Neonatal intensive care unit (NICU) admissions have been increasing. Home visiting services are an integral part of caring for high-risk children with limited resources. The effectiveness of physician-led home visiting programs on post-NICU health outcomes is not well studied. The Pediatric Visiting Doctors (PVD) program provides home-based primary care for high-risk children including NICU graduates, for 6 months after discharge. The team consisted of a pediatrician, and care coordinator or social worker. The study compares the characteristics and care utilization of PVD program participants with a hospital-based pediatric clinic population.

A retrospective cohort study of PVD infants born from 2013–2016, who were enrolled after referral during their NICU admission, was conducted. Data were also obtained on infants who were hospital clinic patients born during the same time frame, with parents residing in the PVD catchment area, and had a minimum 72-hour NICU stay. Between group differences were assessed; and logistic regression and generalized linear models were used to adjust for uneven group characteristics.

Forty-six PVD participants completed the program, and 91 comparison infants had at least 6 months of post-NICU clinic visits. PVD program completers received a median of 5 home visits. There were no differences in emergency care use or hospitalization. PVD program participants were more likely to attend development clinic compared to the non-PVD group (59% vs 12%, p = 0.002).

Physician-led home visiting services is a feasible way of providing clinical care to this population. Additional research is needed to assess patient-centered outcomes of these programs.

Keywords: NICU; home visiting program; care utilization; high risk newborns; high risk infants
Methods
Setting
The Pediatric Visiting Doctors (PVD) program was started in 2013 to care for high-risk children, including NICU graduates. The program is situated within a larger medical clinic at an academic institution, and provides multidisciplinary, home-based primary care for 6 months, post NICU discharge. Each home visit is made by a team consisting of a pediatrician and social worker or care coordinator. During the home visits, patients receive their routine well child screening and physical exam, a home assessment, psychosocial screening, and vaccinations. In addition, acute medical concerns are addressed. They are seen in accordance with the standard well child visit schedule, with additional visits as needed depending on medical needs. Patients are referred to the program during their NICU admission or shortly thereafter for prematurity of <34 weeks gestational age—a risk factor for increased length of stay and co-morbidity; having a chronic medical condition requiring specialized care; or discharge to a high-risk social environment. Families in the program receive assistance with care coordination and connection to support services as needed, in addition to routine clinical care. Individuals are followed in the program for six months post-NICU, since many issues of prematurity and parental anxiety are highest in the first few months of discharge.

Data Analysis
The investigators compared patients receiving PVD services with a group of patients who were born in the same time period, in the same NICU with a minimum stay of 72 hours, lived in the same zip codes, and were primary care patients of the larger clinic in which the PVD program was housed. A 72-hour minimum length of stay was chosen to exclude infants who were admitted to the NICU for routine newborn issues such as hypoglycemia, delayed respiratory transition after birth, and monitoring for neonatal sepsis. Our main outcomes were: acute care service utilization during the six months of program participation, overall outpatient clinic no-show rate, and use of development clinic. Clinic no-show rate was calculated using the number of outpatient clinic visits and the number of no-show visits recorded in the electronic medical record regardless of service date. Both sick and well outpatient pediatric visits, inclusive of the PVD home visits were included in the denominator for our analyses. Use of development clinic was defined as attending at least one scheduled appointment in the clinic.

The investigators excluded from analysis: infants with less than 6 months of pediatric clinic visits in the comparison group; and those who did not complete the 6 month PVD program, post NICU discharge. Between-group differences in both demographic characteristics and care utilization measures were assessed using the Wilcoxon rank-sum test for continuous measures, and the Chi-square and Fisher Exact tests as appropriate for categorical measures. Multicollinearity was assessed using variance inflation factors to identify highly correlated variables. Multivariable logistic regression and generalized linear models were used to adjust for birthweight, NICU length of stay, teen parent status, diagnosis of respiratory distress syndrome, and whether they required ventilator support greater than a nasal cannula when comparing care utilization outcomes. Gestational age was excluded from the final adjusted analyses due to high correlation with birthweight in the assessment of collinearity. Term infant was not included as it was clinically redundant with gestational age. All statistical analyses were conducted in SAS version 9.4 (SAS Institute, Cary, North Carolina).

Results
Data from 46 PVD and 91 hospital-based clinic (non-PVD) NICU graduates were analyzed. Mean maternal age was 26.1 and 27.6 in the PVD and non-PVD group (p = 0.15). The majority of the patients: were Black/African American race or Latino/Hispanic ethnicity; received public health insurance; and were children of first time mothers (Table 1). Median BW was 1703 g in PVD and 2965 g in the non-PVD group. About 80% of PVD participants were born prematurely compared to only half of the non-PVD group (p < 0.001).

PVD program completers received a median of 5 home visits over a 6 month period. We adjusted for the following unbalanced patient characteristics: birthweight (BW), NICU length of stay, teen motherhood, ventilator requirement (inclusive of continuous positive airway pressure therapy), and respiratory distress syndrome diagnosis (RDS). After adjustment, more PVD participants: had at least one hospitalization in the 6 months post NICU discharge (26.1% vs 8.8% p = 0.11) compared to the non-PVD group but the difference was not statistically significant. There were no differences in emergency department (ED) visits, ICU admissions, or clinic no-show rate as outlined in Table 2. PVD program participants were more likely to attend development clinic compared to the non-PVD group (58.7% vs 12.1%, p = 0.002).

Discussion
The study found that PVD group participants were of lower GA and BW; had a higher prevalence of respiratory sequelae and longer NICU stay than non-PVD group participants; and were more likely to attend a development clinic appointment. There were no statistically significant differences in ED use, hospitalization and ICU care after adjusting for BW and other unbalanced factors, when comparing the two groups.

The longer NICU length of stay among PVD participants is consistent with a higher level of patient acuity and potentially more post-discharge care needs. The higher prevalence of development clinic attendance highlights the ability of our program to provide care coordination for patients with specialty care needs. As the cost of healthcare...
### Table 1: Summary of patient characteristics in PVD and hospital clinic patients.

|                        | Hospital Clinic* (N = 91) | Pediatric Visiting Doctors Program* (N = 46) | p-value+ |
|------------------------|----------------------------|---------------------------------------------|----------|
|                        | No. Observed               | n (%) or Median [IQR]                      | No. Observed | n (%) or Median [IQR] |
| **Sex (M)**            | 91                         | 47 (51.6)                                  | 46        | 27 (58.7)            | 0.43 |
| **Race**               |                            |                                            |            |                      |      |
| White                  | 2 (2.2)                    |                                            | 4 (8.7)    |                       | 0.17 |
| Black                  | 38 (41.8)                  |                                            | 18 (39.1)  |                       |      |
| Asian                  | 3 (3.3)                    |                                            | 0 (0.0)    |                       |      |
| Native American        | 2 (2.2)                    |                                            | 1 (2.2)    |                       |      |
| Other                  | 44 (48.4)                  |                                            | 19 (41.3)  |                       |      |
| Unknown                | 2 (2.2)                    |                                            | 4 (8.7)    |                       |      |
| **Ethnicity**          |                            |                                            |            |                      | 0.07 |
| Hispanic               | 34 (37.4)                  |                                            | 10 (21.7)  |                       |      |
| Non-Hispanic           | 45 (49.5)                  |                                            | 24 (52.2)  |                       |      |
| Unknown                | 12 (13.2)                  |                                            | 12 (26.1)  |                       |      |
| **Public Insurance (Y)** | 91                         | 82 (90.1)                                  | 44        | 42 (95.5)            | 0.50 |
| **Gestational Age (days)** | 91                      | 261 [237, 280]                             | 42        | 235 [208, 250]       | <0.001 |
| **Birthweight (g)**    | 91                         | 2965 [2015, 3430]                          | 42        | 1702.5 [1210, 2470]  | <0.001 |
| **NICU LOS (days)**    | 91                         | 6 [3, 15]                                  | 45        | 23 [11, 66]          | <0.001 |
| **Maternal Age (years)** | 91                      | 27.6 [22.8, 33.5]                          | 42        | 26.1 [21.5, 30.9]    | 0.15 |
| **Discharge Weight (g)** | 91                        | 3035 [2230, 3430]                          | 43        | 2690 [2135, 3295]    | 0.21 |
| **Teen Parent (Y)**    | 91                         | 1 (1.2)                                    | 38        | 4 (10.5)             | 0.03 |
| First Child (Y)        | 91                         | 73 (80.2)                                  | 42        | 36 (85.7)            | 0.44 |
| Term Infant (Y)        | 91                         | 49 (53.8)                                  | 42        | 9 (21.4)             | <0.001 |
| RDS Diagnosis (Y)      | 91                         | 12 (13.2)                                  | 46        | 19 (41.3)            | <0.001 |
| Required Vent (Y)      | 91                         | 34 (37.4)                                  | 46        | 31 (67.4)            | <0.001 |

* Patients who attended either outpatient pediatrics clinic or Pediatric Visiting Doctors Program for at least 6 months were included.

+ P-values represent results of Chi-square, Fishers’ exact, Wilcoxon rank-sum analyses as is appropriate for the variable type and data distribution.

### Table 2: Comparison of care utilization between PVD and hospital clinic patients.

|                        | Hospital Clinic* (N = 91) | Pediatric Visiting Doctors Program* (N = 46) | Adjusted p-value+ |
|------------------------|----------------------------|---------------------------------------------|-------------------|
|                        | n (%) or Median [IQR]      | n (%) or Median [IQR]                       |                   |
| **6 months post NICU discharge** |                           |                                            |                   |
| At least one ED Visit (Y) | 45 (49.5)                  | 22 (47.8)                                  | 0.48              |
| At least one Hospitalization (Y) | 8 (8.8)                  | 12 (26.1)                                  | 0.11              |
| At least one ICU Stay (Y)** | 5 (5.6)                   | 6 (13.0)                                   | 0.89              |
| **First year of life** |                           |                                            |                   |
| At least one ED Visit (Y) | 61 (67.0)                  | 27 (58.7)                                  | 0.65              |
| At least one Hospitalization (Y) | 12 (13.2)                | 13 (28.3)                                  | 0.35              |
| At least one ICU Stay (Y) | 3 (3.3)                    | 6 (13.0)                                   | 0.12              |
| **Clinic No-Show Rate** | 17% [10%, 27%]             | 18% [8%, 28%]                              | 0.13              |
| **Attendance in Development Clinic** | 11 (12.1)               | 27 (58.7)                                  | 0.002             |
| **Median # of Home Visits** | N/A                      | 5 [4, 7]                                   | N/A               |

* Patients who attended either Pediatric Associates clinic or Pediatric Visiting Doctors Program for at least 6 months were included.

+ Adjusted p-value comes from generalized linear model results (for continuous outcomes) and logistic regression model results (for categorical outcomes) adjusting for unbalanced patient characteristics Birthweight, NICU LOS, Teen Parent, RDS Diagnosis and Required Vent.

** One missing value among the infants who had at least six months of pediatric associates visits.
rises, care coordination for medically complex children has become more important. Studies have found that care coordination reduces use of inpatient care and the emergency department for children with complex medical needs [13, 14, 15, 16]. NICU graduates are a group of infants that is at risk for developmental delay since many of them are born prematurely and have low birth weight. In addition, our particular cohort of NICU graduates was of lower socioeconomic status which also contributes to their risk, and this is consistent with the literature [17, 18]. Studies show that early intervention in premature infants improves cognition, and this benefit extends throughout preschool [19]. The program’s ability to successfully connect patients to this critical resource via referral to development clinic serves as an important first step in connecting participating families to resources that promote healthy child development.

The results did not demonstrate a significant change in ED and inpatient care use. However, this may be explained by differences in the medical complexity of our population that were not accounted for. Future studies with an acuity-matched cohort may provide insight into the impact of home-visiting programs on acute care utilization when taking into consideration the level of medical comorbidity.

The study did not examine between-group differences in severity of ED clinical presentation, which is a major determining factor in the need for hospitalization; and as result our ability to assess the true program’s impact on acute care measures may have been limited. Since the PVD NICU graduates were of lower GA and had more respiratory co-morbidity compared to their non-PVD counterparts, it is possible that they presented to the ED more acutely ill, thus requiring a higher level of care including hospitalization. This is consistent with current literature that suggests that preterm infants are more likely to be hospitalized post NICU discharge after adjustment for co-morbidity [20, 21]. Research with a larger sample size may help further characterize reasons for emergency care visits in this population; and identify preventable ED visits types with implementation of clinic-based home visiting programs. Additionally, data were only available for care received at the study’s home institution; and as a result, healthcare utilization at other institutions was not accounted for.

This study is among the first to assess acute care utilization among NICU graduates receiving home-based primary care services in an academic medical center. The study’s home-based care was also physician-led which is unique among which are typically nurse or community health worker based. Also, the primary outcomes of these studies focus on aspects of child development, including better parent-child interaction, higher levels of cognitive development, and reductions in child abuse or neglect [10–12]. Data from studies of national nurse-based home visiting programs show improvements in preventable infant mortality, however these studies do not address acute care utilization [22]. Other nursing-based home visiting programs highlight a reduction in acute care utilization within the first year of life, but do not address these outcomes in a population of NICU graduates [23–25].

The pilot study demonstrates the feasibility of providing home-based physician services for this vulnerable population. PVD participants received an average of 5–6 home visits in a 6-month period, including both preventive and sick visits, which is comparable to the visit frequency expected as part of routine child care in the first 6 months of life [26].

The study design has several limitations. First, the investigators did not track individuals’ reasons for program referral, or data on eligible mothers who declined to participate; nor did they abstract information on medical comorbidities other than RDS. These factors may have impacted the ability to obtain a cohort from the hospital-based clinic for analysis that was comparable in acuity. The impact of number of home visits on our primary outcomes was also not explored. Additional studies should look at the dose response between number of home visits and acute care outcomes. Nevertheless, the study highlighted the overall higher need for medical interventions in the home-based clinic population as well as areas for further study.

Conclusions
NICU graduates are a vulnerable population of infants with greater medical needs and increased risk of poorer long term health outcomes. The PVD population was higher risk compared to the non-PVD NICU graduates, which may highlight a need for more intensive post-discharge services. Physician-led, home visiting services are a feasible way of providing clinical care to this population. Additional research is needed on medical and psychosocial risk factors that impact the efficacy of these programs on reducing acute care utilization among low-income families.

Ethics and Consent
This project was approved by and conducted in accordance with the policies of the institutional review board.

Acknowledgements
The authors would like to thank Ms. Stephanie Pan as well as the members of our data warehouse team for assistance with this project.

Competing Interests
The authors have no competing interests to declare.
References

1. Harrison W and Goodman D. Epidemiologic Trends in Neonatal Intensive Care, 2007–2012. JAMA Pediatr. 2015; 169(9): 855–862. DOI: https://doi.org/10.1001/jamapediatrics.2015.1305
2. American Academy of Pediatrics. Levels of Neonatal Care. Pediatr. 2004; 114(5): 1341–1347. DOI: https://doi.org/10.1542/peds.2004-1697
3. Purdy IB, Craig JW and Zeanah P. NICU discharge planning and beyond: recommendations for parent psychosocial support. J Perinatol. 2015; 35(Suppl 1): S24–8. DOI: https://doi.org/10.1038/jp.2015.146
4. Jefferies AL, Canadian Paediatric Society and Fetus and Newborn Committee. Going home: Facilitating discharge of the preterm infant. Paediatr Child Health. 2014; 19(1): 31–42. PMID: 24627654. DOI: https://doi.org/10.1093/pch/19.1.31
5. Boylan J, Alderdice FA, McGowan JE, Craig S, Perra O and Jenkins J. Behavioural outcomes at 3 years of age among late preterm infants admitted to neonatal intensive care: a cohort study. Archives of Disease in Childhood – Fetal and Neonatal Edition. 2014; 99(5): 359–365. DOI: https://doi.org/10.1136/archdischild-2013-304785
6. Stoll BJ, Hansen NI, Bell EF, et al. Neonatal outcomes of extremely preterm infants from the NICHD Neonatal Research Network. Pediatrics. 2010; 126(3): 443–456. DOI: https://doi.org/10.1542/peds.2010-2411
7. Donovan EF, Ammerman RT, Bes J, Atherton H, Khoury JC, Altaye M, Putnam FW and Van Ginkel JB. Intensive home visiting is associated with decreased risk of infant death. Pediatrics. 2007; 119: 1145–1151. DOI: https://doi.org/10.1542/peds.2006-2411
8. Thomas BH. Home visits by para-professionals improved maternal mental health and mother-child interaction 2 years after visits ended. Evidence Based Nursing. 2005; 8(3): 75. DOI: https://doi.org/10.1116/ebn.8.3.75
9. Yonemoto N, Dowswell T, Nagai S and Mori R. Schedules for home visits in the early postpartum period. Cochrane Database of Syst Rev. 2017; Issue 8. Art. No.: CD009326. DOI: https://doi.org/10.1002/14651858.CD009326.pub3
10. Goyal NK, Teeters A and Ammerman RT. Home visiting and outcomes of preterm infants: a systematic review. Pediatrics. 2013; 132(3): 502–16. DOI: https://doi.org/10.1542/peds.2013-0077
11. Olds D, Donelan-McCall N, O’Brien R, MacMillan H, Jack S, Jenkins T, Dunlap WP III, O’Fallon M, Ost E, Thorland B, Pinto F, Gasbarro M, Baca P, Melnick A and Beeber L. Improving the nurse-family partnership in community pediatrics. Pediatrics. 2013; 132(Suppl 2): S110–7. DOI: https://doi.org/10.1542/peds.2013-1021
12. Sandstrom H. Early Childhood Home Visiting Programs And Health. Health Affairs Health Policy Brief. April 25, 2019. DOI: https://doi.org/10.1377/hpb20190321.382895
13. Weier RC, Gardner W, Conkol K, Pajer K and Kelleher KJ. Partners for Kids Care Coordination: Lessons from the Field. Pediatrics. 2017; 139(Suppl 2): S109–S116. DOI: https://doi.org/10.1542/peds.2016-2786E
14. Kitzner TS, Rabbitt LA and Chang RR. Benefits of care coordination for children with complex disease: a pilot medical home project in a resident teaching clinic. 2010; Pediatrics. 156(6): 1006–1010. DOI: https://doi.org/10.1516/jjpeds.2009.12.012
15. Weiss MA, Marchese S and Zhang L. Effective Care Management for Children With Special Health Care Needs in the Era of Value-Based Payment. Clinical Pediatrics; 2019. DOI: https://doi.org/10.1177/0009922819839231
16. Zanello E, Calugi S, Sanders LM, Lenzi J, Faldaella G, Rucci P and Fantini MP. Care coordination for children with special health care needs: a cohort study. Italian journal of pediatrics. 2017; 43(1): 18. DOI: https://doi.org/10.1186/s13052-017-0342-3
17. Ozkan M, Senel S, Arslan EA and Can DK. The socioeconomic and biological risk factors for developmental delay in early childhood. Eur J Pediatr. 2012; 171: 1815–1821. DOI: https://doi.org/10.1007/s00431-012-1826-1
18. Simon AE, Pastor PN, Avila RM and Blumberg SJ. Socioeconomic disadvantage and developmental delay among US children aged 18 months to 5 years. J Epidemiol Community Health. 2013; 67: 689–695. DOI: https://doi.org/10.1136/jech.2013.202610
19. Spittle A, Orton J, Anderson PJ, Boyd R and Doyle LW. Early developmental intervention programmes provided post hospital discharge to prevent motor and cognitive impairment in preterm infants. Cochrane Database of Systematic Reviews. 2015; 11. Art. No.: CD005495. DOI: https://doi.org/10.1002/14651858.CD005495.pub4
20. Paranjothy S, Dunstan F, Watkins WJ, Hyatt M, Demmler JC, Lyons RA and Fone R. Gestational age, birth weight, and risk of respiratory hospital admission in childhood. Pediatrics. 2013; 132(6): e1562–e1569. DOI: https://doi.org/10.1542/peds.2013-1373
21. Iacobelli S, Combier E, Roussot A, Cottenet J, Gouyon JB and Quantin C. Gestational age and 1-year hospital admission or mortality: a nation-wide population-based study. BMC Pediatrics. 2017; 17(1): 28. DOI: https://doi.org/10.1186/s12887-017-0787-y
22. Olds DL, Kitzman H, Knudtson MD, Anson E, Smith JA and Cole R. Effect of home visiting by nurses on maternal and child mortality: results of a 2-decade follow-up of a randomized clinical trial. JAMA pediatrics. 2014; 168(9): 800–806. DOI: https://doi.org/10.1001/jamapediatrics.2014.472
23. Koniak-Griffin D, Anderson NLR, Brecht M, Verzemnieks I, Lesser J, and Kim S. Public health nursing care for adolescent mothers: impact on infant health and selected maternal outcomes at 1 year post-birth. *J Adolescent Health*. 2002; 30(1): 44–54. DOI: https://doi.org/10.1016/S1054-139X(01)00330-5

24. Dodge KA, Goodman WB, Murphy RA, O’Donnell K and Sato J. Randomized controlled trial of universal postnatal nurse home visiting: impact on emergency care. *Pediatrics*. 2013; 132(Suppl 2): S140–S146. DOI: https://doi.org/10.1542/peds.2013-1021M

25. Kilburn MR and Cannon JS. Home Visiting and Use of Infant Health Care: A Randomized Clinical Trial. *Pediatrics*. 2017; 139(1): e20161274. DOI: https://doi.org/10.1542/peds.2016-1274

26. Hagan JF, Shaw JS and Duncan PM. (eds.) Bright Futures: Guidelines for Health Supervision of Infants, Children, and Adolescents. 4th ed. Elk Grove Village, IL: American Academy of Pediatrics; 2017.