for categorical variables. We also determined the number of pregnant women who had HCV RNA test results in ODRS and identified the proportion with present HCV infection confirmed at any time prior to delivery and specifically during pregnancy. Analyses were performed using STATA 12.1 (StataCorp, TX).

3 | RESULTS

From 2012 to 2015, the proportions of livebirths to women identified as having past or present HCV infection, using both methods, rose from 0.82% (n = 1137/139 005) in 2012 to 1.54% (n = 2151/140 127) in 2015. After accounting for multiple gestation births, the proportion of pregnancies to women with past/present HCV similarly rose from 0.82% (n = 1112/136 429) in 2012 to 1.54% (n = 2114/137 603) in 2015 (Figure 2). Of the 6473 pregnancies to women classified as having past/present HCV infection during the study period, 1778 (27.5%) were only identified using Method 2 (Figure 2). The majority of pregnancies occurred to women who had been previously reported to ODRS (85.2%; n = 5514/6473), while 959 (14.8%) were identified through VS records only. We approximated that the 6473 pregnancies occurred in 5829 unique women, of whom 10.5% (n = 610/5829) had repeat pregnancies between 2012 and 2015. Of the 1110 women who gave birth in 2012, 256 (23.0%) had at least 1 additional delivery before 2016.

Figure 3 shows the county-specific rates of maternal past/present HCV infection (per 1000 live births) from 2012 to 2015. There was variation in the prevalence of maternal HCV

infection across Ohio counties and over time, ranging from 0.0 to 333.3 per 1000 livebirths. In almost all counties, the prevalence rose during the study period (Figure 3; Appendix 2).

Table 1 compares the demographic and clinical characteristics of pregnant women identified as having past/present HCV infection using VS alone (Method 1) versus the additional women found by linking VS and ODRS data (Method 2). The cohort of additional women identified by Method 2 were more likely to be African-American, unmarried, have private/commercial insurance, and reside in small or medium metropolitan areas (Table 1). The women identified by the 2 methods did not differ substantially with respect to most clinical characteristics, although the additional women identified by Method 2 were less likely to have used cigarettes during pregnancy, deliver prematurely, or report a prior pregnancy (Table 1).

Of the 5514 women with past/present HCV infection reported to ODRS, 2989 (54.2%) had pre-delivery HCV RNA test results available, but only 1911 (34.7%) had results of HCV RNA testing performed during pregnancy (Appendix 3). There were 2,842 (51.5%) women with detectable HCV RNA indicative of present HCV infection at some point prior to delivery, while 1776 (32.2%) had detectable HCV RNA identified during pregnancy. Using VS alone, 1,421 (80.0%) of these women with present HCV infection during pregnancy would have been identified, while 355 women with confirmed viraemia would not have been detected (Appendix 3).

4 | COMMENT

4.1 | Principal findings

Using surveillance data routinely collected by ODH, we developed a new approach to more comprehensively assess the magnitude of HCV infection among pregnant women in Ohio. This method, which takes advantage of ongoing, real-time reporting of positive HCV results through ODRS, led to the identification of an additional 1778 pregnancies to women with past/present infection, including 355 with confirmed viraemia during pregnancy, who would not have been detected by relying on VS data alone. Furthermore, while most women with past/present HCV infection had been reported to ODRS, there were 959 pregnancies identified based only on VS data, demonstrating the value of assessing both data sets to most accurately measure the prevalence of maternal HCV infection. Combining methods, there were 6473 pregnancies to women with past/present HCV infection delivering in Ohio during the study period, and the prevalence of maternal HCV infection rose from 0.82% in 2012 to 1.54% in 2015.

4.2 | Interpretation

Consistent with other epidemiologic studies showing increasing rates of HCV infection in young adults,^{18,19} we observed an almost twofold rise in the prevalence of maternal HCV during the study period. While possibly due in part to higher screening rates over time, these data also mirror recent trends in opioid and heroin use among pregnant women and likely reflect a major increase in the proportion of pregnant women actually infected with HCV.^{18,19,21,22}

The failure of VS records to capture large fractions of HCV-infected mothers each year points to ongoing deficits in the recognition of HCV in pregnancy. Although the women identified in our study were demographically similar to other regional and national cohorts of HCV-infected young adults,^{18,19,21,22} there were several differences between infected women identifiable by VS alone (Method 1) and those identified by the ODRS linkage (Method 2) that may provide insight into specific gaps in HCV screening and follow-up processes in Ohio. Women recognized as HCV-infected using VS alone were more likely to have Medicaid than private or commercial insurance and to reside in large metropolitan areas. This may reflect higher rates of HCV awareness and screening by providers who practice in urban settings or safety net clinics caring for a greater proportion of patients with classic HCV risk factors.²³ It is conceivable that women may have been more likely to be identified in VS if tested specifically during pregnancy. Conversely, the additional women identified by linkage to ODRS were less likely to report tobacco use or go on to have a preterm birth, which has been associated with active substance use during pregnancy. Thus, these women may have acquired HCV infection through prior risky behaviour but may not have been actively engaged in high-risk behaviours during pregnancy, which could decrease the likelihood of a provider testing for HCV in pregnancy. Furthermore, the additional women identified in our study were more likely to be nulligravid and may have had fewer health care encounters in which to learn about their HCV diagnosis. Differences in marriage status may have been driven by our methodology, wherein women who changed last names and addresses after marriage would go unlinked between ODRS and VS.

Failure to recognize HCV infection can lead to significant clinical and public health consequences for both the pregnant woman and newborn infant. Untreated HCV infection is associated with substantial ongoing morbidity and mortality in the US.^{1,24} At the same time, HCV therapy has improved dramatically with the availability of all-oral, direct-acting antiviral drugs that can cure over 95% of patients with typically no more than 12 weeks of therapy. As a result, clinicians and public health professionals are advocating for earlier and more universal treatment of chronic HCV infection. Women of reproductive age may represent an important subgroup to pursue early treatment to prevent the risk of MTCT and potential exacerbation of pre-existing liver disease by concomitant pregnancy-associated liver injury.^{14,25} At least 23% of the women with past/present HCV infection who delivered in 2012 in this study had multiple pregnancies over the ensuing 3 years. Although treatment is not currently recommended during pregnancy to mitigate MTCT risk,¹⁴ anti-HCV treatment post-partum is advocated to eliminate MTCT risk in future pregnancies and reduce the mother's risk of progressive liver disease.²⁶

Awareness of active maternal HCV infection is also critical for ensuring appropriate evaluation and follow-up in the newborn infant following delivery. The failure of VS to capture 20% of women with confirmed present HCV infection during pregnancy is particularly concerning as HCV viraemia is the chief risk factor for MTCT.¹⁴ Although the long-term clinical consequences of HCV in childhood are not fully understood,^{27,28} chronic infection in these children can lead to hepatic disease including liver fibrosis.^{28,29} Prior studies have consistently found low rates of HCV testing and identification of vertically transmitted disease among infants born to mothers with HCV infection.^{6,30,31} A recent analysis of Wisconsin Medicaid recipients from 2011 to 2015 reported that 30% of children

born to women with HCV infection did not have maternal HCV indicated on their birth certificates, and only 34% of infants born to women with confirmed HCV viraemia during pregnancy received appropriate HCV testing. These data support our findings that not only is maternal HCV infection being frequently overlooked during pregnancy, but even in situations where active HCV is identified in the mother, the majority of infants are not being evaluated for possible vertical transmission.

The significant gap in recognition of maternal HCV highlights a need to improve screening and follow-up practices for HCV in general and during pregnancy in particular. One approach would be to use local HCV surveillance data to refine risk factor-based screening. However, the success of this strategy requires strengthening of existing HCV surveillance systems and improving physician comfort with risk assessment in patients. Additionally, our data suggest that infections acquired by past risky behaviour may be less readily identified with risk factor-based screening in pregnancy. Furthermore, pregnant women may be hesitant to disclose illegal risky behaviours because of potential legal impact on them or their newborn. An alternative strategy may be to move towards universal prenatal screening for HCV, akin to current recommendations for HIV testing. This approach would alleviate providers' and patients' discomfort around risk assessment and avoid any missed opportunities in testing due to changes in at-risk behaviours. Our data suggest that routine screening would not only improve diagnosis of new cases of maternal HCV, but also would aid in recognition and re-engagement of women previously diagnosed with HCV. Universal HCV screening during pregnancy offers a strategic opportunity to test young women who may be otherwise unlikely to establish primary care, to ensure identification of vertically exposed infants, and to offer post-partum treatment to cure maternal infection and prevent risk of transmission with subsequent pregnancies.

4.3 | Strengths of the study

This study has improved the accuracy of HCV surveillance among pregnant women using 2 data sources that should be readily available in most states (ie birth certificate records and mandatory disease reporting), suggesting that our approach may serve as a viable model for other states to follow. In addition, linking of births data with disease-specific surveillance data may provide an efficient mechanism for improving recognition of other maternal and perinatal conditions that are not subject to universal prenatal screening. Furthermore, by highlighting discrepancies in disease status between birth certificate data and ODRS case records, public health professionals can identify individual cases where further action for disease notification and linkage to care are warranted.

4.4 | Limitations of the data

Our study has several limitations. First, although a robust matching algorithm was developed to link women between ODRS and VS, we may have missed linking women who changed names or residences due to marriage or other life events. Second, because HCV RNA testing is not routinely performed during pregnancy and negative RNA test results are not routinely reported to the ODRS, our cohort may include some women with previous HCV infection that had cleared by the time of pregnancy. However, this likely represented only a minority of identified women because spontaneous clearance occurs in less than 20–40% of acutely

infected individuals and HCV treatment was unlikely to be offered to these women during the study period.²⁷ Furthermore, the methodology presented here is applicable to surveillance in Ohio in particular, but as mentioned above, it is anticipated that our approach may be transferrable to other states.

5 | CONCLUSIONS

Using a new method to expand HCV case identification during pregnancy that capitalized on existing surveillance systems, we demonstrate that HCV infection in pregnant women continues to be under-recognized. With the availability of highly effective anti-HCV therapy, there may be novel opportunities for early treatment to prevent the development of liver disease in individual women and also reduce HCV transmission at a population level. Recognition of maternal HCV infection is also necessary to ensure that newborns at risk of MTCT receive appropriate testing and care. Further studies are needed to explore how our enhanced HCV case identification during pregnancy can be translated into improved rates of diagnosis and treatment among reproductive-aged women and newborns at risk of MTCT.

ACKNOWLEDGEMENTS

This study includes data provided by the Ohio Department of Health which should not be considered endorsement of this study or its conclusions. The authors acknowledge John Paulson and Debbie Merz at the Ohio Department of Health for providing access to Vital Statistics records and Ohio Disease Reporting System data respectively.

Funding information

This study was supported by research grants from the National Institutes of Health (R01-AI096882 to J.H. and C.E.G.), the Research Institute at Nationwide Children's Hospital (to J.H. and C.E.G.), and the Ohio State University Clinical and Translational Science Award (UL1TR001070).

APPENDIX 1

Inclusion linkage criteria used to match women in Vital Statistics (VS) records to reported cases in Ohio Disease Reporting System (ODRS)

Parameters for matching^a in Link Plus

Round 1^b

File 1 (Data type):	VS records, 2012 ^c (Delimited)
File 2 (Data type):	ODRS, 2003 – 2015 (Delimited)

Round 2^b

File 1 (Data type):	ODRS, 2003 – 2015 (Delimited)
File 2 (Data type):	VS records, 2012 ^c (Delimited)

Selected blocking variables (Type of phonetic system used, if applicable):

First name (Soundex)
Last name (Soundex)
Date of birth (None)
Street address (None)

Selected matching variables (Matching method):

First name (First name)
Last name (Last name)
Date of birth (Date)
Street address (Value-specific)

User-specified M-probability:

First name, .96
Last name, .97
Date of birth, .999

Parameters for matching^a in Link Plus

	Street Address, .95
Cut-off value:	Score 10 used to identify potential matches for manual review

Abbreviations: ODRS, Ohio Disease Reporting System; VS, Vital Statistics.

^a Additional considerations: To address potential typographical errors, all potential matches where only 2 of 4 indicators matched were manually reviewed by 2 authors and matches accepted in cases where differences existed due to likely typographical errors or alternate spellings (eg “Rachael” vs “Rachel”, or “Doe Smith” vs “Doe- Smith”). Similarly, partial address matches were counted as a match after manual review (eg “111 Main St, Apt 1” vs “111 Main”).

^b Linkage was performed twice for each pairing, once with VS data as File 1, and once with ODRS data as File 1, in order to capture duplicate entries in ODRS and women with multiple births in VS.

^c Separate linkage analyses were performed for each birth year 2012, 2013, 2014, and 2015.

APPENDIX 2

County- specific prevalence rates of pregnant women with past or present HCV infection per 1000 livebirths from 2012 to 2015

County	Prevalence of maternal past/present HCV infection (per 1000 livebirths)			
	2012	2013	2014	2015
Overall	8.2	10.4	13.2	15.4
Adams	41.5	16.8	32.3	28.1
Allen	3.9	4.7	11.0	13.4
Ashland	5.0	9.4	3.4	10.0
Ashtabula	4.7	10.3	12.6	24.6
Athens	18.4	33.7	46.8	57.0
Auglaize	2.0	0.0	1.9	7.1
Belmont	11.8	8.2	8.3	15.8
Brown	11.2	15.4	28.0	47.9
Butler	9.3	16.8	20.4	27.7
Carroll	0.0	0.0	7.8	10.5
Champaign	7.0	7.6	13.3	9.6
Clark	10.2	10.9	10.1	12.9
Clermont	18.5	20.1	19.5	31.8
Clinton	16.1	23.6	32.8	27.1
Columbiana	7.7	10.5	11.1	22.3
Coshocton	4.7	4.6	4.5	6.4
Crawford	17.2	24.6	38.1	38.5
Cuyahoga	4.7	4.2	7.0	7.9
Darke	5.3	8.4	9.6	7.4
Defiance	7.2	10.2	5.1	7.9
Delaware	1.0	3.6	8.0	4.5
Erie	5.1	7.2	6.4	12.7
Fairfield	15.3	17.3	29.5	24.6
Fayette	0.0	17.1	18.6	27.4

County	Prevalence of maternal past/present HCV infection (per 1000 livebirths)			
	2012	2013	2014	2015
Franklin	5.2	8.6	10.4	12.0
Fulton	0.0	2.0	3.9	8.2
Gallia	7.1	29.0	55.2	82.4
Geauga	0.0	7.7	3.3	7.9
Greene	11.8	9.0	12.2	15.4
Guernsey	10.8	6.7	15.3	12.9
Hamilton	9.9	10.3	16.3	15.6
Hancock	4.6	6.5	7.4	7.7
Hardin	23.1	48.0	15.7	31.8
Harrison	0.0	27.5	40.7	0.0
Henry	2.9	0.0	3.4	6.6
Highland	14.1	25.4	28.3	24.9
Hocking	18.4	18.5	26.5	30.8
Holmes	0.0	0.0	3.0	2.7
Huron	16.7	12.3	17.7	27.7
Jackson	27.5	42.7	34.7	51.5
Jefferson	9.6	14.3	32.2	42.9
Knox	7.9	7.0	4.2	10.7
Lake	5.6	5.2	7.7	5.6
Lawrence	136.4	125.0	333.3	166.7
Licking	8.2	8.4	9.1	13.3
Logan	5.7	8.9	13.5	3.5
Lorain	6.3	8.8	8.4	12.7
Lucas	5.9	7.1	6.9	9.8
Madison	7.1	2.4	16.5	22.2
Mahoning	11.5	16.0	18.5	15.7
Marion	15.4	15.5	29.5	42.3
Medina	10.0	9.3	5.9	7.0
Meigs	21.3	13.3	44.7	70.4
Mercer	6.1	8.9	13.1	17.3
Miami	4.6	11.9	6.6	11.9
Monroe	12.5	34.5	13.3	0.0
Montgomery	10.5	14.7	14.3	17.8
Morgan	6.6	8.3	13.2	13.1
Morrow	7.9	16.8	8.2	17.7
Muskingum	6.9	13.8	10.6	14.6
Noble	0.0	0.0	21.6	22.6
Ottawa	0.0	3.1	11.2	0.0
Paulding	0.0	5.8	5.7	5.8
Perry	10.7	9.0	11.9	42.7
Pickaway	22.7	23.7	33.8	41.3

County	Prevalence of maternal past/present HCV infection (per 1000 livebirths)			
	2012	2013	2014	2015
Pike	41.9	37.8	53.1	36.9
Portage	2.2	6.1	11.2	11.4
Preble	16.6	9.5	27.4	25.5
Putnam	2.3	0.0	2.1	2.4
Richland	15.3	10.4	25.1	17.3
Ross	18.2	35.2	48.2	35.6
Sandusky	2.9	6.3	8.0	11.5
Scioto	63.8	73.9	91.7	96.7
Seneca	3.7	5.0	10.6	15.2
Shelby	8.2	6.5	16.2	14.8
Stark	3.0	4.3	4.5	6.2
Summit	7.9	7.8	10.4	13.1
Trumbull	12.0	14.6	15.6	25.9
Tuscarawas	2.6	1.7	3.4	5.9
Union	18.8	14.9	15.9	24.4
Van Wert	0.0	14.0	11.4	19.4
Vinton	12.6	50.4	74.1	69.6
Warren	7.5	15.3	14.1	12.4
Washington	9.1	4.1	6.8	8.2
Wayne	5.2	5.4	5.6	6.9
Williams	5.2	2.6	10.8	7.8
Wood	2.2	4.4	9.3	2.2
Wyandot	7.3	3.7	7.8	8.2

Abbreviations: HCV, hepatitis C virus.

APPENDIX 3

Proportion of pregnancies between 2012 and 2015 to women who were identified as having present HCV infection at time of delivery by year, determined by available HCV RNA testing in the Ohio Disease Reporting Surveillance system

	Overall	2012	2013	2014	2015
Pregnancies to women with past/present HCV reported in ODRS, n	5514	924	1216	1535	1839
Available HCV RNA testing prior to delivery, n (%)	2989 (54.2%)	472 (51.1%)	597 (49.1%)	843 (54.9%)	1077 (58.6%)
Detectable HCV RNA prior to delivery, n (%)	2842 (51.5%)	464 (50.2%)	584 (48.0%)	787 (51.3%)	1007 (54.8%)
Detectable HCV RNA prior to delivery and identified in VS as having HCV, n (% of women with detectable HCV RNA)	2162 (76.1%)	325 (70.0%)	431 (73.8%)	611 (77.6%)	795 (78.9%)
Available HCV RNA testing during pregnancy, n (%)	1911 (34.7%)	282 (30.5%)	362 (29.8%)	569 (37.1%)	698 (38.0%)

	Overall	2012	2013	2014	2015
Detectable HCV RNA during pregnancy, n (%)	1776 (32.2%)	278 (30.1%)	350 (28.8%)	513 (33.4%)	635 (34.5%)
Detectable HCV RNA during pregnancy and identified in VS as having HCV, n (% of women with detectable HCV RNA during pregnancy)	1421 (80.0%)	207 (74.5%)	275 (78.6%)	416 (81.1%)	523 (82.4%)

Abbreviations: HCV, hepatitis C virus; ODRS, Ohio Disease Reporting System; RNA, ribonucleic acid; VS, Vital Statistics records.

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FIGURE 1.

Flow diagram of the study approach to identify women with past or present hepatitis C virus (HCV) infection using Vital Statistics and Ohio Disease Reporting System surveillance data from the Ohio Department of Health. Footnotes: Abbreviations: DOB, date of birth; HCV, hepatitis C virus; ODH, Ohio Department of Health; ODRS, Ohio Disease Reporting System; VS, Vital Statistics. ^aLink Plus is a probabilistic record linkage program available through the Centers for Disease Control & Prevention: <https://www.cdc.gov/cancer/npcr/tools/registryplus/lp.htm>. ^bSee methods section for matching rules in cases of suspected typographical errors

FIGURE 2.

Proportion of women with past or present HCV infection among all women delivering livebirths in Ohio 2012–2015. Stacked bars include all mothers with an HCV-positive Status recorded in the Vital Statistics birth database (grey bars, Method 1) and additional mothers identified by linking Vital Statistics records of pregnant women to HCV infections reported to the Ohio Disease Reporting System (ODRS) (black bars, Method 2), by year of delivery. For Method 2, past or present infection was defined by having at least one of the following positive tests documented prior to or on the delivery date: positive HCV antibody, detectable HCV RNA, or detectable HCV genotype. Multiple gestation births are represented by a single pregnancy

FIGURE 3.

County-specific prevalence rates of pregnant women with past or present HCV infection per 1000 livebirths from 2012 to 2015

TABLE 1

Characteristics of pregnancies between 2012 and 2015 among women with past or present HCV infection in Ohio identified using 2 surveillance methods

	Pregnancies between 2012 and 2015 in Ohio among women identified with past or present HCV infection		Additional women identified using Method 2 ^b (VS and ODRS) (n = 1778)		Method 1 vs Method 2 point estimate (95% confidence interval) ^c
	Overall (n = 6473)	Identified using Method 1 ^a (VS) (n = 4695)	Method 2 ^b (VS and ODRS) (n = 1778)		
Maternal demographics					
Median age, years (IQR)	27 (24–30)	27 (24–30)	27 (24–31)		0 (–0.49, 0.49)
Race, n (%)					
White	5845 (90.3%)	4275 (91.1%)	1570 (88.3%)		2.8 (1.1, 4.5)
Black	331 (5.1%)	205 (4.4%)	126 (7.1%)		–2.7 (–4.0, –1.4)
Other	84 (1.3%)	54 (1.2%)	30 (1.7%)		–0.5 (–1.2, 0.1)
Hispanic ethnicity, n (%)	161 (2.5%)	110 (2.3%)	51 (2.9%)		–0.5 (–1.4, 0.4)
Highest degree of education attained, n (%)					
Less than 12th grade	1749 (27.0%)	1285 (27.4%)	464 (26.1%)		1.3 (–1.1, 3.7)
High School degree/ GED	2509 (38.8%)	1818 (38.7%)	691 (38.9%)		–0.1 (–2.8, 2.5)
Some post-secondary education or degree	2105 (32.5%)	1511 (32.2%)	594 (33.4%)		–1.2 (–3.8, 1.3)
Unknown	110 (1.7%)	81 (1.7%)	29 (1.6%)		0.1 (–0.6, 0.8)
Currently married, n (%)	1384 (21.4%)	1047 (22.3%)	337 (19.0%)		3.3 (1.2, 5.5)
Insurance, n(%)					
Medicaid	4957 (76.6%)	3643 (77.6%)	1314 (73.9%)		3.7 (1.3, 6.1)
Private/commercial	744 (11.5%)	503 (10.7%)	241 (13.6%)		–2.8 (–4.7, –1.0)
Other/unknown	772 (11.9%)	549 (11.7%)	223 (12.5%)		–0.8 (–2.6, 0.9)
Residence ^d , n (%)					
Large metropolitan area	2977 (46.0%)	2197 (46.8%)	780 (43.9%)		2.9 (0.2, 5.6)
Medium metro area	1341 (20.7%)	911 (19.4%)	430 (24.2%)		–4.8 (–7.1, –2.5)
Small metro area	257 (4.0%)	161 (3.4%)	96 (5.4%)		–2.0 (–3.1, –0.8)
Micropolitan	1331 (20.6%)	972 (20.7%)	359 (20.2%)		0.5 (–1.7, 2.7)
Noncore	325 (5.0%)	228 (4.9%)	97 (5.5%)		–0.6 (–1.8, 0.6)
Maternal clinical characteristics					
Median pre-pregnancy body mass index, kg/ m ² (IQR)	23.5 (20.8–27.5)	23.5 (20.9–27.4)	23.8 (20.8–27.7)		–0.34 (–0.70, 0.02)

Pregnancies between 2012 and 2015 in Ohio among women identified with past or present HCV infection				
	Overall (n = 6473)	Identified using Method 1 ^a (VS) (n = 4695)	Additional women identified using Method 2 ^b (VS and ODRS) (n = 1778)	Method 1 vs Method 2 point estimate (95% confidence interval) ^c
Any cigarette use during pregnancy, n (%)	4645 (71.8%)	3472 (74.0%)	1173 (66.0%)	8.0 (5.4, 10.5)
One or more previous pregnancies, n (%)	5377 (83.1%)	3935 (83.8%)	1442 (81.1%)	2.7 (0.6, 4.8)
No prenatal care, n (%)	5577 (7.9%)	365 (7.8%)	149 (8.4%)	-0.6 (-2.1, 0.9)
Pre-pregnancy diabetes, n (%)	71 (1.1%)	57 (1.2%)	14 (0.8%)	0.4 (-0.1, 0.9)
Gestational diabetes, n (%)	283 (4.4%)	208 (4.4%)	75 (4.2%)	0.2 (-0.9, 1.3)
Infant ^e clinical characteristics				
Low birth weight (<2500 g), n (%)	1172 (18.1%)	870 (18.5%)	302 (17.0%)	1.5 (-0.5, 3.6)
Preterm birth (<37 wk gestational age), n (%)	1205 (18.6%)	906 (19.3%)	299 (16.8%)	2.5 (0.4, 4.6)

GED, general education diploma; IQR, interquartile range; ODRS, Ohio Disease Reporting Surveillance; VS, Vital Statistics.

^aMethod 1 determines past/present HCV infection status based on data provided in Vital Statistics.

^bMethod 2 refers to identification of pregnancies by linking pregnant women in Vital Statistics to records of HCV infection reported in ODRS prior to delivery date.

^cPoint estimates of the difference in medians (with Bonnet-Price 95% confidence intervals) are presented for continuous variables and of the difference in proportions (with 95% confidence intervals) are presented for categorical variables.

^dDetermined using the 2013 NCHS Urban-Rural Classification Scheme for Counties: available at https://www.cdc.gov/nchs/data/series/sr_02/sr02_166.pdf.

^eFor twin pregnancies, data for only 1 infant is presented.