Improving Perinatal Regionalization for Preterm Deliveries in a Medicaid Covered Population: Initial Impact of the Arkansas ANGELS Intervention

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Objective. To examine the factors associated with delivery of preterm infants at neonatal intensive care unit (NICU) hospitals in Arkansas during the period 2001–2006, with a focus on the impact of a Medicaid supported intervention, Antenatal and Neonatal Guidelines, Education, and Learning System (ANGELS), that expanded the consulting capacity of the academic medical center's maternal fetal medicine practice.

Data Sources. A dataset of linked Medicaid claims and birth certificates for the time period by clustering Medicaid claims by pregnancy episode. Pregnancy episodes were linked to residential county-level demographic and medical resource characteristics. Deliveries occurring before 35 weeks gestation ($n = 5,150$) were used for analysis.

Study Design. Logistic regression analysis was used to examine time trends and individual, county, and intervention characteristics associated with delivery at hospitals with NICU, and delivery at the academic medical center.

Principal Findings. Perceived risk, age, education, and prenatal care characteristics of women affected the likelihood of use of the NICU. The perceived availability of local expertise was associated with a lower likelihood that preterm infants would deliver at the NICU. ANGELS did not increase the overall use of NICU, but it did shift some deliveries to the academic setting.

Conclusion. Perinatal regionalization is the consequence of a complex set of provider and patient decisions, and it is difficult to alter with a voluntary program.

Key Words. Medicaid, preterm births, perinatal regionalization, NICU

Perinatal regionalization is a system for increasing the likelihood that newborns that require technological support for survival are born in appropriately equipped hospitals. Extensive evidence indicates that infants delivered before 35 weeks gestation are more likely to survive if they are born in hospitals with

neonatology expertise, neonatal intensive care unit (NICU) capacity, and higher patient volumes (Phibbs et al. 1996, 2007; Lasswell et al. 2010). Transport after delivery is not an effective substitute for delivery in such a setting (Warner et al. 2004).

In 2003, the maternal fetal medicine (MFM) Division of the University of Arkansas for Medical Sciences (UAMS), with the support of the Arkansas Medicaid Agency and the cooperation of the Arkansas Department of Health and the state Medical Society, launched an intervention called Antenatal and Neonatal Guidelines, Education, and Learning System (ANGELS). One goal of this intervention was to increase the portion of preterm newborns delivered in hospitals with neonatologist-staffed intensive care units. The ANGELS program has four components: (1) development of consensus practice guidelines for specific perinatal conditions, (2) weekly telemedicine conferences on obstetric topics, (3) a 24/7 call center located at UAMS providing specialty consultations and arranging maternal transports to the university hospital setting for delivery services, and (4) enhanced telemedicine communication lines enabling remote consults at locations around the state (Lowery et al. 2007).

This study examines time trends between April 2001 and December 2006 in the delivery of preterm infants (<35 weeks gestation) of mothers covered by Arkansas Medicaid in hospitals with neonatology-staffed intensive care units. We assess whether the various components of the ANGELS intervention were associated with the likelihood of any NICU delivery and the likelihood of delivery at UAMS. We also explore the impact of maternal demographic characteristics, pregnancy risk factors and characteristics of prenatal care, local resources for maternity care in the woman's residential county, and mileage to the closest hospital with neonatology-staffed intensive care services.

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CONCEPTUAL FRAMEWORK

Although there have been several studies of the factors associated with delivery of preterm or low birth weight newborns in neonatal intensive care settings (Phibbs et al. 1993; Bronstein et al. 1995; Gould et al. 1999; Samuelson et al. 2002; Sinkin et al. 2005; Attar et al. 2006; Zeitlin et al. 2008), they have not been oriented toward an explicit conceptual framework. Perinatal regionalization is a consequence of an interaction between a primary obstetrics provider and a pregnant woman needing delivery services for a high-risk newborn. From a provider point of view, perinatal regionalization is a physician referral behavior. From a patient point of view, perinatal regionalization is both a hospital choice behavior and an indicator of a patient's decision to complete a referral from primary to specialty care.

Perinatal Regionalization as a Physician Referral Behavior

There are two component decisions of physician referral, whether to refer a patient and to whom (Shortell and Anderson 1971). In general, physicians refer cases that are beyond their expertise, but community norms and patient expectations also play a role (Ludke 1982; Cain and Jonsen 1992; Donohoe et al. 1999). Physicians choose referral recipients based on their professional networks; referrals are a type of social exchange that occurs among network members (Shortell and Anderson 1971; Gonzalez and Rizzo 1991; Grembowski et al. 1999). The choice of a referral partner depends both on the perception of care quality at the referral site and on the trust relationship developed between the referral partners (Gonzalez and Rizzo 1991; Anthony 2003).

The primary expertise required for delivery of a preterm infant is in the coordination of obstetrics interventions with optimal care for the preterm newborn. Obstetrics providers do not consistently evaluate or treat high-risk pregnancies in the same way as neonatology providers (Bottoms et al. 1997; Morse et al. 2000; Brown et al. 2006). Thus, it is not always clear to obstetrics providers when the delivery for a woman in preterm labor is beyond their expertise (or that of their institution) because of the care needs of the newborn.

In addition to evaluating their own expertise, obstetrics providers may have difficulty sorting out the quality signals as to which settings are truly equipped to care for preterm newborns. Over the past two decades there has been an increase in the number of hospitals claiming to provide neonatal intensive care at some level, even if they have a relatively low volume of patients and lack full-time coverage by neonatologists (Richardson, Reed, and

Cutler 1995; Goodman et al. 2001; Howell et al. 2002). Perinatal regionalization to tertiary settings is reduced in locales with more availability of intermediate NICU hospital settings because of shifts in obstetrics referral patterns (Powell et al. 1995; Gould et al. 1999; Haberland, Phibbs, and Baker 2006; Zeitlin et al. 2008).

Finally, there is a cost to the primary obstetrics provider for referring the patient at delivery. In the theoretical formulation of physician referral decisions, it is hypothesized that referrals occur only when the benefits to the physician outweigh the loss of revenue and patient volume (Grembowski et al. 1999). The majority of a physician's payment for care of pregnant women and all of a hospital's payment is derived from providing delivery services, so transferring a patient at the point of delivery is a major revenue loss.

Perinatal Regionalization as a Patient Hospital Choice and Referral Completion Behavior

Convenience, often measured as distance or travel time, is an important predictor for patient hospital choice. In addition, patients prefer hospitals with more specialty features, more amenities, and greater technological capacity (Porell and Adams 1995). In obstetrics, this has led to the phenomenon of bypassing the closest provider and traveling to larger, better equipped, and specialty staffed hospitals for maternity care (Bronstein and Morrissey 1990, 1991; Phibbs et al. 1993; Truman et al. 2004). One implication of this dynamic is that women with more resources may select better equipped hospitals for their care, whether or not they need high-risk services. This is one explanation for the finding that patient characteristics and neighborhood poverty measures are associated with the rate of high-risk deliveries at hospitals with NICU (Bronstein et al. 1995; Gould et al. 1999; Samuelson et al. 2002; Sinkin et al. 2005; Zeitlin et al. 2008).

While it is a common expectation that women who realize they are in preterm labor or have a high-risk pregnancy would comply with a provider referral to a specialty obstetrics setting, there are cases where such obstetrics advice is not followed (Oberman 2000; Adams, Mahowald, and Gallagher 2003; Samuels et al. 2007). Pregnant women may not understand or may not agree with the risk assessment made by medical personnel (Blankson, Goldenberg, and Keith 1994), or the actions needed to comply with treatment are not perceived as feasible given their life circumstances (Campbell et al. 2000). Preference not to receive specialty treatment may be confounded with difficulty in complying with recommendations for care. Delay in presenting for delivery services at a hospital when in preterm labor may be another

manifestation of a preference not to receive specialty treatment or of difficulty complying with treatment recommendations. One chart review study of Medicaid covered women with preterm deliveries in Arkansas found that 35 percent of women arrived at their delivery setting <4 hours before delivery (Golden, Hopkins, and Sanchez 1998).

Potential Impact of the ANGELS Intervention

The four interventions that are part of the ANGELS program may operate in several ways to increase the likelihood of appropriate physician and patient behavior. Guidelines can align primary obstetrics referral norms in the state to the specialists' understanding of when such referrals are appropriate. Weekly telemedicine conferences can reinforce these practice norms and signal that UAMS is a high-quality referral partner. The development of local telemedicine sites and the call center for physicians builds a professional referral relationship between practicing physicians and the university-based specialists. By arrangement with local physicians, the call center also accepts phone calls from pregnant women concerned about pregnancy complications. This is the only ANGELS intervention that targets the decisions of pregnant women as opposed to physicians. This intervention may increase the likelihood that women recognize their high-risk status and are prepared to transfer their obstetrics care to specialty settings. Note that several of these interventions may increase referrals to UAMS, but not necessarily to other neonatology staffed hospitals in the state.

Although the ANGELS program is supported by the state Medicaid Agency, none of the ANGELS interventions apply exclusively to Medicaid covered pregnancies. However, this study focuses on the impact of the interventions on place of delivery for Medicaid covered infants only. This focus is due in part to data restrictions, but it has the advantage of eliminating maternal insurance coverage as a factor that would need to be taken into account in any analysis of location of delivery.

METHODOLOGY

Data Sources and Variable Selection

The primary data source for this study is a set of Medicaid claims for pregnancy linked to birth certificates for women covered by Medicaid in Arkansas who delivered infants between April 2001 and December 2006. The matching process is described elsewhere (Bronstein et al. 2009). By clustering claims into

pregnancy episodes by date in association with the infant's birth date recorded on the birth certificate, we identified a total of 108,771 pregnancies. We focus this study of perinatal regionalization on deliveries occurring before 35 weeks gestation as the most straightforward way to identify deliveries that should occur in NICU equipped settings. We used young gestational age rather than low birth weight to select candidates for NICU care for two reasons. First, birth weight is not known before delivery, so pregnant women and their primary obstetrics providers make decisions based on the estimated gestational age of the fetus, rather than weight. Second, in this Medicaid population there is a relatively high incidence of small for gestational age newborns (13.7 percent at < 10th percentile for gestational age [Alexander et al. 1996]). If birth weight were used as a criteria for grouping, pregnancies that were not actually preterm would be included in the analysis. Using gestational age as recorded on the birth certificate based on reported last menstrual period, adjusted for compatibility with the birth weight recorded on the birth certificate (Alexander et al. 1996), we identified 5,150 (4.7 percent) live births that occurred at < 35 weeks gestation.

Arkansas is one of only three states that do not maintain a state-based categorization for levels of neonatal services available in hospitals (Blackmon, Barfield, and Statk 2009). We considered hospitals to have level 3 neonatal care available if they had a neonatologist on staff and if they maintained long-term ventilation support for newborns. During the 2001–2005 time period, this included only five hospitals in Arkansas, three in central Arkansas, one in northwest Arkansas, and one in southern Arkansas. An additional hospital in northwest Arkansas added a neonatologist in 2006. Neonatology-staffed hospitals in surrounding states were counted as appropriate care sites when preterm infants were delivered there.

Maternal characteristics, including education, parity, age, race, Hispanic ethnicity, and marital status, were acquired from the linked birth certificate record and included in the analysis. Marital status was coded in conjunction with whether any paternal data were recorded on the birth certificate as the presence of paternal data has been shown in other studies to be correlated with infant mortality (Guadino et al. 1999). Using Medicaid claims data, pregnancies were flagged if they included any diagnoses that ANGELS guidelines indicate should be referred to MFM specialists for consultation (see <http://www.uams.edu/cdh1/guidelines.aspx>), and flagged if the woman received prenatal care from a combination of health department and physician providers. In these cases, nurse practitioner-staffed prenatal clinics in health departments provide prenatal care through the third trimester of pregnancy, and clients are referred to office-based providers for late prenatal care and delivery

services. The Kessner index was applied to reports of prenatal care use on birth certificates to generate a measure of prenatal care adequacy (Alexander and Kotelchuck 1996).

County of residence for pregnant women in the dataset was ascertained based on the zip code of residence recorded on Medicaid claims. The percent of the county population that was African American in the 2000 census, the estimated poverty rate of the county and the presence of OB/GYN physicians in office practice in the calendar year were extracted from the Area Resource File and linked to the maternal records. Counties were flagged as having no maternity services if no hospitals in the county had more than five deliveries in state vital records files for the birth year. County rural–urban commuting areas (RUCA codes) were used to designate counties as rural (categories 7–9), urban (categories 1–3), or small town (categories 4–6).

As noted above, an important issue in measuring the availability of perinatal resources is the tendency for hospitals to claim higher levels of expertise than can be substantiated based on the actual resources available. To proxy this situation, American Hospital Association survey data for the calendar year were used to flag residential counties if the hospitals located there reported having NICU units and/or level 2 or level 3 obstetrics care (indicating that they have the capacity to care for higher risk obstetrics patients). Where these levels of care were reported by hospitals, but the hospitals did not have neonatologists on staff, we recoded the counties as having hospitals with “perceived” high-risk obstetrics care and neonatal units.

Distance to the closest level 3 hospital (including out of state hospitals) and differential differences between the closest level 3 hospital and UAMS were estimated as straight line distances between centroids of the residential and hospital zip codes.

Finally, we included seven measures of ANGELS program activity in the time period of the pregnancy as a measure of exposure to the intervention. These measures were the number of completed obstetrics and neonatal practice guidelines, the number of guidelines actively in preparation in the 6 months including the delivery, whether the delivery took place before or after the completion of the guideline on maternal transport (January 2006), distance in miles to a clinical telemedicine site, participation in ANGELS obstetrics teleconferences at the hospitals in the residential county in the year of delivery, and presence of physician calls and patient calls to the ANGELS call center from the county in the 6-month period that included the delivery.

This study was approved by Institutional Review Boards at UAMS and the University of Alabama at Birmingham.

Statistical Approaches

Descriptive statistical techniques were used to examine changes in individual and county characteristics over the 69-month period (April 2001 through December 2006). We then used logistic regression analysis to assess whether the likelihood of delivery first at a neonatology staffed NICU, and second at UAMS changed over the six-year period. We estimated one model that included only the year of delivery, with 2001 as the reference year, and a second model that adjusted for individual- and county-level factors, but did not adjust for program variables. These are presented as the unadjusted and adjusted probability of delivery at the two settings by year.

We then estimated models for each outcome that controlled for time elapsed since April 2001 (expressed as months), included the ANGELS program variables, and focused on which factors were significantly associated with delivery at any NICU and at UAMS. We adjusted for the lack of independence in some variables due to clustering of observations at the county level by using the Huber–White “sandwich” statistic to obtain robust standard errors. All *p*-values and standard errors reported for the two logistic regressions are based on the Huber–White method. Analyses were conducted using SAS 9.2 with the Proc Survey Logistic procedure.

We tested for collinearity across variables in the regression model by examining the variance inflation factors in the overall model and found high collinearity between the measure of elapsed time, the cumulative number of guidelines completed, and the number of counties from which calls were received by patients (almost all counties by the end of the time period). The model was refined by excluding the measure of completed guidelines. We tested the sensitivity of our model to the inclusion of moderately preterm deliveries; gestational ages 33–34 weeks, by also modeling deliveries <33 weeks. The extent to which the findings for these very early deliveries are different from the findings for all deliveries <35 weeks is discussed in “Findings.”

Findings

Table 1 shows the changes in individual- and county-level characteristics over time. There was a general trend toward more deliveries at hospitals with NICU and at UAMS. There was also a shift in the composition of gestational ages among the preterm infants, with fewer very early deliveries and more deliveries between 33 and 34 weeks. Over time, the portion of mothers who were white or Hispanic, who had completed some college, and were

Table 1: Individual and County Characteristics of Infant Deliveries <35 Weeks Gestation by Calendar Year of Delivery

	2001	2002	2003	2004	2005	2006
<i>N</i>	812	1,105	824	824	887	698
Delivered at hospital with NICU %**	37.7	37.6	43.0	44.1	43.4	39.1
Delivered at UAMS %***	20.6	21.5	23.3	27.3	26.6	19.6
Gestational age <25 weeks %*	5.4	3.3	5.6	5.1	5.0	2.9
Gestational age 25–27 weeks %*	7.0	8.1	9.6	8.0	8.5	4.9
Gestational age 28–31 weeks %**	25.4	21.5	18.9	23.9	18.6	20.1
Gestational age 32–34 weeks %***	62.2	67.0	65.9	63.0	68.0	72.2
Maternal age above 34 %	6.7	6.7	5.8	6.9	7.1	5.3
Maternal age below 20 %	27.6	26.7	25.1	30.6	26.0	25.9
Black %***	47.9	41.1	37.6	36.8	35.7	34.2
Other/unknown %**	2.5	2.4	1.8	2.4	3.8	4.9
Hispanic %***	6.2	5.5	8.5	8.5	12.2	14.6
Less than high school or low education for age %**	32.9	30.1	25.4	27.8	31.5	27.7
More than high school education %***	14.3	15.1	22.2	19.9	19.6	21.1
High parity for age %**	4.9	2.8	2.4	4.6	2.0	3.4
Primiparous %***	35.0	38.6	43.6	44.1	46.0	37.7
Any health department care %***	26.1	25.1	21.5	33.9	26.9	26.8
Multiple birth	7.4	7.6	10.0	10.3	8.2	10.3
Adequate prenatal care %*	47.8	49.7	52.8	53.9	55.7	53.6
Unmarried, father known %*	27.3	27.8	28.4	29.0	32.9	33.7
Unmarried, father not known %*	41.3	38.8	34.8	36.5	34.5	34.0
High risk targeted for MFM referral***	65.5	66.9	69.1	67.7	66.6	46.7
County has OB/GYNs**	25.4	24.8	22.6	19.8	22.3	18.6
More than five births in hospital in county*	82.9	84.0	81.2	78.5	78.7	81.1
Hospital in county reports high-level OB and NICU but has no MFM or neonatologist***	9.9	8.0	17.1	11.9	13.6	9.6
Hospital in county reports high-level OB but no NICU and has no MFM or neonatologist***	29.6	31.9	20.3	28.3	24.6	31.9

County rural	28.4	26.3	30.6	30.9	29.1	30.9
County urban	45.3	46.2	45.0	47.0	48.1	49.4
County has small town	26.3	27.5	24.4	22.1	22.8	19.7
Any ANGELS teleconference site in county % ^{***}	0.0	0.0	6.9	5.7	16.3	26.4
Any physician calls from county ^{***}	0.0	0.0	0.0	78.5	66.1	82.5
Any patient calls from county ^{***}	0.0	0.0	0.0	90.0	96.3	93.7
Mean number of guidelines completed ^{***}	—	—	9.5	46.0	68.9	96.4
Mean number of guidelines under review ^{***}	—	—	11.0	9.9	11.3	11.7
Guideline on neonatal transport available % ^{***}	—	—	—	—	—	100.0
Mean percent under poverty in county ^{***}	17.8	17.4	16.8	16.6	18.0	18.9
Mean percent black in county	6.4	6.8	6.3	6.2	6.1	6.1
Mean minimum distance to NICU ^{**}	42.9	40.7	41.2	41.6	40.2	37.4
Mean minimum distance to clinical telemedicine facility ^{***}	91.8	90.4	65.9	39.2	32.5	27.6

Note. χ^2 for frequencies, t -test for means.

* $p < .05$,

** $p < .01$,

*** $p < .001$.

ANGELS, Antenatal and Neonatal Guidelines, Education, and Learning System; MFM, maternal fetal medicine; NICU, neonatal intensive care unit; UAMS, University of Arkansas for Medical Sciences.

primiparous increased, while the portion who were black, unmarried, had less than a high school education, and had no father named on the birth certificate decreased. The portion with adequate prenatal care increased and the portion with diagnosed high-risk conditions decreased. There was some decline in the number of counties with OB/GYN physicians in office practice, and considerable variability over the period in the number of counties reporting high-risk obstetrics and NICUs. Similarly, the portion of women receiving prenatal care in health departments was variable over the period, suggesting considerable turnover in the mix of physicians providing prenatal care to Medicaid covered women. As expected, ANGELS intervention activity increased after 2003.

Table 2 shows the crude and adjusted odds ratios for delivery at an NICU and for delivery at UAMS over time. Use of these delivery settings increased over the time period, with unadjusted odds ratios showing a significant increase in 2003, 2004, and 2005 for delivery at any NICU and 2004 and 2005 for delivery at UAMS, both compared with 2001. When the probability of any NICU delivery was adjusted for individual and county characteristics, the differences across years were not statistically significant. This suggests that changes in the composition of the Medicaid preterm population and characteristics of their residential counties, rather than the passage of time per se, primarily accounted for the change in likelihood of use of these facilities. However, after adjustment for individual and county characteristics, the probability of delivery at UAMS remained significantly higher in 2004 ($p = .01$) and in 2005 ($p = .07$) compared with 2001.

Table 3 shows the findings from the models examining factors associated with delivery at any NICU and at UAMS for all infants <35 weeks gestation. Gestational age, parity, prenatal care adequacy, risk conditions, education level, health department prenatal care, and age were all associated with delivery at an NICU. Delivery at an NICU was less likely if a woman's residential county had no neonatologist, but had a hospital that reported being able to care for high-risk obstetrics patients, whether or not the hospital reported having an NICU. No ANGELS program variables were significantly associated with delivery at an NICU.

Many of the same maternal characteristics associated with delivery at any NICU were associated with delivery at UAMS. However, women cared for in health departments and those with inadequate prenatal care were more likely to deliver at UAMS, while they were less likely in general to deliver at an NICU. Level of education was not associated with use of UAMS, but marital/partner status was associated with use. Level of perceived obstetrics expertise in the residential county was not associated with delivery at UAMS. Women

Table 2: Likelihood of Delivery of Infant <35 Weeks Gestation at NICU and UAMS, by Calendar Year Compared with 2001

	2002	2003	2004	2005	2006
Likelihood of delivery at any NICU					
Unadjusted odds ratio (95% CI, <i>p</i> value)	1.00 (0.83, 1.20, <i>p</i> = .987)	1.24 (1.02, 1.52, <i>p</i> = .030)	1.30 (1.07, 1.59, <i>p</i> = .009)	1.27 (1.04, 1.54, <i>p</i> = .017)	1.06 (0.86, 1.31, <i>p</i> = .570)
Adjusted odds ratio (95% CI, <i>p</i> value)	0.98 (0.76, 1.27, <i>p</i> = .908)	1.15 (0.81, 1.62, <i>p</i> = .429)	1.25 (0.85, 1.83, <i>p</i> = .250)	1.22(0.81,1.83, <i>p</i> = .338)	1.26 (0.87, 1.81, <i>p</i> = .221)
(controlling for individual and county characteristics)					
Likelihood of delivery at UAMS					
Unadjusted odds ratio (95% CI, <i>p</i> value)	1.06 (0.85, 1.32, <i>p</i> = .606)	1.17 (0.93, 1.48, <i>p</i> = .182)	1.45 (1.15, 1.82, <i>p</i> = .001)	1.40 (1.12, 1.76, <i>p</i> = .003)	0.94 (0.73, 1.21, <i>p</i> = .650)
Adjusted odds ratio (95% CI, <i>p</i> value)	1.13 (0.85, 1.51, <i>p</i> = 0.402)	1.20 (0.84, 1.72, <i>p</i> = .314)	1.27 (0.81, 2.02, <i>p</i> = .013)	1.38 (1.10, 1.74, <i>p</i> = .067)	1.11 (0.98, 1.95, <i>p</i> = .537)
(controlling for individual and county characteristics)					

NICU, neonatal intensive care unit; UAMS, University of Arkansas for Medical Sciences.

Table 3: Likelihood of Infant Delivery <35 Weeks Gestation at NICU and UAMS, Controlling for Individual, County, and Program Variables

<i>Effect</i>	<i>Likelihood of Any NICU Delivery</i>			<i>Likelihood of Delivery at UAMS</i>		
	<i>O.R.</i>	<i>95% Confidence Limits</i>	<i>p-value</i>	<i>O.R.</i>	<i>95% Confidence Limits</i>	<i>p-value</i>
Individual measures						
GA <25 weeks	0.65	0.43	0.99	0.59	0.40	0.86
GA 25–27 weeks	1.48	1.10	1.98	1.45	1.16	1.82
GA 33–34 weeks	0.35	0.28	0.45	0.44	0.29	0.68
Age > 34	0.99	0.71	1.37	1.10	0.84	1.45
Age < 20	0.83	0.69	1.01	0.73	0.59	0.92
Black versus white	1.17	0.82	1.68	0.81	0.67	0.98
Other versus white	1.19	0.79	1.81	1.05	0.64	1.73
Hispanic	1.22	0.79	1.87	1.70	0.92	3.15
Less than high school education	0.90	0.77	1.05	1.03	0.87	1.23
More than high school education	1.42	1.19	1.69	0.97	0.75	1.25
High parity for age	1.01	0.63	1.60	1.20	0.71	2.04
Primiparous	1.69	1.35	2.11	1.55	1.16	2.07
Some health dept. prenatal care	0.72	0.54	0.96	1.22	1.01	1.47
Multiple birth	1.67	1.21	2.30	1.42	1.05	1.93
Adequate prenatal care	1.44	1.26	1.65	0.71	0.50	1.01
Unmarried, father known	0.87	0.71	1.08	0.80	0.66	0.98
Unmarried, father not known	1.06	0.90	1.26	1.18	1.00	1.39
High risk targeted for MFM referral	2.65	1.90	3.71	3.20	2.43	4.21
Cumulative months elapsed since April 2001	0.99	0.98	1.00	1.00	0.99	1.01
County level measures						
County has OB/GYNs	0.61	0.32	1.19	0.95	0.69	1.31
More than five births in hospital in county	1.38	0.79	2.39	0.71	0.43	1.16
Hospital in county reports high-level OB care and NICU	0.33	0.14	0.79	0.90	0.56	1.44

Hospital in county reports high-level OB care, no NICU	0.44	0.24	0.78	0.005	1.12	0.79	1.57	0.532
County rural versus small town	1.14	0.57	2.27	0.711	1.00	0.68	1.47	0.992
County urban versus small town	1.71	0.84	3.46	0.139	1.39	0.95	2.03	0.089
Percent of county population black	1.03	1.00	1.05	0.020	0.99	0.98	1.01	0.439
Percent of county population under poverty level	0.99	0.95	1.02	0.355	1.00	0.97	1.03	0.956
Zip code-based measures								
Minimum distance to NICU	0.99	0.98	1.00	0.133				
Distance to UAMS					0.99	0.99	1.00	0.002
Difference between UAMS distance and minimum NICU distance					1.00	0.99	1.01	0.587
ANGELS program measures								
Any teleconference site in county	1.38	0.91	2.11	0.131	1.64	1.17	2.30	0.004
Number of active guidelines in draft	1.01	0.99	1.03	0.275	1.00	0.99	1.02	0.775
Delivery after guideline on maternal transport in draft	1.05	0.71	1.55	0.821	0.75	0.48	1.18	0.219
Any physician calls from county	1.12	0.72	1.75	0.618	1.06	0.74	1.53	0.736
Any patient calls from county	1.30	0.81	2.09	0.283	1.39	0.92	2.11	0.119
Minimum distance to clinical telemedicine site	1.00	0.99	1.00	0.304	1.002	0.998	1.006	0.4600

ANGELS, Antenatal and Neonatal Guidelines, Education, and Learning System; MFM, maternal fetal medicine; NICU, neonatal intensive care unit; UAMS, University of Arkansas for Medical Sciences.

who lived closer to UAMS were more likely to deliver there, although the differential distance between UAMS and their closest NICU hospital as not associated with delivery at UAMS. Among ANGELS program variables, women living in counties with hospitals that participated in teleconferences on high-risk obstetrics with UAMS were more likely to deliver at UAMS. There was some association between living in a county where women had called the ANGELS call line in the 6-month time period and delivery at UAMS ($p = .12$).

Sensitivity tests using only pregnancies <33 weeks gestation ($n = 2090$) yielded essentially the same findings for delivery at any NICU, except that women residing in counties with any OB/GYNs in office practice were also less likely to deliver in these settings, compared with women in other counties ($p = .06$). However, there were some differences for likelihood of delivery at UAMS for this subgroup of women with earlier preterm deliveries. Individual demographic characteristics were not as strongly associated with location of delivery in this subgroup: there was no greater likelihood of UAMS use by Hispanic women, those unmarried with no father identified and those with health department prenatal care, and no lower likelihood of use by black women. Women residing in counties with no maternity services were less likely to deliver at UAMS, but those residing in counties that reported high-risk obstetrics but not NICU were more likely to deliver at UAMS. There was no association between residing in a county with a teleconference site and delivery at UAMS for this subgroup of younger newborns, but some association between counties where women had contacted the call center and delivery at UAMS ($p = .07$).

Across the entire time period, the likelihood of delivery at any NICU was 40.4 percent for deliveries under 35 weeks and 52.7 percent for deliveries under 33 weeks gestation. The likelihood of delivery at UAMS was 22.9 percent for deliveries under 35 weeks and 31.1 percent for deliveries under 33 weeks gestation.

DISCUSSION

We observed an overall trend toward increased delivery of preterm births at hospitals with NICU over this period, but this was accounted for by changes in the demographics of the covered population. The demographic changes observed—smaller portion of black women, unmarried women with no infant father identified, less educated women—are likely related to the change in the income eligibility threshold for Medicaid covered maternity care in Arkansas,

which rose from 133 percent to 200 percent of the Federal Poverty Level in 2001. We observed an increase in deliveries at UAMS, however, which was not accounted for by changes in demographic characteristics of the population.

At the individual level, women's resources have an impact on use of NICU for preterm delivery: less educated and younger women were less likely to use this care, in accord with the literature on hospital choice. Because this analysis was conducted only on a Medicaid covered population, other important factors affecting hospital choice, insurance coverage, and income are not measured here. Factors that affect women's likelihood of complying with the referral for NICU delivery were also found to be significantly associated with place of delivery: signals of high risk, including primiparity, presence of a diagnosed high-risk condition, and timing within the pregnancy (gestational age of the newborn) were associated with use of NICU, while having mixed sources of prenatal care and having inadequate care were associated with delivery at a hospital without an NICU. The availability of obstetricians in a county and the presence of hospitals reporting the ability to provide more complex services, although they had no local neonatologists, were associated with a lower likelihood that women with preterm births delivered in neonatology-staffed NICU. This verifies the findings of others (Gould et al. 1999; Haberland, Phibbs, and Baker 2006) that perceived local expertise reduces the likelihood of use of more appropriate delivery facilities, and the finding persisted when examining only births at <33 weeks gestation. As the overall trend analysis suggested, there were no significant associations between the ANGELS intervention and delivery at an NICU.

While many of the same individual characteristics were associated with delivery at UAMS as at all hospitals with NICU, women's level of education was not associated with this decision. Interestingly, women with inadequate prenatal care and those with some health department prenatal care were more likely to deliver at UAMS than at other NICU hospitals and hospitals without NICU combined. This suggests a differential referral pattern among prenatal care providers, with office-based physicians either retaining or referring to community-based NICU hospitals, those women, in preterm labor whom they had seen consistently over their pregnancies and referring women with who they did not have this type of relationship to UAMS for care. The ANGELS intervention which established a call center for women to contact UAMS with questions regarding their pregnancies was positively associated with delivery at UAMS, another indication of the influence of established referral patterns on location of delivery. A third indication of differential referral patterns is the

finding that perceived local physician resources were not negatively associated with delivery of local preterm births at UAMS as they were with delivery at other NICU hospitals. In fact, settings that claimed high-risk obstetrics care but no NICU were more likely to refer preterm deliveries <33 weeks gestation to UAMS.

The ANGELS program intervention that encouraged local physicians to participate in UAMS high-risk obstetrics rounds via teleconferencing was also associated with preterm delivery at UAMS. There is no indication that this occurred because of a change in the consensus of appropriate standards for referral of preterm deliveries to hospitals with NICU, because there was no generalization toward referral at any NICU hospital. Rather, some combination of clarifying the signals of quality of care available at UAMS and expansion of local physicians' professional networks to include UAMS providers seems to be the more likely explanation for the shift toward UAMS for provision of care to women with preterm deliveries.

LIMITATIONS

This analysis is limited in a number of ways. We do not have a nuanced measure of the functional capacity of hospitals to care for preterm infants and have made assumptions based on known staffing. The reporting of obstetrics and NICU units on the AHA survey may not accurately reflect local physician perceptions, and measures of obstetrics care capacity at the county level are relatively crude markers of resources, both because of the geographic unit used and the accuracy of information recorded in the Area Resource File. Some observations are not included in our analysis because of missing gestational ages or zip codes. In addition, the study focuses on Medicaid covered deliveries in Arkansas, and it may not be generalizable to other populations in other states.

CONCLUSION

Perinatal regionalization, or the extent to which women in preterm labor or with complicated pregnancies deliver their high-risk infants in settings that are appropriately equipped and staffed, is the consequence of a complex set of provider and patient choices. Many of the factors structuring these choices—physician perceptions of their expertise, desire to retain obstetrics volume,

preference of women to deliver in nearby settings, difficulties in identifying women likely to need NICU care in time to build referral relationships with them—are difficult to change. The approach being tested in Arkansas for improving perinatal regionalization rates, at least within the Medicaid covered population (which represents about 60 percent of all of the deliveries in the state [Kaiser Family Foundation, State Health Facts.org 2009]) is to support the state's academic medical center in expanding its MFM practice to include remote consulting sites, educational activities, and a call center to respond to physician and patient questions regarding high-risk pregnancies. In the first three and a half years of ANGELS program operation, these activities appear to have had a modest positive influence on the likelihood that preterm deliveries occurred in the university setting, but no general impact overall in increasing the likelihood of delivery in any NICU setting. The likelihood of delivery in any NICU setting did in fact increase over this time period, but this was due to changes in the population rather than to the program intervention.

In Arkansas over the period 2001–2006, 52.7 percent of newborns younger than 33 weeks gestation were delivered in hospitals staffed by neonatologists. This is well below the 90 percent goal set by the Healthy People 2010 task force (DHHS 2000). Additional efforts will be necessary to generate the behavior change that will markedly improve this situation.

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Appendix SA1: Author Matrix.

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