Vital Surveillances

Evaluation of Integrated Service Strategy Based on Diagnosis of Duct-Dependent Congenital Heart Disease and Neonatal Mortality Data Analysis — Beijing, China, 2021–2022

Wen Zhang[1]; Zhengchao Chen[1]; Xiaozheng Chen[1]; Hongyan Xu[1]; Yanchun Zhang[1]; Kaibo Liu[1,#]

ABSTRACT

Objective: Integrated congenital heart disease (CHD) services were implemented in Beijing in 2022. This study analyzed prenatal diagnosis patterns and neonatal mortality data for duct-dependent CHDs before and after implementation to provide insights for service optimization.

Methods: We conducted a retrospective analysis of 487 cases of duct-dependent CHDs identified through the Beijing Birth Defects Monitoring System from January 2021 to December 2022. The study population included fetuses and infants from 13 weeks gestation to one year after birth. Cases underwent descriptive analysis focusing on disease occurrence, diagnostic timing, and mortality outcomes.

Results: The prenatal diagnosis rate for duct-dependent CHDs increased from 93.39% in 2021 to 93.91% in 2022, while delayed diagnosis rates decreased from 4.28% to 3.91%. Genetic diagnosis rates improved from 27.92% to 31.94%. Live birth rates following prenatal diagnosis increased substantially from 28.75% to 40.28%. Outcomes varied significantly by CHD subtypes, with complete transposition of the great arteries with intact ventricular septum achieving an 82.14% live birth rate, while hypoplastic left heart syndrome cases resulted in no live births. Notably, neonatal mortality decreased markedly from 7.23% to 3.03%.

Conclusions: Beijing's integrated service model for CHDs has effectively strengthened the connection between secondary and tertiary prevention strategies, reduced unnecessary pregnancy terminations, and improved neonatal survival outcomes.

Congenital Heart Defects (CHDs) represent the leading cause of birth defects and infant mortality worldwide (*1*). Among these, duct-dependent congenital heart defects constitute a particularly severe subset of CHDs that critically impact neonatal survival. These conditions are characterized by significant anomalies in systemic or pulmonary circulation that complicate the transition from fetal to postnatal circulation. Affected neonates depend heavily on systemic-pulmonary shunts, particularly the patency of the ductus arteriosus and foramen ovale, to maintain adequate systemic and pulmonary blood flow. Without intervention, ductal constriction occurring within hours to days after birth can precipitate severe cyanosis, circulatory collapse, or death. Early diagnosis coupled with prostaglandin E administration to maintain ductal patency postnatally has emerged as a crucial strategy for reducing neonatal mortality in these cases (*2*).

The etiology of duct-dependent CHDs is multifactorial, and effective primary prevention strategies remain elusive. Current clinical practice emphasizes secondary and tertiary prevention approaches, comprising mid-trimester ultrasound screening, neonatal physical examination with cardiac auscultation, and targeted echocardiographic evaluation following pulse oximetry screening when indicated. Beijing has maintained standardized prenatal ultrasound screening protocols since 2007, achieving coverage rates exceeding 95% (*3*). A significant advancement occurred in 2014 by incorporation right and left ventricular outflow tract views into prenatal ultrasound screening protocols, substantially improving the detection of complex CHDs. In 2022, Beijing implemented a comprehensive integrated service strategy for CHDs (*4*), establishing a coordinated network of prenatal diagnostic centers (n=10) that complete ultrasound consultations within 10 days, evaluating both cardiac and extracardiac malformations while investigating potential genetic etiologies. These centers collaborate with pediatric treatment facilities (n=5) through multidisciplinary consultations, providing evidence-based intervention recommendations for fetuses with severe, life-

threatening, or disabling conditions, thereby facilitating informed decision-making for pregnant women. For cases with well-defined treatment protocols and favorable postoperative outcomes, comprehensive counseling addresses disease progression, therapeutic options, prognosis, delivery hospital selection, and postnatal intervention strategies. This integrated prenatal screening and diagnosis model has maintained citywide ultrasound screening rates above 95% (*3*), with systematic referral pathways directing qualifying cases from screening institutions to prenatal diagnostic centers for definitive intrauterine diagnosis (*4*).

This study presents a retrospective analysis of duct-dependent CHDs diagnosis and neonatal mortality data in Beijing, comparing outcomes before and after the implementation of the integrated service strategy, with the aim of establishing baseline metrics and evaluating the effectiveness of current prevention and control measures.

METHODS

The birth defect surveillance system encompasses all maternity, induced labor, and pediatric institutions throughout Beijing. All CHDs diagnosed between 13 weeks of gestation and one year post-birth must be documented on birth defect registration cards, which capture comprehensive information including the infant's demographics, prenatal screening results, prenatal diagnosis details, and specific CHD subtype classification. In accordance with the "China Birth Defects Monitoring Program" (*5*), all Beijing medical institutions providing these services are designated as surveillance facilities and are mandated to complete registration cards for each confirmed case. Quality assurance measures include systematic medical record reviews, source document verification, cross-validation with perinatal and infant mortality databases, and follow-up investigations of unreported cases to ensure complete documentation.

The study population comprised late-term miscarriages, stillbirths, and live births from hospital deliveries or pregnancy terminations in Beijing. Data were extracted from the Beijing Birth Defects Hospital Surveillance Network across two distinct periods: pre- and post-implementation of the integrated service strategy. The pre-implementation period (January 1 to December 31, 2021) identified 257 fetuses/infants with duct-dependent CHDs among 147,305 perinatal cases. The post-implementation period (January 1 to December 31, 2022) documented 230 fetuses/infants with duct-dependent CHDs among 135,065 perinatal cases from the same surveillance network.

Patient follow-up was extended through the first year of life. To ensure accurate survival outcome tracking, particularly during the neonatal period, all cases underwent cross-verification against citywide infant mortality surveillance data, enabling comprehensive outcome assessment.

Diagnoses were established according to the International Classification of Diseases (ICD-11) (*6*). Prenatal diagnoses were confirmed exclusively through assessments conducted at designated prenatal diagnostic centers. The classification of duct-dependent CHDs (*2*) followed these distinct categories:

1) Systemic circulation disorder duct-dependent CHDs: These encompassed hypoplastic left heart syndrome, severe coarctation, and interrupted aortic arch;

2) Pulmonary circulation disorder duct-dependent CHDs: This category included tetralogy of Fallot, pulmonary atresia with intact ventricular septum, tricuspid atresia, and severe Ebstein's anomaly;

3) Other types of duct-dependent CHDs: This group comprised transposition of the great arteries with intact ventricular septum and total anomalous pulmonary venous return.

The timing of diagnosis was stratified into three distinct categories: prenatal diagnosis, early postnatal diagnosis (within 3 days of birth), and delayed diagnosis (≥3 days after birth) (*7*).

Statistical analyses were performed using IBM SPSS Statistics for Windows (version 19.0, IBM Corp., Armonk, NY, USA). The primary outcome measure was incidence rate, expressed in per mille (‰), which quantifies the frequency of duct-dependent CHDs in the study population and enables direct comparison between pre- and post-implementation periods of the integrated service strategy. Secondary outcome measures included prenatal diagnosis rate, genetic diagnosis rate, live birth rate following prenatal diagnosis, and neonatal mortality rate. These additional metrics provided comprehensive assessment parameters for evaluating the effectiveness of the integrated service strategy on duct-dependent CHD management and clinical outcomes.

RESULTS

The incidence rates of duct-dependent CHDs in

Beijing, including late-term miscarriages, stillbirths, and pediatric supplemental reports, were 1.74 ‰ (257/147,305) and 1.70 ‰ (230/135,065) before and after the implementation of the integrated service strategy, respectively.

Following the implementation of integrated services, several trends emerged in diagnostic patterns. The proportion of delayed diagnoses showed a modest decrease, while both prenatal and prenatal genetic diagnosis rates demonstrated slight increases. However, these changes did not reach statistical significance (delayed diagnoses: χ^2=0.042, P=0.839; prenatal and prenatal genetic diagnoses: χ^2=0.699, P=0.348), as detailed in Table 1. These findings suggest a trend toward earlier detection, although the differences remained statistically non-significant in our study population.

Following the implementation of the integrated services, referral rates for abnormal ultrasound screenings to prenatal diagnosis centers increased substantially from 60.61% in 2021 to 98.19% in 2022. The proportion of live births following prenatal diagnosis of duct-dependent CHDs rose to 41.20% (89/216), compared to 28.75% (69/240) before strategy implementation. Among cases undergoing invasive prenatal diagnosis, live birth rates increased from 24.24% to 40% following strategy implementation. Analysis by subtype, as shown in Table 2, revealed the highest survival rates for complete transposition of the great arteries with intact ventricular septum (82.14%, 23/28), followed by total anomalous pulmonary venous return (52%, 13/25), and moderate to severe aortic coarctation (45.65%, 21/46). No live births were recorded for hypoplastic left heart syndrome cases, reflecting its poor prognosis.

The proportion of duct-dependent CHD cases delivered in tertiary institutions increased from 83.13% to 89.9% following strategy implementation, with neonatal mortality rates decreasing from 7.23% to 3.03%. Statistical analysis using continuity-corrected χ^2 testing (χ^2=1.693, P=0.193) indicated that this difference in mortality rates was not statistically significant.

In 2022, three neonatal deaths occurred post-implementation, all involving isolated CHD cases. Two deaths resulted from protocol deviations: one case bypassed the mandated prenatal diagnostic center referral following abnormal screening, proceeding directly to pediatric consultation. This oversight resulted in missed extracardiac and genetic anomaly screenings, culminating in death 22 days post-surgery. The second case, lacking systematic prenatal care, led to delayed diagnosis following positive neonatal CHD screening and death 11 days before planned surgical intervention.

DISCUSSION

Over the past decade, Beijing's surveillance of CHD subtypes has generated data on critical CHDs that closely align with international benchmarks and accurately reflect population-level incidence (*8*). While most epidemiological studies of CHDs in China focus exclusively on perinatal outcomes, congenital cardiac defects can manifest throughout gestation (*9*). Severe cases may result in spontaneous miscarriage, intrauterine death, or therapeutic pregnancy termination, with the potential for missed diagnoses postnatally. Beijing has pioneered comprehensive CHD surveillance in China by including late-term miscarriages (13–27 weeks of gestation), stillbirths, and initial pediatric diagnoses in its monitoring period, thereby providing robust data on true CHD incidence and establishing a reliable foundation for assessing prevention strategies.

In this study, the prenatal ultrasound diagnosis rate for duct-dependent CHDs reached 93%, comparable to rates reported in developed nations (*10*). Following the implementation of the integrated service strategy, the referral rate of abnormal ultrasound screenings to

TABLE 1. Time of diagnosis and neonatal mortality of duct-dependent CHDs from 2021 to 2022.

Year	Occurrence	Time of diagnosis								Childbirth in tertiary institutions		Live birth	Neonatal death	
		Delayed diagnosis		Diagnosis within 3 days of birth		Prenatal diagnosis		Genetic diagnosis						
	No. of cases	No. of cases	Percentage (%)	No. of cases	Percentage (%)	No. of cases	Percentage (%)	No. of cases	Percentage (%)	No. of cases	Percentage (%)	No. of cases	No. of cases	Percentage (%)
2021	257	11	4.28	6	2.33	240	93.39	67	27.92	69	83.13	83	6	7.23
2022	230	9	3.91	5	2.17	216	93.91	69	31.94	89	89.9	99	3	3.03

Abbreviation: CHD=congenital heart disease.

TABLE 2. Incidence,diagnosis, and neonatal mortality of duct-dependent CHDs following the implementation of integrated strategies (case-based statistics).

Category	Subtype	Throughout pregnancy	Pediatric supplementary report	Total	Prenatal diagnosis		Diagnosis within 3 days of birth		Delayed diagnosis		Live birth	Neonatal death	
					No. of cases	Percentage (%)	No. of cases	Percentage (%)	No. of cases	Percentage (%)	No. of cases	No. of cases	Percentage (%)
Duct-dependent systemic circulation CHD	Hypoplastic left heart syndrome	18	0	18	18	100.00	0	–	0	–	0	0	0
	Interrupted aortic arch	10	0	10	9	90.00	1	10	0	–	4	0	0
	Severe aortic stenosis	47	2	49	46	93.88	2	4.08	1	2.04	24	0	0
Duct-dependent pulmonary circulation CHD	Tetralogy of Fallot	73	3	76	73	96.05	1	1.32	2	2.63	22	0	0
	Pulmonary atresia with intact ventricular septum	16	1	17	16	94.12	0	–	1	5.88	3	0	0
	Tricuspid atresia	4	1	5	4	80.00	0	–	1	20.00	1	1	100.00
	Ebstein's anomaly	10	0	10	10	100.00	0	–	0	–	4	0	0
Complete transposition of the great arteries with intact ventricular septum		28	1	29	28	96.55	1	3.45	0	–	24	1	4.17
Total anomalous pulmonary venous connection		25	4	29	25	86.21	0	–	4	13.79	17	1	5.88
Subtotal (Case-based statistics)		218	12	230	216	93.31	5	2.18	9	3.91	99	3	3.03

Abbreviation: CHD=congenital heart disease.
"–" means: "0".

prenatal diagnosis centers increased dramatically from 60.61% in 2021 to 98.19% in 2022, demonstrating significantly improved standardization of the referral process under the new protocol.

The prenatal genetic diagnosis rate increased modestly from 27.92% in 2021 to 31.94% in 2022, reflecting enhanced screening capacity and awareness of genetic factors. However, this proportion remains suboptimal, potentially due to families opting for pregnancy termination without genetic investigation when severe structural anomalies are detected. Precise prenatal ultrasound diagnosis of CHD subtypes is essential for prognostic assessment and informed maternal decision-making. Among those continuing pregnancies, the rate of invasive prenatal diagnosis increased from 24.24% to 40% following strategy implementation. The factors influencing acceptance of invasive prenatal diagnosis are likely multifaceted, encompassing procedural concerns and financial considerations, warranting dedicated investigation.

Following integration, the proportion of deliveries at tertiary institutions increased from 83.13% to 89.90%, while delayed diagnoses decreased from 4.28% to 3.91%. Current literature identifies non-tertiary hospital deliveries and delayed diagnosis of isolated cases as significant risk factors for adverse outcomes in critical CHDs (*11*). The integrated service strategy established robust obstetric-pediatric collaboration, resulting in nearly 90% of deliveries occurring at tertiary centers where prostaglandin E administration maintains ductal patency postnatally. Evidence suggests that optimized perinatal interventions reduce neonatal complications including distress, acidosis, intubation requirements, resuscitation needs, and emergency surgical interventions, thereby providing superior preoperative conditions for subsequent cardiac procedures (*12*). These interventions can significantly lower both preoperative and postoperative mortality rates in patients with transposition of the great arteries [95% confidence interval (*CI*): 0.06, 0.80; 95% *CI*: 0.01, 0.82] (*13*), potentially yielding improved long-term neurodevelopmental outcomes and quality of life (*14*).

Following the implementation of the integrated strategy, the live birth rate after prenatal diagnosis of duct-dependent CHDs increased from 28.75% in

2021 to 40.28% in 2022. For subtypes with established treatment protocols and favorable postoperative outcomes, particularly complete transposition of the great arteries with intact ventricular septum (*13*), the live birth rate following prenatal diagnosis increased markedly to 82.14% from 52.38% in 2021, substantially higher than previously reported rates of 22.79% (*15*). Conversely, in cases with poor prognosis, such as hypoplastic left heart syndrome (18 cases), families opted for pregnancy termination after comprehensive counseling. These preliminary findings suggest effective coordination between secondary and tertiary prevention under the integrated service strategy, with families of CHD patients with favorable prognoses more frequently choosing to continue pregnancies following thorough prenatal counseling.

The neonatal mortality rate for duct-dependent CHDs decreased from 7.23% in 2021 to 3.03% in 2022 after one year of strategy implementation. However, this difference did not reach statistical significance. Larger cohort studies with extended follow-up periods are necessary to definitively assess mortality trends in duct-dependent CHDs. Despite these initial promising outcomes, significant challenges remain in standardizing care protocols. Some institutions continue to deviate from established guidelines, either by bypassing prenatal diagnostic centers and referring cases directly to pediatric departments — potentially missing critical extracardiac malformations and genetic anomalies — or by providing inadequate follow-up for high-risk newborns after positive CHD screenings, resulting in delayed diagnoses and missed intervention opportunities. To address these issues, Beijing has initiated a specialized CHD infant mortality review process to refine referral criteria, enhance referral efficiency, and strengthen high-risk infant follow-up protocols, ensuring strict adherence to the integrated service strategy across all institutions to optimize treatment timing and further reduce infant mortality.

There were still some limitations. First, the study analyzed data from 2021 to 2022, with a sample size of 487 cases. Although this period covers the period before and after the implementation of the integrated service strategy, the sample size is relatively small and the time span is short, which may not fully reflect the long-term effects after the implementation of the strategy. Future studies may consider expanding the sample size and extending the observation period to obtain a more accurate and comprehensive assessment. Second, the study focused on changes in diagnostic patterns of duct-dependent congenital heart disease and neonatal mortality before and after the implementation of the integrated service strategy, but did not delve into other potential factors that may influence these outcomes. For example, economic status, preterm birth, low birth weight, distribution of medical resources and other factors. Future studies may incorporate these variables to more fully assess the effects of integrated service strategies.

In conclusion, Beijing's integrated strategy for congenital heart disease has successfully transcended traditional institutional boundaries, creating a comprehensive network that coordinates professional resources across the city's medical institutions. The strategy has evolved from institution-specific multidisciplinary cooperation to city-wide collaborative management, from risk stratification based solely on structural anomalies to comprehensive assessment incorporating genomic factors, and from reactive postnatal treatment to proactive integration of secondary and tertiary prevention. This systematic approach has effectively reduced unnecessary pregnancy terminations while decreasing neonatal mortality rates in the region.

Conflicts of interest: No conflicts of interest.

Funding: Supported by the National Key Research and Development Program of China (grant number 2018YFC1002304).

doi: 10.46234/ccdcw2025.025

[#] Corresponding author: Kaibo Liu, liukb@mail.ccmu.edu.cn.

[1] Beijing Obstetrics and Gynecology Hospital, Capital Medical University, Beijing Maternal and Child Health Care Hospital, Beijing, China.

Submitted: August 26, 2024
Accepted: November 28, 2024
Issued: January 31, 2025

REFERENCES

1. Zhang YY, Wang JY, Zhao JX, Huang GY, Liu KB, Pan W, et al. Current status and challenges in prenatal and neonatal screening, diagnosis, and management of congenital heart disease in China. Lancet Child Adolesc Health 2023;7(7):479 – 89. https://doi.org/10.1016/S2352-4642(23)00051-2.
2. Xia B, Zhang YQ. Pediatric ultrasound imaging handbook. Beijing: People's Medical Publishing House. 2018. https://book.kongfz.com/301245/7160653574. (In Chinese).
3. Zhang W, Xu HY, Zhang YC, Li DY, Liu KB. Epidemiological investigation of congenital hydrocephalus fetuses or infants and their

prognosis among surveillance period in Beijing. Chin J Obstet Gynecol Pediatr (Electron Ed) 2021;17(6):657 – 62. https://doi.org/10.3877/cma.j.issn.1673-5250.2021.06.006.
4. Beijing Municipal Health Commission. Notice on the Implementation of Integrated Services for Congenital Heart Disease，2022. https://wjw.beijing.gov.cn/zwgk_20040/zxgk/202202/t20220221_2613785.html [in Chinese].
5. National Office for Maternal and Child Health Surveillance. China Birth Defect Surveillance - Guidelines for Reporting Difficult and Minor Malformations (2012 Edition). https://www.mchscn.cn/BirthDefectMonitoring-25/417.html [in Chinese].
6. International Classification of Diseases Eleventh Revision (ICD-11). Geneva: World Health Organization; 2022. https://icd11.pumch.cn/ [in Chinese]
7. Olney RS, Ailes EC, Sontag MK. Detection of critical congenital heart defects: review of contributions from prenatal and newborn screening. Semin Perinatol 2015;39(3):230 – 7. https://doi.org/10.1053/j.semperi.2015.03.007.
8. Zhang W, Xu HY, Zhang YC, Liu KB. Epidemiological analysis of congenital heart disease in Beijing from 2017 to 2021. Chin J Obstet Gynecol Pediatr (Electron Ed) 2023;19(1):61 – 8. https://doi.org/10.3877/cma.j.issn.1673-5250.2023.01.009.
9. Zhang YL, Riehle-Colarusso T, Correa A, Li S, Feng XH, Gindler J, et al. Observed prevalence of congenital heart defects from a surveillance study in China. J Ultrasound Med 2011;30(7):989 – 95. https://doi.org/10.7863/jum.2011.30.7.989.
10. Bakker MK, Bergman JEH, Krikov S, Amar E, Cocchi G, Cragan J, et al. Prenatal diagnosis and prevalence of critical congenital heart defects: an international retrospective cohort study. BMJ Open 2019;9(7):e028139. https://doi.org/10.1136/bmjopen-2018-028139.
11. Liberman RF, Getz KD, Lin AE, Higgins CA, Sekhavat S, Markenson GR, et al. Delayed diagnosis of critical congenital heart defects: trends and associated factors. Pediatrics 2014;134(2):e373 – 81. https://doi.org/10.1542/peds.2013-3949.
12. Chakraborty A, Gorla SR, Swaminathan S. Impact of prenatal diagnosis of complex congenital heart disease on neonatal and infant morbidity and mortality. Prenat Diagn 2018;38(12):958 – 63. https://doi.org/10.1002/pd.5351.
13. Słodki M, Rizzo G, Augustyniak A, Seligman NS, Zych-Krekora K, Respondek-Liberska M, et al. Retrospective cohort study of prenatally and postnatally diagnosed coarctation of the aorta (CoA): prenatal diagnosis improve neonatal outcome in severe CoA. J Matern Fetal Neonat Med 2020;33(6):947 – 51. https://doi.org/10.1080/14767058.2018.1510913.
14. Bonnet D. Impacts of prenatal diagnosis of congenital heart diseases on outcomes. Transl Pediatr 2021;10(8):2241 – 9. https://doi.org/10.21037/tp-20-267.
15. Zhang W, Xu HY, Zhang YC, Liu KB. Delayed diagnosis of critical congenital heart defects predicting risk factors and survival rate in newborns in Beijing: a retrospective study. J Int Med Res 2021;49(7):3000605211028028. http://dx.doi.org/10.1177/03000605211028028.