Statewide Medicaid Enhanced Prenatal Care Programs and Infant Mortality

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abstract

OBJECTIVE: To evaluate whether participation in a statewide enhanced prenatal and postnatal care program, the Maternal Infant Health Program (MIHP), reduced infant mortality risk.

METHODS: Data included birth and death records, Medicaid claims, and program participation. The study population consisted of Medicaid-insured singleton infants born between January 1, 2009, and December 31, 2012, in Michigan (n = 248 059). The MIHP participants were propensity score–matched with nonparticipants based on demographics, previous pregnancies, socioeconomic status, and chronic disease. Infant mortality, neonatal mortality, and postneonatal mortality analyses were presented by race.

RESULTS: Infants with any MIHP participation had reduced odds of death in the first year of life compared with matched nonparticipants (odds ratio [OR] 0.73, 95% confidence interval [CI] 0.63–0.84). Infant death odds were reduced both among black infants (OR 0.71, 95% CI 0.58–0.87) and infants of other races (OR 0.74, 95% CI 0.61–0.91). Neonatal death (OR 0.70, 95% CI 0.57–0.86) and postneonatal death odds (OR 0.78, 95% CI 0.63–0.96) were also reduced. Enrollment and screening in MIHP by the end of the second pregnancy trimester and at least 3 additional prenatal MIHP contacts reduced infant mortality odds further (OR 0.70, 95% CI 0.58–0.85; neonatal: OR 0.67, 95% CI 0.51–0.89; postneonatal: OR 0.74, 95% CI 0.56–0.98).

CONCLUSIONS: A state Medicaid-sponsored population-based home-visitation program can be a successful approach to reduce mortality risk in a diverse, disadvantaged population. A likely mechanism is the reduction in the risk of adverse birth outcomes, consistent with previous findings on the effects of the program.

WHAT'S KNOWN ON THIS SUBJECT: Medicaid made substantial investments in enhanced prenatal and postnatal care programs to address maternal and infant health, including infant mortality. Evaluations of population-based programs are few, and although some have reported reductions in infant mortality, they have methodological limitations.

WHAT THIS STUDY ADDS: A population-based home visitation program can be a successful approach to reduce infant mortality. The reduced risk of infant death is consistent with previous findings on the effects of the program on health care utilization and birth outcomes.

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The American Academy of Pediatrics encourages[1] and recently reaffirmed support[2] for home-visitation programs for high-risk families as early as possible, "ideally before or at the time of the prenatal visit." Medicaid insures close to half of all US pregnancies and births (45% in Michigan) and has made substantial investments in programs to address maternal and infant health.[3,4] Enhanced prenatal and postnatal care (EPC) programs, including home visitation, target improved birth outcomes and child health and development through mechanisms such as maternal and infant care coordination, promoting maternal healthy behaviors, providing health education, addressing social determinants of health, and delivering psychosocial support.[4–7] These programs often serve low-income families who are at greater risk for adverse health outcomes and infant mortality.[8–14]

Infant mortality is a significant public health problem, with socioeconomic and racial/ethnic disparities. However, understanding the effects of EPC participation is a challenge in randomized controlled trials and other small-sample studies, as infant mortality is a rare event (6/1000 live births nationwide). Evaluations of population-based statewide or regional programs with large sample sizes are few, and although some have reported reductions in infant mortality, limitations included the inability to account for program selection bias and the dosage of services, lack of analyses within racial/ethnic groups, and not differentiating between neonatal and postneonatal death.[13,14]

The purpose of this study was to examine infant mortality as part of a quasi-experimental evaluation of the effectiveness of Medicaid's statewide EPC in Michigan, the Maternal Infant Health Program (MIHP), by using propensity score matching to address selection bias, and accounting for program timing and dosage. Early enrollment and the dosage of services have been shown to be important components of EPC programs, including MIHP.[15–18] We previously found that participation in MIHP improved health care utilization for mothers and infants and that early prenatal program enrollment and screening and a dosage of MIHP services reduced the risk of prematurity and low birth weight.[16,18] We tested the hypothesis that participation in MIHP reduced the risk of infant death. The large study population allowed for analyses by race, relevant due to the large disparities in birth outcomes and infant mortality (whites 5/1000 versus blacks 12/1000), and separate neonatal and postneonatal analyses, important because causes and potential mechanisms of program effect may be very different in the 2 periods.

DESCRIPTION OF THE MIHP PROGRAM

The MIHP program is a population-based EPC home-visiting program available to all Medicaid-eligible pregnant women and for infants until age 1 in Michigan.[19] Supplementing regular prenatal and infant care, MIHP provides home visitation and care coordination. Participation is voluntary, and can result from self-referral or referral by a medical provider. Services are delivered by registered nurses and licensed social workers both in the prenatal clinic or home setting. MIHP promotes healthy pregnancies, positive birth outcomes, and child health and development through comprehensive risk screening, care coordination, and evidence-based interventions embedded in standardized program protocols. This study followed an extensive effort in program improvement, including risk-appropriate standardized care protocols.

DATA AND METHODS

Study Population and Data Sources

The study population consisted of all the linked Medicaid-insured singleton births between January 1, 2009, and December 31, 2012, in Michigan (n = 248 059). Infants' and mothers' data available in the Michigan Department of Community Health data warehouse were linked based on unique Michigan Department of Community Health master record numbers, with a linking rate of >95%. Infants with nonmissing baseline covariates, MIHP, and outcome data were retained in the analyses, resulting in an analytical sample of 229 633 infants. Data consisted of all Medicaid maternal medical claims during pregnancy, monthly mother and infant Medicaid eligibility from 3 months before conception through the first year after birth, and other program participation and infant birth and death records.[18]

Measures

Outcomes

The infant death was coded binary, 1 if the newborn birth certificate was linked to a death certificate in the state of Michigan with a death date in the first year of life, and 0 otherwise. Neonatal infant death was coded binary, 1 if the newborn birth certificate was linked to a death certificate in the state of Michigan with a death date in the first 28 days of life, and 0 otherwise. Postneonatal infant death was coded binary, 1 if the newborn birth certificate was linked to a death certificate in the state of Michigan with a death date between 29 and 365 days of life, and 0 otherwise.

MIHP Participation

An overall MIHP participation indicator was coded 1 if at least 1 maternal claim with MIHP reimbursement codes was present during pregnancy and 0 otherwise. The small group of women who did not participate in MIHP during

pregnancy and they or their infants enrolled in MIHP after birth were not included as participants. The decision was made to ensure that MIHP participation predates the infant death outcome and to avoid potential bias due to selection into MIHP if, potentially, mothers with infants at higher mortality risk due to adverse birth outcomes chose to enroll in MIHP after birth. To capture the effects of MIHP enrollment timing and dosage, a second MIHP participation indicator was coded 1 if women enrolled in MIHP and were screened in the first or second trimester and had at least 3 additional MIHP contacts during pregnancy and 0 if not participating in MIHP. This allowed testing whether the more engaged clients experienced more favorable program effects, consistent with previous birth outcomes findings.[16] Another reason for excluding those with third-trimester MIHP enrollment from the second participation definition was that the pregnancies were more likely to be carried full-term, potentially biasing our analyses, as adverse birth outcomes are major determinants of infant death.[16]

Matching Maternal Baseline Characteristics

Maternal age, marital status (married; not married but father's name on the birth certificate; not married, and father's name not on the birth certificate), race/ethnicity, county of residence, pregnancy smoking, first-time birth, a previous birth within 18 months of conception, and 2 socioeconomic status (SES) measures were included as baseline matching characteristics. By using the individual county of residence (versus state regions) as a baseline covariate minimized the number of duplicate propensity scores. The first binary SES indicator identified pregnant women at or below 33% federal poverty level (FPL) based on their participation in the Low-Income Family program and receipt of cash assistance. The second binary SES indicator distinguished between women who had Medicaid before pregnancy (income up to 64% FPL for adult parents) and higher-income women who became Medicaid eligible after confirming the pregnancy, with income up to 185% FPL regardless of age.[3] Three binary indicators for maternal chronic conditions were also included, coded 1 if related claims during pregnancy were present, based on diagnostics and procedure codes, and 0 otherwise: asthma (International Classification of Diseases, Ninth Revision [ICD-9] 491–493), diabetes (ICD-9 250), and hypertension (ICD-9 401–405).

Analyses

A quasi-experimental design was used to compare the mortality of infants whose mothers were in MIHP with a matched comparison group from among the Medicaid beneficiaries who did not participate in MIHP. The study was exempt from approval by the Michigan State University institutional review board.

MIHP participants were compared with all women not enrolled in the program (Table 1). Then, propensity score matching was used to account for potential differences between MIHP participants and nonparticipants. The probability of MIHP participation (the propensity score) was estimated for the entire sample as a function of all the baseline characteristics by using logistic regression.[20,21] Propensity score estimations were performed separately for black women and for women of other races to ensure baseline equivalence on race. One-to-one random-sorted nearest neighbor caliper matching without replacement with a ± 0.05 SD caliper, where SD was the SD of the linear logit-transformed propensity score, within the same race group (black and others), was used to select matched control groups from among the nonparticipants. Paired comparisons were performed using the McNemar test for binary variables, the Bowker test for categorical variables, and paired *t* tests for continuous variables to assess baseline equivalence between the MIHP participants and the matched comparison group (Table 2). By using the first MIHP indicator, the reported propensity score analysis retained in the analyses 86% of the MIHP clients matched with nonparticipants, and 93% using the second MIHP indicator, similar rates as in our previous MIHP-matched evaluations.[16,18] The analyses were separately estimated for both MIHP indicators, including propensity score estimations and matching.

To test the hypothesis of MIHP having favorable effects on infant mortality, MIHP participants were compared with matched nonparticipant pairs using conditional logistic regressions adjusted for the county of residence imbalance (Table 3). The estimations provided the MIHP effects largely free of bias from associations between MIHP participation and observed covariates. To assess the robustness of the estimated MIHP effects to "hidden bias" arising from unobserved covariates, we measured how strongly an unobserved variable must affect selection into MIHP to invalidate the findings. The larger the hidden bias needed to invalidate the MIHP effects (available from the authors), the more likely the findings were to be robust. MIHP participation was shown to improve prenatal care and reduced risk of adverse birth outcomes,[16] all influencing infant mortality.[22] To investigate potential mechanisms through which MIHP may affect the risk of infant death, we adjusted our matched analysis for binary indicators of inadequate prenatal care, by using the Kotelchuck index (adequate/adequate plus versus intermediate/inadequate),[23] and of premature birth (<37 completed weeks) (Table 4). SAS, version 9.1.3 (SAS Institute, Inc, Cary, NC) was used to perform the analyses.

TABLE 1 Baseline Comparisons: MIHP Participants Versus Nonparticipants, Singleton Births, January 1, 2009, to December 31, 2012

	Any MIHP, n = 73 810		No MIHP, n = 155 823		P	MIHP First- or Second-Trimester Enrollment and >3 Total Contacts, n = 37 239		No MIHP, n = 155 823		P
	n	%	n	%		n	%	n	%	
Mother race category					<.01					<.01
White	42 303	57.3	105 513	67.7		21 152	56.8	105 513	67.7	
Black	26 511	35.9	35 433	22.7		13 650	36.7	35 433	22.7	
American Indian	509	0.7	630	0.4		265	0.7	630	0.4	
Other	4487	6.1	14 247	9.1		2172	5.8	14 247	9.1	
Mother age group					<.01					<.01
<20	14 480	19.6	20 031	12.9		7612	20.4	20 031	12.9	
20–29	46 756	63.3	99 890	64.1		23 356	62.7	99 890	64.1	
30–39	11 757	15.9	33 632	21.6		5857	15.7	33 632	21.6	
≥40	817	1.1	2270	1.5		414	1.1	2270	1.5	
Married	18 305	24.8	57 738	37.1	<.01	9096	24.4	57 738	37.1	<.01
Smoked during pregnancy	24 127	32.7	45 567	29.2	<.01	12 269	32.9	45 567	29.2	<.01
Previous birth <18 mo from conception					<.01					<.01
<18 mo	17 807	24.1	42 113	27.0		8907	23.9	42 113	27.0	
≥18 mo	24 033	32.6	58 425	37.5		12 015	32.3	58 425	37.5	
No previous births	28 789	39.0	48 046	30.8		14 768	39.7	48 046	30.8	
Unknown	3181	4.3	7239	4.6		1549	4.2	7239	4.6	
Income ≤33% of FPL	21 230	28.8	26 360	16.9	<.01	10 997	29.5	26 360	16.9	<.01
Medicaid before conception	42 369	57.4	72 091	46.3	<.01	22 281	59.8	72 091	46.3	<.01
Asthma	2411	3.3	3108	2.0	<.01	1415	3.8	3108	2.0	<.01
Diabetes	2394	3.2	3848	2.5	<.01	1330	3.6	3848	2.5	<.01
Hypertension	1773	2.4	2545	1.6	<.01	962	2.6	2545	1.6	<.01
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Mother age	24.2	5.5	25.6	5.6	<.01	24.2	5.5	25.6	5.6	<.01

All P values were based on the χ^2 test except for mother age, based on the 2-sample t test.

RESULTS

There were significant differences among all the baseline characteristics between MIHP participants and the women who did not participate in the program (Table 1). Table 2 shows that after selecting a matched comparison group by using the propensity score method, we established baseline equivalence on all the characteristics included in our analyses by using both MIHP participation indicators (except on the 83 individual counties of residence, unreported results).

Overall, infants whose mothers had any prenatal participation in MIHP had reduced infant mortality compared with matched nonparticipants (Table 3, odds ratio [OR] 0.73, $P < .01$). Both neonatal (OR 0.70, $P < .01$) and postneonatal infant mortality were reduced (OR 0.78, $P = .02$). When considering infants whose mothers enrolled and screened in the program by the second pregnancy trimester and had at least 3 additional prenatal MIHP contacts, we found significant reductions in infant mortality (Table 3, OR 0.70, $P < .01$). Significant reductions were found both in neonatal (OR 0.67, $P = .01$) and postneonatal infant mortality (OR 0.74, $P = .03$).

Among infants whose mothers were black, both the infants whose mothers had any prenatal participation in MIHP (OR 0.71, $P < .01$) and infants whose mothers enrolled and screened in the program by the second pregnancy trimester and had at least 3 additional prenatal MIHP contacts (OR 0.73, $P = .02$) had reduced infant mortality compared with matched nonparticipants. The reductions were significant in the neonatal infant death reduction among all MIHP black participants (OR 0.66, $P < .01$).

Among infants whose mothers were of other races, infants whose mothers had any prenatal participation in MIHP had reduced infant mortality compared with matched nonparticipants (Table 3, OR 0.74, $P < .01$). Neonatal infant mortality reductions also reached significance (OR 0.74, $P = .05$). When considering infants whose mothers enrolled and screened in the program by the second pregnancy trimester and had at least 3 additional prenatal MIHP contacts, reductions were found in infant mortality (Table 3, OR 0.67, $P = .01$). A significant reduction was found in neonatal mortality (OR 0.63, $P = .03$). When the matched comparisons between MIHP participants and nonparticipants were adjusted for an indicator of preterm birth, the infant mortality reductions did not reach statistical significance in any of the estimations (Table 4).

The results suggest that among MIHP participants, 28% of the potential infant deaths may be prevented through program participation. Basic

TABLE 2 MIHP Participants (Baseline Equivalence) Versus Propensity Score–Matched Nonparticipants, Singleton Births, January 1, 2009, to December 31, 2012

Baseline Covariates	Any MIHP, n = 63 440		No MIHP, n = 63 440		P	MIHP First- or Second-Trimester Enrollment and >3 Total Contacts, n = 34 664		No MIHP, n = 34 664		P
	n	%	n	%		n	%	n	%	
Mother race category					.51					.65
White	35 933	56.6	35 834	56.5		19 116	55.1	19 002	54.8	
Black	23 061	36.4	23 061	36.4		13 260	38.3	13 260	38.3	
American Indian	373	0.6	354	0.6		215	0.6	212	0.6	
Other	4073	6.4	4191	6.6		2073	6.0	2190	6.3	
Mother age group					.82					.60
<20	11 280	17.8	11 344	17.9		6776	19.5	6818	19.7	
20–29	40 690	64.1	40 533	63.9		21 856	63.1	21 814	62.9	
30–39	10 727	16.9	10 819	17.1		5637	16.3	5642	16.3	
≥40	743	1.2	744	1.2		395	1.1	390	1.1	
Married	16 519	26.0	16 463	26.0	.32	8541	24.6	8599	24.8	.86
Smoked during pregnancy	19 555	30.8	19 606	30.9	.22	11 017	31.8	10 995	31.7	.53
Previous birth <18 mo from conception					.13					.19
<18 mo	15 957	25.2	16 223	25.6		8491	24.5	8664	25.0	
≥18 mo	21 431	33.8	21 563	34.0		11 511	33.2	11 583	33.4	
No previous births	23 166	36.5	22 720	35.8		13 155	38.0	12 853	37.1	
Unknown	2886	4.5	2934	4.6		1507	4.3	1564	4.5	
Income ≤33% of FPL	16 778	26.4	16 754	26.4	.86	10 176	29.4	10 183	29.4	.95
Medicaid before conception	35 157	55.4	35 339	55.7	.28	20 575	59.4	20 553	59.3	.86
Asthma	1757	2.8	1723	2.7	.55	1196	3.5	1178	3.4	.70
Diabetes	1881	3.0	1850	2.9	.61	1147	3.3	1147	3.3	1.00
Hypertension	1394	2.2	1376	2.2	.73	863	2.5	876	2.5	.75
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Mother age	24.5	5.5	24.6	5.5	.14	24.3	5.5	24.3	5.5	.25

Paired comparisons were performed by using the McNemar test (if 2 × 2 table) or the Bowker test (if $r \times r$ table) for categorical variables and paired t tests were performed for the age of the mother.

calculations indicate that approximately 2 deaths can be prevented for each 1000 singleton Medicaid-insured birth (0.71%–0.52%, Table 3). Considering the MIHP counterfactual of 7.1/1000 infant death rate among the matched MIHP nonparticipants, the 2/1000 deaths represent approximately 28% of the infant deaths potentially prevented by MIHP. The current MIHP participation rate is ∼30%, with potentially 40 infant deaths prevented yearly among the estimated 20 000 singleton MIHP newborns.

Hidden bias analyses of the unadjusted matched comparisons indicated that unobserved variables that would cause differences in the odds of treatment assignment between the MIHP group and the control group as small as OR of 1.12 (MIHP first indicator) and OR of 1.2 (MIHP second indicator) would invalidate our findings. The results are available from the authors. The assumption of no hidden bias is equivalent to OR of 1.

DISCUSSION

Participation in MIHP reduced the risk of infant death, with significant reductions both in neonatal and postneonatal infant death. Infants whose mothers enrolled in the program by the second trimester of pregnancy and received at least 3 additional prenatal contacts had decreased risk of infant death compared with matched nonparticipants, with significant reductions both in neonatal and postneonatal death. These analyses excluded late-enrolled women who were also more likely to deliver full-term, therefore reducing the likelihood of overestimating the program effects.

The effects in reducing infant death risk, both among all MIHP participants and among those enrolled early and receiving a dosage of MIHP services were significant for both black and nonblack participants. For blacks, the effects were larger and reached statistical significance in the neonatal period among all enrolled in MIHP, whereas the postneonatal effects were marginally significant. Among nonblacks, the reductions in infant death among all enrolled in MIHP were significant overall, and both in the neonatal and postneonatal periods. Among nonblacks enrolled early and receiving a dosage of MIHP services, overall and neonatal infant death reductions were significant. Our previous studies found that MIHP participation improved birth outcomes and adequacy of prenatal care.[16,18] When the infant mortality–matched analyses were adjusted for prematurity, the MIHP

TABLE 3 MIHP Participants (Infant Mortality) Versus Propensity Score–Matched Nonparticipants, Singleton Births, January 1, 2009, to December 31, 2012, by Race, Neonatal Versus Postneonatal

Outcome	Any MIHP, n = 63 440		No MIHP, n = 63 440		OR (95% CI) (P)	MIHP First- or Second-Trimester Enrollment and >3 Total Contacts, n = 34 664		No MIHP, n = 34 664		OR (95% CI) (P)
	n	%	n	%		n	%	n	%	
All races										
Infant death <1 y, all races	328	0.52	449	0.71	0.73 (0.63–0.84) (<.01)	173	0.50	246	0.71	0.70 (0.58–0.85) (<.01)
Infant death <28 d, all races, neonatal	159	0.25	226	0.36	0.70 (0.57–0.86) (<.01)	80	0.23	119	0.34	0.67 (0.51–0.89) (.01)
Infant death 28–365 d, all races, postneonatal	171	0.27	225	0.36	0.78 (0.63–0.96) (.02)	90	0.26	131	0.38	0.74 (0.56–0.98) (.03)
Black										
Infant death <1 y, black women	168	0.73	234	1.01	0.71 (0.58–0.87) (<.01)	94	0.71	128	0.97	0.73 (0.56–0.96) (.02)
Infant death <28 d, black women, neonatal	81	0.35	121	0.52	0.66 (0.50–0.88) (.00)	45	0.34	63	0.48	0.71 (0.49–1.05) (.08)
Infant death 28–365 d, all races, postneonatal	87	0.38	115	0.50	0.76 (0.57–1.03) (.07)	48	0.36	68	0.51	0.77 (0.53–1.13) (.18)
Nonblack										
Infant death <1 y, nonblack women	160	0.40	215	0.53	0.74 (0.61–0.91) (<.01)	79	0.37	118	0.55	0.67 (0.50–0.89) (.01)
Infant death <28 d, nonblack women, neonatal	78	0.19	105	0.26	0.74 (0.55–0.99) (.05)	35	0.16	56	0.26	0.63 (0.41–0.95) (.03)
Infant death 28–365 d, all races, postneonatal	84	0.21	110	0.27	0.79 (0.59–1.07) (.13)	42	0.20	63	0.29	0.71 (0.47–1.05) (.09)

Paired comparisons were performed by using the McNemar test (if 2 × 2 table) or the Bowker test (if $r \times r$ table) for categorical variables and paired t tests were performed for the mother's age.

effects did not reach statistical significance. Adjusting for adequacy of prenatal care had virtually no influence on the findings. This suggests that the MIHP reduction in the risk of adverse birth outcomes is a likely mechanism of effect decreasing infant mortality risk, consistent with the neonatal infant death reductions both among blacks and among those of other races.

Additional analyses supported the reduction in the risk of adverse birth outcomes as a likely mechanism of MIHP effect in decreasing the risk of infant mortality. Repeating the analyses only with full-term infants showed no significant MIHP effects in reducing the risk of infant mortality (results available from the authors). Additionally, exploratory analyses revealed that MIHP participants had fewer infant deaths with causes related to gestation length and fetal growth and to complications of pregnancy, labor, and delivery than matched nonparticipants and both groups had similar sudden infant death syndrome rates. Although no definitive conclusions can be drawn, as a significant portion of infant deaths had the cause of death missing in the data, this lends further support to prematurity reduction risk as the mechanism of effect, and is consistent with the robust neonatal effects.

Our MIHP evaluation had several strengths. The quasi-experimental propensity score–matching design was rigorous, accounting for potential selection bias and timing and dosage of services. Analyses were performed by race, differentiated between neonatal and postneonatal infant mortality. In addition, our study population was composed of 4 full-year statewide birth cohorts of Medicaid-insured infants and their mothers, and, unlike other programs, MIHP is available to all Medicaid beneficiaries regardless of age, gravidity, or other characteristics. With MIHP eligibility population-based, the results of the study are more generalizable compared with other programs' evaluations, as the Michigan population is racially heterogeneous and includes rural and large metropolitan areas. In addition, we performed analyses of the robustness of our findings to the possibility of hidden bias due to unobserved selection factors.

The findings reported here are highly promising, but it is important to understand the existing limitations. The MIHP dosage construct did not consider dimensions such as amount of time spent with the MIHP provider, breadth of interventions received, and duration of enrollment. The small percentage of mothers unable to be linked to birth records and the possibility of not observing infant deaths for families who moved out of state are potential sources of bias. The analyses balanced on selection factors that could influence participation in MIHP, yet, as with other observational studies, the matching was limited to observable

TABLE 4 MIHP Participants (Infant Mortality) Versus Propensity Score–Matched Nonparticipants, Singleton Births, January 1, 2009, to December 31, 2012, by Race, Neonatal, and Postneonatal mortality

Outcome: Infant Death, OR and 95% CI	Any MIHP			MIHP First- or Second-Trimester Enrollment and >3 Total Contacts		
	I	II	III	I	II	III
	Adjusted for Inadequacy of Prenatal Care	Adjusted for Preterm	Adjusted for Preterm and Inadequacy of Prenatal Care	Adjusted for Inadequacy of Prenatal Care	Adjusted for Preterm	Adjusted for Preterm and Inadequacy of Prenatal Care
All races						
Infant death <1 y, all races	0.73 (0.63–0.84)	0.95 (0.81–1.11)	0.95 (0.81–1.11)	0.70 (0.58–0.85)	0.95 (0.76–1.18)	0.95 (0.76–1.18)
Infant death <28 d, all races, neonatal	0.70 (0.57–0.86)	1.13 (0.87–1.46)	1.13 (0.87–1.46)	0.67 (0.50–0.89)	1.24 (0.85–1.81)	1.23 (0.85–1.80)
Infant death 28–365 d, all races, postneonatal	0.78 (0.63–0.96)	0.86 (0.69–1.07)	0.86 (0.69–1.07)	0.74 (0.56–0.97)	0.80 (0.60–1.06)	0.80 (0.60–1.06)
Black						
Infant death <1 y, all races	0.71 (0.58–0.87)	1.01 (0.80–1.29)	1.02 (0.80–1.30)	0.73 (0.56–0.96)	1.16 (0.83–1.63)	1.17 (0.83–1.63)
Infant death <28 d, all races, neonatal	0.66 (0.50–0.88)	1.21 (0.78–1.88)	1.22 (0.79–1.90)	0.70 (0.47–1.03)	1.53 (0.85–2.76)	1.50 (0.83–2.71)
Infant death 28–365 d, all races, postneonatal	0.76 (0.57–1.03)	0.90 (0.65–1.23)	0.90 (0.65–1.23)	0.77 (0.52–1.12)	0.99 (0.64–1.50)	0.98 (0.64–1.49)
Nonblack						
Infant death <1 y, all races	0.74 (0.60–0.91)	0.92 (0.73–1.14)	0.91 (0.73–1.14)	0.67 (0.50–0.89)	0.85 (0.63–1.15)	0.85 (0.63–1.15)
Infant death <28 d, all races, neonatal	0.74 (0.55–1.00)	1.13 (0.81–1.58)	1.13 (0.81–1.58)	0.63 (0.41–0.96)	1.09 (0.65–1.81)	1.09 (0.65–1.81)
Infant death 28–365 d, all races, postneonatal	0.78 (0.58–1.06)	0.83 (0.61–1.13)	0.82 (0.60–1.12)	0.71 (0.47–1.05)	0.72 (0.48–1.07)	0.72 (0.48–1.07)

Matched comparisons adjusted for preterm, inadequacy of prenatal care, and both preterm and inadequacy of prenatal care.

characteristics. Hidden bias analyses revealed that relatively small biases due to unobserved program-control differences could invalidate our findings. However, additional exploratory analyses accounted for differences in a significantly expanded set of characteristics and risk factors and confirmed that infant mortality risk was reduced when mothers screened in MIHP during pregnancy and received additional services (MIHP participants) versus screened-only women (quasi-nonparticipants). This supports the notion that unobserved differences in common characteristics and risk factors do not drive the results of the matched analyses reported in this study. To eliminate the potential bias induced by unobserved previous preterm births and infant deaths, all results were replicated among women having a first birth. One major limitation is the potentially imprecise MIHP effect estimation due to the two-thirds reduction in overall sample size, in particular in the subgroups separated by time of death and race. The MIHP effects reducing infant mortality among all women having a first birth retained statistical significance, lending support to the fact that unobserved differences in common characteristics and risk factors do not drive the results (results available from the authors).

Our findings should be interpreted cautiously. This study and our previous MIHP research[16,18] suggest that MIHP participation reduces the infant mortality risk through reductions in the risk of adverse birth outcomes and that the effects are more consistent in the neonatal period. However, infant mortality is the result of a multitude of interdependent factors, some poorly understood. Enhanced prenatal and postnatal programs use multiple strategies to address it, including risk behavior reduction and safe sleep initiatives, which makes it difficult to definitively identify mechanisms of program effect.

Our results are similar to a statewide home-visiting study in Oklahoma[22] that reported lower infant mortality among program participants compared with nonparticipants. However, the findings were limited to firstborn infants of single mothers without pregnancy risk factors (eg, previous stillbirth) and the authors did not use matching methods to account for potential bias. A study of a community-based home-visitation program, Cincinnati's Every Child Succeeds program, also demonstrated reduced risk of infant death, with infants of home-visiting participants less likely to die than infants of nonparticipants. The study matched program participants with nonparticipants, but the matching relied on a limited set of characteristics.[24] Neither of the 2 studies accounted for the timing and dosage of services.

Home-visiting–based EPC programs with population-based eligibility, using standardized risk-assessment and evidence-based interventions and delivered in community settings, may be effective tools to reduce infant mortality. Given the benefits of MIHP

participation in improving health care utilization,[18] birth outcomes,[16] and reducing the risk of infant mortality, more focused efforts are needed to align clinical and community providers and services to provide EPC to the most vulnerable families, including improved early engagement and retaining of women and infants in EPC programs. Enhanced coordination of care between perinatal providers, pediatricians, health systems, and policy makers is needed for these families at risk to achieve population care and health outcomes.[25] New models of care are needed in the era of health reform. Recent efforts to integrate prenatal care and the family-centered medical home with home-visiting programs suggest that such alternative models may provide better care that the traditional medical model.[26,27]

CONCLUSIONS

Our study suggests that a state Medicaid-sponsored population-based home-visiting EPC program can be a successful approach to reduce mortality risk among Medicaid-insured infants of all races. The reduced risk of death among infants participating in the EPC program compared with matched nonparticipants is consistent with previous findings on the effects of the program on health care utilization and birth outcomes. A likely mechanism is the reduction in the risk of adverse birth outcomes. Increased efforts are needed in the postneonatal period. Programs targeting Medicaid-insured pregnant women that bundle interventions addressing multiple determinants at multiple levels can be an important mechanism to reach underserved women and their infants at greater risk of infant death.[25]

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ABBREVIATIONS

CI: confidence interval
EPC: enhanced prenatal and postnatal care
FPL: federal poverty level
ICD-9: International Classification of Diseases, Ninth Revision
MIHP: Maternal Infant Health Program
OR: odds ratio
SES: socioeconomic status

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REFERENCES

1. American Academy of Pediatrics. Council on Child and Adolescent Health. The role of home-visitation programs in improving health outcomes for children and families. *Pediatrics*. 1998;101(3 pt 1): 486–489
2. Council on Community Pediatrics. The role of preschool home-visiting programs in improving children's developmental and health outcomes. *Pediatrics*. 2009;123(2):598–603
3. The Henry Kaiser J. Family Foundation. Medicaid matters: understanding Medicaid's role in our health care system. Kaiser Commission on Key Facts. Available at: http://kaiserfamilyfoundation.files.wordpress.com/2013/01/8165.pdf. Accessed May 8, 2013
4. The Annie E. Casey Foundation. Data center, Kids Count, Michigan. 2013. Available at: datacenter.kidscount.org/data/bystate/Rankings.aspx?state=MI&ind=1716. Accessed May 8, 2013
5. Johnson K. *State-based Home Visiting Strengthening Programs through State Leadership*. New York, NY: National Center for Children in Poverty, Mailman School of Public Health at Columbia University; 2009
6. Witgert K, Giles B, Richardson A. Medicaid Financing of Early Childhood Home Visiting Programs: Options, Opportunities, and Challenges. Washington, DC: Pew Center on the States, Pew Charitable Trusts; National Academy for State Health Policy; 2012
7. Johnson CB, Witgert KE. *Enhanced Pregnancy Benefit Packages: Worth Another Look*. Portland, ME: National Academy for State Health Policy; 2010
8. Gavin AR, Nurius P, Logan-Greene P. Mediators of adverse birth outcomes among socially disadvantaged women. *J Womens Health (Larchmt)*. 2012;21(6): 634–642
9. Holzman C, Eyster J, Tiedje LB, Roman LA, Seagull E, Rahbar MH. A life course perspective on depressive symptoms in mid-pregnancy. *Matern Child Health J*. 2006;10(2):127–138
10. Cook CAL, Flick LH, Homan SM, Campbell C, McSweeney M, Gallagher ME. Psychiatric disorders and treatment in low-income pregnant women. *J Womens Health (Larchmt)*. 2010;19(7):1251–1262
11. Giurgescu C, Zenk SN, Dancy BL, Park CG, Dieber W, Block R. Relationships among neighborhood environment, racial discrimination, psychological distress, and preterm birth in African American women. *J Obstet Gynecol Neonatal Nurs*. 2012;41(6):E51–E61
12. Roman LA, Meghea CI, Raffo JE, et al. Who participates in state sponsored Medicaid enhanced prenatal services? *Matern Child Health J*. 2010;14(1):110–120
13. Blumenshine P, Egerter S, Barclay CJ, Cubbin C, Braveman PA. Socioeconomic

disparities in adverse birth outcomes: a systematic review. *Am J Prev Med*. 2010;39(3):263–272

14. Brintnell D, Peterson-Hickey M, Stroud D, Castellano S, Fogarty C. The birth certificate and Medicaid data match project: initial findings in infant mortality. Available at: www.health.state.mn.us/divs/chs/infantmortality/medicaidmortalityfindings.pdf. Accessed May 15, 2015
15. Slaughter J, Issel LM, Handler A, Rosenberg D, Kane D, Stayner L. Measuring dosage: a key factor when assessing the relationship between prenatal case management and birth outcomes. *Matern Child Health J*. 2013;17(8):1414–1423
16. Roman L, Raffo JE, Zhu Q, Meghea CI. A statewide Medicaid enhanced prenatal care program: impact on birth outcomes. *JAMA Pediatr*. 2014;168(3):220–227
17. Wilkinson DS, Korenbrot CC, Greene J. A performance indicator of psychosocial services in enhanced prenatal care of Medicaid-eligible women. *Matern Child Health J*. 1998;2(3):131–143
18. Meghea CI, Raffo JE, Zhu Q, Roman L. Medicaid home visitation and maternal and infant healthcare utilization. *Am J Prev Med*. 2013;45(4):441–447
19. Michigan Department of Community Health. Maternal Infant Health Program (MIHP). Available at: www.michigan.gov/mihp. Accessed May 15, 2015
20. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. *Biometrika*. 1983;70(1):41–55
21. Rubin DB. Estimating causal effects from large data sets using propensity scores. *Ann Intern Med*. 1997;127(8 pt 2):757–763
22. Carabin H, Cowan LD, Beebe LA, Skaggs VJ, Thompson D, Agbangla C. Does participation in a nurse visitation programme reduce the frequency of adverse perinatal outcomes in first-time mothers? *Paediatr Perinat Epidemiol*. 2005;19(3):194–205
23. Kotelchuck M. An evaluation of the Kessner Adequacy of Prenatal Care Index and a proposed adequacy of prenatal care utilization index. *Am J Public Health*. 1994;84(9):1414–1420
24. Donovan EF, Ammerman RT, Besl J, et al. Intensive home visiting is associated with decreased risk of infant death. *Pediatrics*. 2007;119(6):1145–1151
25. Krans EE, Davis MM. Strong Start for Mothers and Newborns: implications for prenatal care delivery. *Curr Opin Obstet Gynecol*. 2014;26(6):511–515
26. Tschudy MM, Toomey SL, Cheng TL. Merging systems: integrating home visitation and the family-centered medical home. *Pediatrics*. 2013;132 (suppl 2):S74–S81
27. Rowley DL, Hogan V. Disparities in infant mortality and effective, equitable care: are infants suffering from benign neglect? *Annu Rev Public Health*. 2012;33:75–87

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