

Positive Predictive Value of Administrative Data for Neonatal Abstinence Syndrome

Faouzi I. Maalouf, MD,^a William O. Cooper, MD, MPH,^{b,c,d} Shannon M. Stratton, BS,^c Judith A. Dudley, BS,^c Jean Ko, PhD,^{e,f} Anamika Banerji, MD,^g Stephen W. Patrick, MD, MPH, MS^{b,c,d}

abstract

OBJECTIVES: Neonatal abstinence syndrome (NAS) is a postnatal withdrawal syndrome experienced by some infants with opioid exposure. Hospital administrative data are commonly used for research and surveillance but have not been validated for NAS. Our objectives for this study were to validate the diagnostic codes for NAS and to develop an algorithm to optimize identification.

METHODS: Tennessee Medicaid claims from 2009 to 2011 (primary sample) and 2016 (secondary sample; post-*International Classification of Diseases, 10th Revision, Clinical Modification [ICD-10-CM]*) were obtained. Cases of NAS were identified by using *International Classification of Diseases, Ninth Revision, Clinical Modification* code (2009–2011) 779.5 and ICD-10-CM code (2016) P96.1. Medical record review cases were then conducted by 2 physicians using a standardized algorithm, and positive predictive value (PPV) was calculated. Algorithms were developed for optimizing the identification of NAS in administrative data.

RESULTS: In our primary sample of 112 029 mother-infant dyads, 950 potential NAS cases were identified from Medicaid claims data and reviewed. Among reviewed records, 863 were confirmed as having NAS (including 628 [66.1%] cases identified as NAS requiring pharmacotherapy, 224 [23.5%] as NAS not requiring pharmacotherapy, and 11 [1.2%] as iatrogenic NAS), and 87 (9.2%) did not meet clinical criteria for NAS. The PPV of the *International Classification of Diseases, Ninth Revision, Clinical Modification* code for NAS in clinically confirmed NAS was 91% (95% confidence interval: 88.8%–92.5%). Similarly, the PPV for the ICD-10-CM code in the secondary sample was 98.2% (95% confidence interval: 95.4%–99.2%). Algorithms using elements from the Medicaid claims and from length of stay improved PPV.

CONCLUSIONS: In a large population-based cohort of Medicaid participants, hospital administrative data had a high PPV in identifying cases of clinically diagnosed NAS.



^aDepartment of Pediatrics and Adolescent Medicine, American University of Beirut, Beirut, Lebanon; Departments of ^bPediatrics and ^cHealth Policy, Vanderbilt University, Nashville, Tennessee; ^dVanderbilt Center for Child Health Policy, Nashville, Tennessee; ^eDivision of Reproductive Health, Centers for Disease Control and Prevention, Atlanta, Georgia; ^fUnited States Public Health Service Commissioned Corps, Rockville, Maryland; and ^gDivision of Neonatology, Loma Linda University, Loma Linda, California

Dr Maalouf conducted the data collection and the initial analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Patrick conceptualized and designed the study, conducted the data collection and the initial analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Cooper conceptualized and designed the study and reviewed and revised the manuscript; Dr Ko contributed to the interpretation of the data and reviewed and revised the manuscript; Dr Banerji conducted the data collection and reviewed and

WHAT'S KNOWN ON THIS SUBJECT: Neonatal abstinence syndrome (NAS) is a postnatal opioid withdrawal syndrome experienced by infants and is increasing in incidence. Administrative data could be a source of data to use in surveilling different conditions, including NAS.

WHAT THIS STUDY ADDS: Diagnostic codes for NAS have a high positive predictive value in identifying the syndrome.

To cite: Maalouf FI, Cooper WO, Stratton SM, et al. Positive Predictive Value of Administrative Data for Neonatal Abstinence Syndrome. *Pediatrics*. 2019;143(1):e20174183

Neonatal abstinence syndrome (NAS) is a drug withdrawal syndrome that may occur after a neonate is exposed to opioids in utero. In the United States, approximately one-fifth of pregnant women enrolled in Medicaid fill a prescription for an opioid pain reliever each year.¹ The high prevalence of opioid use has been accompanied by an increase in the incidence of NAS, which grew nearly sevenfold over the last decade.²⁻⁴ By 2014, 1 infant was born every 15 minutes with the syndrome, accounting for an estimated \$500 million in hospital costs nationwide.⁴ With the rapid rise of the syndrome, there is a critical need for public health officials to develop surveillance systems to identify cases of NAS to monitor rates and trends.⁵ Hospital administrative data could serve as a readily available and inexpensive source of data for NAS surveillance in communities; however, diagnostic codes for NAS have not been validated.

In addition, research commonly relies on administrative data⁶⁻⁸; however, these data, especially diagnosis codes, vary in accurately representing certain clinical conditions.^{9,10} To inform public health systems and future research, our primary objectives were to validate the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnostic code for NAS using medical record review in a large statewide population-based cohort and to develop an algorithm to optimize identification of NAS in these data. Our secondary objective was to validate the *International Classification of Diseases, 10th Revision, Clinical Modification* (ICD-10-CM) diagnostic code for NAS among a subset of hospitals.

METHODS

Study Design and Setting

This was a retrospective cohort study of all neonates enrolled in TennCare, Tennessee's Medicaid program, between 2009 and 2011 (primary sample) and of a geographically diverse sample from 3 hospitals in 2016 (secondary sample, after implementation of *ICD-10-CM*). Medicaid administrative data from inpatient files were combined with vital records to create mother-infant dyads for our primary sample. Medicaid provides an ideal source of data for a study of NAS given that the majority of infants with the syndrome (81%) are enrolled in state Medicaid programs.² This study was approved with a waiver of informed consent by the Vanderbilt University Institutional Review Board, the State of Tennessee Department of Health, and the Bureau of TennCare.

Cohort Assembly ICD-9-CM: Primary Sample

Patients were included if (1) the mothers were between 15 and 44 years old at the time of delivery; (2) the infants were enrolled in TennCare within 30 days after birth; and (3) the infants were born between January 1, 2009, and December 31, 2011. Potential cases were identified with the presence of ICD-9-CM code 779.5 (drug withdrawal syndrome in newborn) in any diagnostic field.

Cohort Assembly ICD-10-CM: Secondary Sample

Patients were included if they were born at 1 of 3 hospitals chosen for geographic diversity across the state of Tennessee and enrolled in the TennCare between January 1, 2016, and December 31, 2016. Potential cases were identified with the presence of ICD-10-CM code P96.1 (neonatal withdrawal symptoms from maternal use of drugs of addiction) in any diagnostic field.

Maternal-infant linkages and linkages to vital records were not available in the secondary sample.

Adjudication Process

For *ICD-9-CM* validation, the medical records of all potential cases were requested from 72 medical centers throughout Tennessee. All personal health information was removed from medical records before the independent review and adjudication by 2 physicians (F.I.M. or A.B. and S.W.P.), masked to case status, using an algorithm developed a priori (Fig 1).¹¹ Any discordance in adjudication was reconciled between the adjudicators or reviewed with a third reviewer (W.O.C.). For *ICD-10-CM* validation, medical records were requested from 3 medical centers chosen for geographic diversity. Similarly, all personal health information was removed from the medical record before the independent review and adjudication by 2 physicians (W.O.C. and S.W.P.) using the same algorithm (Fig 1). Any discrepancies were discussed and resolved by strictly adhering to the adjudication algorithm. Patients receiving pharmacologic treatment of NAS were noted if the use of medications such as morphine, methadone, phenobarbital, or diluted tincture of opium was documented. Patients were then categorized as either (1) not having NAS, (2) having NAS not requiring medical therapy, (3) having NAS requiring medical therapy, (4) having possible NAS not requiring medical therapy, (5) having possible NAS requiring medical therapy, or (6) having iatrogenic NAS.

Of potential cases identified by a diagnostic code, cases were considered possible NAS if a diagnosis was documented in the medical record by a physician or if there were clinical indicators for that diagnosis, including a Finnegan score of >4 in addition to signs of NAS (tremors, excessive Moro reflex, and increased tone).¹¹ Although

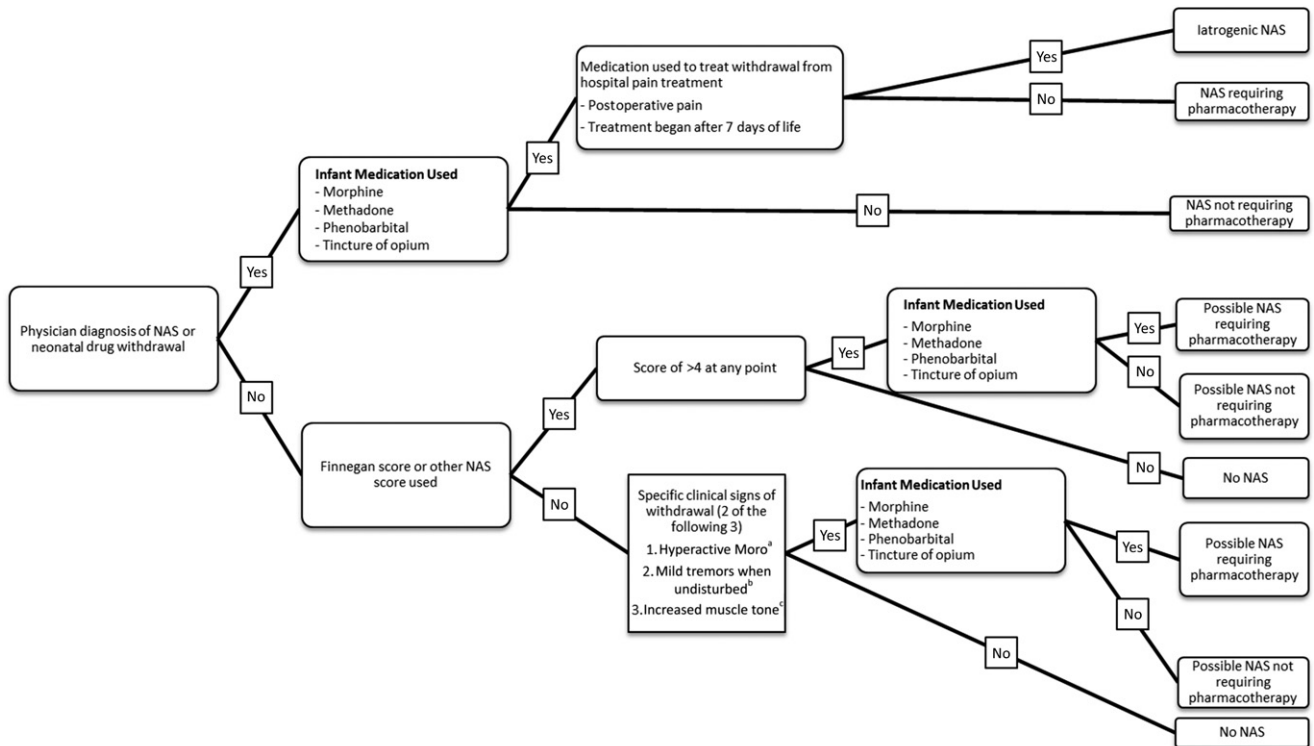


FIGURE 1

Algorithm used to identify different cases of NAS. ^a Arms stay up 3 to 4 seconds and/or pronounced jitteriness of the hands during or at the end of the Moro reflex. ^b Described in any extremity. ^c Difficult to straighten or bend the arms (but is possible) and head lag is present, or no head lag noted and/or arms or legs will not straighten or bend.

some consider a score of >8 as a requirement to diagnose NAS, this cut point has never been validated, and the Substance Abuse and Mental Health Administration considers scores of <8 as mild NAS.¹²

Descriptors

For dyads in the primary sample of 2009–2011, maternal demographic information, including maternal age and race, was obtained from birth certificates. Data regarding maternal smoking status were obtained from birth certificate data and from outpatient and hospital administrative records by using diagnosis codes for tobacco use: 305.1, 649.0x, 989.84, and V15.82. Infant demographic information, including gestational age, sex, and birth weight, was obtained from birth certificates. We used hospital claims to identify cases of transient tachypnea of the newborn (770.6), meconium aspiration syndrome

(770.11 and 770.12), respiratory distress syndrome (769.x), seizures (779.0 and 780.39), jaundice (774.x), and feeding difficulties (779.3x). These descriptors were not obtained for 2016 because data linkages to vital records were not available.

Statistical Analyses

Cases adjudicated as possible NAS not requiring medical therapy and possible NAS requiring medical therapy were considered to be confirmed for analyses. The positive predictive value (PPV) of ICD-9-CM code 779.5 and ICD-10-CM code P96.1 for the diagnosis of NAS was calculated by dividing the number of confirmed cases by the number of potential cases. Wilson confidence intervals (CIs) were calculated for each PPV.

With our primary sample of infants born between 2009 and 2011, PPVs were compared by using different

infant hospital lengths of stay (LOS) and dividing the number of confirmed cases by the number of potential cases after restricting LOS to ≥ 5 , ≥ 6 , and ≥ 7 days. Additionally, an analysis excluding possible NAS cases was also performed to assess changes in PPV. Of the remaining 111 079 births without ICD-9-CM code 779.5 for NAS, 100 records with similar maternal and/or infant characteristics (ie, geographic location and opioid use patterns) were blindly adjudicated to evaluate for potential NAS. All analyses were conducted by using Stata version 14.2 (Stata Corp, College Station, TX).

RESULTS

In our primary statewide analysis of infants born between 2009 and 2011, there were 112 029 mother-infant dyads identified. A total of 1086 infants had ICD-9-CM code 779.5 present in their administrative

TABLE 1 Maternal and Infant Characteristics of Confirmed Cases of NAS, Primary Sample 2009–2011, *N* = 863

Characteristics	Results
Maternal characteristics	
Age, y, mean (SD)	25.9 (4.6)
Race, <i>n</i> (%)	
White	836 (97.3)
African American	22 (2.6)
Other ^a	1 (0.1)
Cigarette use, <i>n</i> (%)	697 (80.8)
Infant characteristics	
Gestational age, mean (SD), wk	38.3 (2.3)
Birth wt, mean (SD), g	2910.4 (539.4)
Female sex, <i>n</i> (%)	401 (46.5)
Respiratory diagnoses (TTN, MAS, RDS), <i>n</i> (%)	214 (24.8)
Seizures, <i>n</i> (%)	29 (3.4)
Jaundice, <i>n</i> (%)	321 (37.2)
Feeding difficulties, <i>n</i> (%)	117 (13.6)

MAS, meconium aspiration syndrome; RDS, respiratory distress syndrome; TTN, transient tachypnea of the newborn.

^a Values <10 suppressed.

record, and 950 (87.5%) medical records were received. Reasons for inability to retrieve medical records included missing records, hospital refusal to release records, and inadequate documentation. Characteristics of mothers and infants are listed in Table 1. The vast majority of mothers (97%) were white, and ~80% of mothers were smokers. Of the infants with ICD-9-CM code 779.5 adjudicated to have NAS (*N* = 863), 94% had a gestational age of >35 weeks.

For ICD-9-CM codes (using a population-wide sample), adjudication by 2 physicians determined that of the 950 cases reviewed, 66.1% were found to be NAS requiring pharmacotherapy (*n* = 628), 23.5% were found to be NAS not requiring pharmacotherapy (*n* = 224), 1.2% were found to be iatrogenic NAS (*n* = 11), and 9.1% did not meet our criteria for the syndrome (*n* = 87; Fig 2). In a review of 95 (95% of total requested) non-NAS cases with similar exposure and geographic characteristics, 1 confirmed case of NAS and 1 case of possible NAS were found.

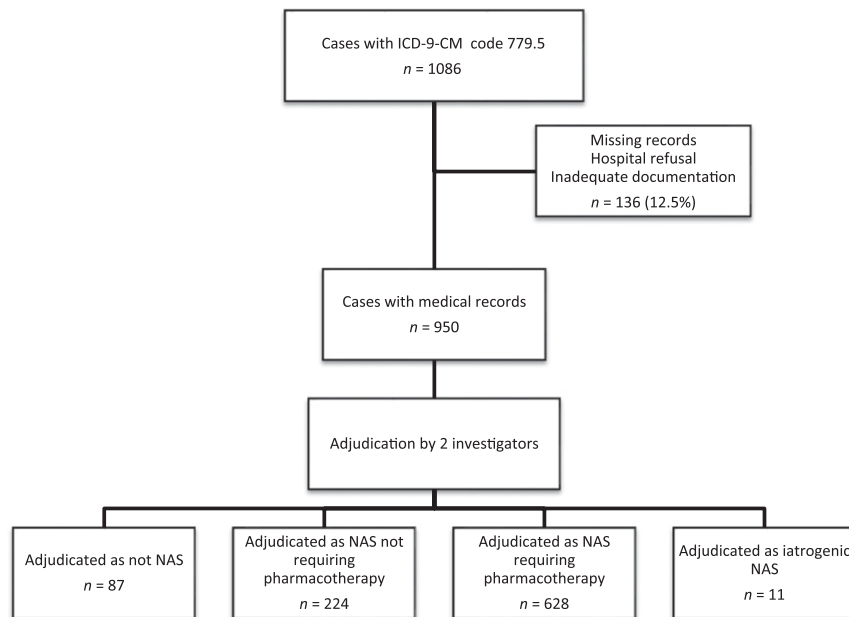


FIGURE 2 Process for identifying different cases of NAS in the primary sample.

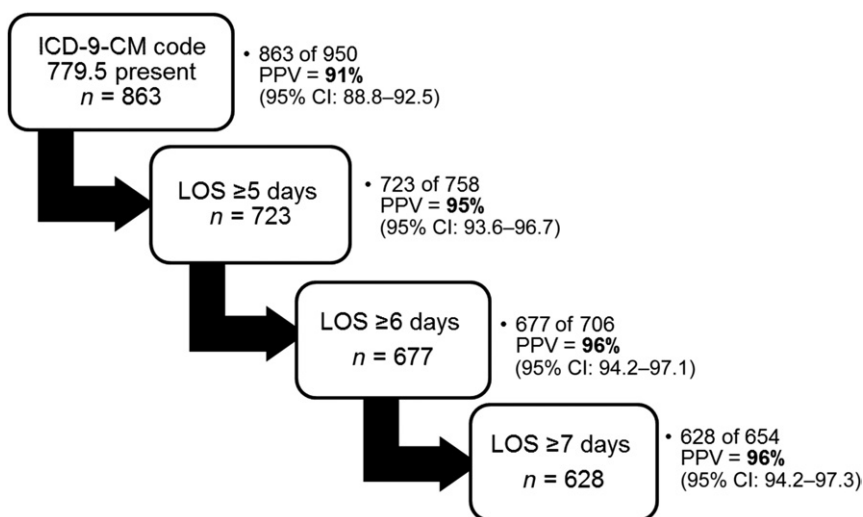


FIGURE 3 Algorithm for identifying NAS cases from administrative data.

The PPV for ICD-9-CM code 779.5 was 91% (863 of 950; 95% CI: 88.8%–92.5%). Exclusion of possible NAS cases resulted in a similar PPV of 86.0% (95% CI: 83.5%–88.0%). After accounting for LOS in addition to the diagnosis code, the PPV increased to 95% (95% CI: 93.6%–96.7%), 96% (95% CI: 94.2%–97.1%) and 96% (95% CI: 94.2%–97.3%) for a LOS of ≥5, ≥6, and ≥7 days, respectively. The algorithm incorporating the

diagnosis code and LOS is shown in Fig 3. Adding LOS as a criterion for identifying NAS increased PPV, but the total number of captured cases decreased from 863 to 628.

For ICD-10-CM codes, 98.6% of 220 hospital records were obtained by using a sample from 3 hospitals. Three cases were not included because of inadequate documentation. Of the 217 records

reviewed, 85.7% were found to be NAS requiring pharmacotherapy ($n = 186$), 12.0% were found to be NAS not requiring pharmacotherapy ($n = 26$), 0.4% were found to be iatrogenic NAS ($n = 1$), and 1.8% did not meet our criteria for the syndrome ($n = 4$). The PPV for ICD-10-CM code P96.1 was 98.2% (213 of 217; 95% CI: 95.4%–99.2%).

DISCUSSION

Using a large cohort and a standardized adjudication process, we found that administrative data accurately represent clinically diagnosed NAS. In a statewide sample of NAS cases, we found that mothers were predominately white and used cigarettes and that infants frequently had respiratory and feeding complications. The high PPV we demonstrated in our study supports the use of administrative data as a valuable resource for researchers and public health officials to monitor the impact of the opioid epidemic on pregnant women and infants.

We found that ICD-9-CM diagnostic code 779.5 had a 91% PPV for identifying clinically diagnosed NAS. Similarly, we found that ICD-10-CM diagnostic code P96.1 had a 98.2% PPV for identifying clinically diagnosed NAS. In our primary analysis (using a population-wide sample), the PPV improved to up to 96% when the code was combined with LOS. We chose the LOS cutoffs of 5, 6, and 7 days given that in a statement by the American Academy of Pediatrics, observation of infants with opioid exposure is recommended for 5 to 7 days to monitor for signs of NAS.¹³ Notably, this improvement in PPV came at the expense of sensitivity because we lost 235 cases when restricting the LOS to ≥ 7 days with minimal improvement in PPV. Thus, it might be reasonable to use a combination of *International Classification of Diseases* codes and LOSs of ≥ 5 days

to accurately capture cases of NAS. For some uses of administrative data, greater sensitivity may be desired (eg, annual incidence); however, some researchers may desire greater specificity, in which case the consideration of LOS may also be beneficial.

With the increasing incidence of NAS in the United States, a reliable and accurate surveillance system in which administrative data are used is important. In this study, we used Tennessee Medicaid administrative data for that purpose. This data source has been used to study several outcomes, such as diabetic ketoacidosis,¹⁴ congenital malformations,¹⁵ preterm births,¹⁶ and sudden cardiac deaths.¹⁷ Similar approaches have been used in many studies to identify diseases and outcomes such as suicidal behavior, opioid toxicity, and spontaneous pneumothorax,^{18–20} with high PPV.

Diagnosis codes have been commonly used in NAS research, including in studies of NAS incidence,^{2,3,6} variable hospital care,²¹ hospital readmissions,²² and the evaluations of maternal prescribing on incidence and severity of the syndrome.^{23–25} Our findings suggest that hospital administrative data are reliable as a highly specific source of information for such studies. We found that the primary diagnostic code for NAS retained a high PPV after transition to ICD-10-CM from ICD-9-CM. Importantly, the previous diagnosis code (779.5) has been replaced with 2 codes: P96.1 (neonatal withdrawal symptoms from maternal use of drugs of addiction) and P96.2 (withdrawal symptoms from therapeutic use of drugs in newborn). We found 11 cases of iatrogenic withdrawal (ie, withdrawal from opioid infusions after critical illness) in our ICD-9-CM sample and 1 case in our ICD-10-CM sample even with the new code in which iatrogenic withdrawal is specified. Differentiating between

withdrawal from antenatal exposure and postnatal treatment is essential for public health and research purposes.

The Protecting Our Infants Act of 2015 included language supporting efforts to improve data on NAS by “providing technical assistance to support States and Federally recognized Indian Tribes in collecting information on neonatal abstinence syndrome through the utilization of existing surveillance systems and collaborating with States and Federally recognized Indian Tribes to improve the quality, consistency, and collection of such data.”⁵ An important attribute of a surveillance system is its timeliness in evaluating and assessing an issue to prompt a public health response. Administrative data often have a time lag because data are processed after patient hospital stays, perhaps limiting their usefulness. Whereas some states rely on administrative records for NAS surveillance, others use direct reporting, which can eliminate a time lag. For example, clinicians in Tennessee must report NAS to the Tennessee Department of Health,²⁶ which improves the timeliness of the data, providing near real-time state incidence data (<https://www.tn.gov/health/article/nas-summary-archive>). States should consider the trade-offs of each data source, including time lags, when assessing optimal mechanisms for public health surveillance.

Our study has limitations that merit mentioning. Because NAS is a clinical diagnosis that is based on several signs and is subject to the clinician’s judgment, making that diagnosis and eventually coding for it have the potential of inaccurate documentation. However, we mitigated this by using a standardized tool, relying on 2 reviewers masked to case status, and including negative controls. Our findings might not be generalizable

to populations outside of Tennessee or the Medicaid program. Next, we were not able to review medical charts of all 111 079 births without ICD-9-CM code 779.5 to determine sensitivity among all births. In the analysis of 95 non-NAS cases with similar exposure and geographic characteristics, 1 confirmed case of NAS and 1 case of possible NAS were found. If extrapolated, this result leads to a sensitivity of <50%, indicating that although true cases of NAS are accurately identified by using ICD-9-CM code 779.5, derived estimates will underestimate the true burden. Finally, because PPV is influenced by prevalence, the PPV of using diagnostic code 779.5 with LOS may differ in states with a lower or higher prevalence of NAS.

CONCLUSIONS

ICD-9-CM code 779.5 and ICD-10-CM code P96.1 accurately identified true cases of NAS in a large population. Using an algorithm that incorporates coding data in addition to LOS leads to a higher PPV at the expense of sensitivity. Our findings suggest that administrative data may be used as a readily available and inexpensive source of data for states and tribes as they monitor the effect of the opioid epidemic on infants in their communities.

ACKNOWLEDGMENTS

We thank the Tennessee Bureau of TennCare of the Department of Finance and Administration for providing the data and the Tennessee

Department of Health, Office of Health Statistics for providing vital records data.

ABBREVIATIONS

CI: confidence interval

ICD-9-CM: *International Classification of Diseases, Ninth Revision, Clinical Modification*

ICD-10-CM: *International Classification of Diseases, 10th Revision, Clinical Modification*

LOS: length of stay

NAS: neonatal abstinence syndrome

PPV: positive predictive value

revised the manuscript; Ms Dudley and Ms Stratton designed the data collection instruments, coordinated and supervised the data collection, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

DOI: <https://doi.org/10.1542/peds.2017-4183>

Accepted for publication Oct 9, 2018

Address correspondence to Stephen W. Patrick, MD, MPH, MS, Vanderbilt Center for Child Health Policy, 2525 West End Ave, Suite 1200, Nashville, TN 37203. E-mail: stephen.patrick@vanderbilt.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2019 by the American Academy of Pediatrics

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Supported by the National Institute on Drug Abuse of the National Institutes of Health under award K23DA038720 and by the Tennessee Department of Health. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention, the National Institutes of Health, or the Tennessee Department of Health. Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

1. Desai RJ, Hernandez-Diaz S, Bateman BT, Huybrechts KF. Increase in prescription opioid use during pregnancy among Medicaid-enrolled women. *Obstet Gynecol*. 2014;123(5):997–1002
2. Patrick SW, Davis MM, Lehmann CU, Cooper WO. Increasing incidence and geographic distribution of neonatal abstinence syndrome: United States 2009 to 2012 [published correction appears in *J Perinatol*. 2015;35(8):667]. *J Perinatol*. 2015;35(8):650–655
3. Patrick SW, Schumacher RE, Benneyworth BD, Krans EE, McAllister JM, Davis MM. Neonatal abstinence syndrome and associated health care expenditures: United States, 2000-2009. *JAMA*. 2012;307(18):1934–1940
4. Winkelmann TNA, Villapiano N, Kozhimannil KB, Davis MM, Patrick SW. Incidence and costs of neonatal abstinence syndrome among infants with Medicaid: 2004-2014. *Pediatrics*. 2018;141(4):e20173520
5. Protecting Our Infants Act of 2015, 42 USC §201 (2015)
6. Ko JY, Patrick SW, Tong VT, Patel R, Lind JN, Barfield WD. Incidence of neonatal abstinence syndrome - 28 states, 1999-2013. *MMWR Morb Mortal Wkly Rep*. 2016;65(31):799–802
7. Davies H, Gilbert R, Johnson K, et al. Neonatal drug withdrawal syndrome: cross-country comparison using hospital administrative data in England, the USA, Western Australia and Ontario, Canada. *Arch Dis Child Fetal Neonatal Ed*. 2016;101(1):F26–F30
8. Okoroh EM, Gee RE, Jiang B, McNeil MB, Hardy-Decuir BA, Zapata AL. Neonatal abstinence syndrome: trend and expenditure in Louisiana Medicaid, 2003-2013. *Matern Child Health J*. 2017;21(7):1479–1487

9. Patrick SW, Davis MM, Sedman AB, et al. Accuracy of hospital administrative data in reporting central line-associated bloodstream infections in newborns. *Pediatrics*. 2013;131(suppl 1):S75–S80
10. Tan C, Hansen M, Cohen G, Boyle K, Daneman N, Adhikari NK. Accuracy of administrative data for identification of patients with infective endocarditis. *Int J Cardiol*. 2016;224:162–164
11. Jones HE, Harrow C, O’Grady KE, Crocetti M, Jansson LM, Kaltenbach K. Neonatal abstinence scores in opioid-exposed and nonexposed neonates: a blinded comparison. *J Opioid Manag*. 2010;6(6):409–413
12. Substance Abuse and Mental Health Services Administration. *Clinical Guidance for Treating Pregnant and Parenting Women With Opioid Use Disorder and Their Infants*. Rockville, MD: Substance Abuse and Mental Health Services Administration; 2018
13. Hudak ML, Tan RC; Committee on Drugs; Committee on Fetus and Newborn; American Academy of Pediatrics. Neonatal drug withdrawal. *Pediatrics*. 2012;129(2). Available at: www.pediatrics.org/cgi/content/full/129/2/e540
14. Bobo WV, Cooper WO, Epstein RA Jr, Arbogast PG, Mounsey J, Ray WA. Positive predictive value of automated database records for diabetic ketoacidosis (DKA) in children and youth exposed to antipsychotic drugs or control medications: a Tennessee Medicaid study. *BMC Med Res Methodol*. 2011;11:157
15. Cooper WO, Hernandez-Diaz S, Gideon P, et al. Positive predictive value of computerized records for major congenital malformations. *Pharmacoepidemiol Drug Saf*. 2008;17(5):455–460
16. Andrade SE, Scott PE, Davis RL, et al. Validity of health plan and birth certificate data for pregnancy research. *Pharmacoepidemiol Drug Saf*. 2013;22(1):7–15
17. Kawai VK, Murray KT, Stein CM, et al. Validation of a computer case definition for sudden cardiac death in opioid users. *BMC Res Notes*. 2012;5:473
18. Callahan ST, Fuchs DC, Shelton RC, et al. Identifying suicidal behavior among adolescents using administrative claims data. *Pharmacoepidemiol Drug Saf*. 2013;22(7):769–775
19. Chung CP, Callahan ST, Cooper WO, et al. Development of an algorithm to identify serious opioid toxicity in children. *BMC Res Notes*. 2015;8:293
20. Frechette E, Guidolin K, Seyam A, et al. Identifying primary spontaneous pneumothorax from administrative databases: a validation study. *Can Respir J*. 2016;2016:1690482
21. Patrick SW, Kaplan HC, Passarella M, Davis MM, Lorch SA. Variation in treatment of neonatal abstinence syndrome in US children’s hospitals, 2004-2011. *J Perinatol*. 2014;34(11):867–872
22. Patrick SW, Burke JF, Biel TJ, Auger KA, Goyal NK, Cooper WO. Risk of hospital readmission among infants with neonatal abstinence syndrome. *Hosp Pediatr*. 2015;5(10):513–519
23. Patrick SW, Dudley J, Martin PR, et al. Prescription opioid epidemic and infant outcomes. *Pediatrics*. 2015;135(5):842–850
24. Desai RJ, Huybrechts KF, Hernandez-Diaz S, et al. Exposure to prescription opioid analgesics in utero and risk of neonatal abstinence syndrome: population based cohort study. *BMJ*. 2015;350:h2102
25. Huybrechts KF, Bateman BT, Desai RJ, et al. Risk of neonatal drug withdrawal after intrauterine co-exposure to opioids and psychotropic medications: cohort study. *BMJ*. 2017;358:j3326
26. Warren MD, Miller AM, Traylor J, Bauer A, Patrick SW; Centers for Disease Control and Prevention (CDC). Implementation of a statewide surveillance system for neonatal abstinence syndrome - Tennessee, 2013. *MMWR Morb Mortal Wkly Rep*. 2015;64(5):125–128