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The Effect of Multidisciplinary Approach on the Birth Rate of Fetuses with Prenatally Diagnosed Congenital Heart Disease

Susan Taejung Kim ,¹ Jinyoung Song ,¹ June Huh ,¹ I-Seok Kang ,¹ Ji-Hyuk Yang ,² Tae-Gook Jun ,² Soo-young Oh ,³ Suk-Joo Choi ,³ and Cheong-Rae Roh ³

¹Department of Pediatrics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

²Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

³Department of Obstetrics and Gynecology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

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Address for Correspondence:

Jinyoung Song, MD, PhD

Department of Pediatrics, Samsung Medical Center, Heart Vascular Stroke Institute, Growth-up Congenital Heart Clinic, Sungkyunkwan University School of Medicine, 81 Irwon-ro, Gangnam-gu, Seoul 06351, Korea.
E-mail: amyjys@naver.com

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ORCID iDs

Susan Taejung Kim

<https://orcid.org/0000-0002-0096-7364>

Jinyoung Song

<https://orcid.org/0000-0002-9660-5949>

June Huh

<https://orcid.org/0000-0003-4523-9632>

I-Seok Kang

<https://orcid.org/0000-0003-4264-0826>

ABSTRACT

Background: This study aimed to determine the effect of a multidisciplinary approach on the birth rate of fetuses with prenatally diagnosed congenital heart diseases (CHDs).

Methods: Among the fetuses of 724 gravidas who underwent fetal echocardiography in Samsung Medical Center from January 2013 to June 2017, 463 fetuses with normal cardiac structure, arrhythmia or simple left-to-right shunt were excluded, and the remaining 261 were included in the study. The subjects were subdivided into groups based on whether they were consulted multidisciplinary, that is, consulted simultaneously by pediatric cardiologists, obstetricians and pediatric cardiac surgeons or not. They were also categorized based on the initial fetal echocardiogram results.

Results: Among the fetuses in the multidisciplinary group, 64.5% of the fetuses were given birth to, and the proportion was not different from that in the non-multidisciplinary group (68.6%, $P = 0.48$). The delivery rate in the multidisciplinary consultation group were 69.2% in the transposition of the great arteries group, 63.6% in the tetralogy of Fallot group, 68.8% in the pulmonary atresia or interrupted aortic arch group, 62.5% in the coarctation of aorta group, 60.0% in the atrioventricular septal defect group, 70.0% in the functional single ventricle group, and 55.6% in the hypoplastic left heart syndrome group; there were no significant differences between the 10 echocardiogram groups. However, when the subjects were categorized into Fontan repair group and biventricular repair group, the Fontan repair group showed a significant increase in the likelihood of delivery when a multidisciplinary approach was taken ($P = 0.035$).

Conclusion: When a fetus was diagnosed with a CHD where Fontan repair should be considered, a multidisciplinary approach resulted in increased possibility of delivery.


Keywords: Congenital Heart Defect; Echocardiography; Prenatal Diagnosis

Ji-Hyuk Yang 

<https://orcid.org/0000-0002-7349-6778>

Tae-Gook Jun 


<https://orcid.org/0000-0002-5161-4665>

Soo-young Oh 

<https://orcid.org/0000-0003-3002-0048>

Suk-Joo Choi 

<https://orcid.org/0000-0002-8946-4789>

Cheong-Rae Roh 

<https://orcid.org/0000-0002-5266-6168>

Disclosure

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Song J, Kang IS, Huh J, Yang JH, Jun TG, Oh SY, Choi SJ, Roh CR. Data curation: Kim ST, Song J, Kang IS, Huh J, Yang JH, Jun TG, Oh SY, Choi SJ, Roh CR. Formal analysis: Kim ST, Song J. Investigation: Kim ST, Song J. Methodology: Song J, Kang IS, Huh J, Yang JH, Jun TG. Supervision: Song J, Kang IS, Huh J. Writing - original draft: Kim ST, Song J. Writing - review & editing: Kim ST, Song J, Kang IS, Huh J.

INTRODUCTION

Congenital heart disease (CHD) is the most common form of congenital anomaly and is regarded as one of the major causes of infant mortality.¹⁻⁴ The severity of CHD varies widely, from mild form where no intervention is required to severe life-threatening form, where immediate intervention is necessary.⁵ As early as in the 1980s, the feasibility of ultrasonography in the prenatal diagnosis of fetal cardiac anomaly had been recognized.⁶ Nowadays, fetal echocardiography, indeed, facilitates the prenatal diagnosis of fetuses with CHDs allowing risk stratification, identification of those who may require special intervention at birth or within the first few days of life, and planning for neonatal resuscitation and initial transitional care.² The positive influence of prenatal diagnosis of CHD is that fetuses with severe cardiac lesions can be prearranged to be delivered in a tertiary care center where proper management is available, while the major downside is that early detections may increase the number of pregnancy terminations.³

Once CHD is diagnosed prenatally, neonatal resuscitation and initial transitional care should be planned carefully. Proper planning requires interaction between diverse specialists; pediatric cardiologists to perform echocardiography to examine the structure and hemodynamics of the fetal heart, pediatric cardiac surgeons to devise necessary surgical corrections, and obstetricians for planning of the delivery. Multidisciplinary approach would not only allow improvement in the area of perinatal management but it is also expected that such approach would give opportunities to develop prenatal techniques; that is, techniques to manage CHD patients within the uterus, or prior to birth.⁷ For this reason there had been notions around the globe on the importance of assembling multidisciplinary teams for the care of fetuses with CHDs. However, the discussion merely started a decade ago⁸ and there had been limited studies to support such opinion.

The purpose of this paper was to compare the likelihood of delivery of infants with CHDs depending on the initial diagnosis based on the fetal echocardiography performed by a pediatric cardiologist, and on the specialists involved in the initial medical consultation.

METHODS

We retrospectively reviewed the medical records of 724 women who obtained fetal echocardiography from January 2013 to June 2017 at Samsung Medical Center, a tertiary care center located in Korea. The 463 cases with normal cardiac structure, or those with arrhythmia and simple left-to-right shunt were excluded, and the remaining 261 cases were included in the study.

In Samsung Medical Center, there is a special outpatients' session every other Saturday where pediatric cardiology specialists, obstetricians and pediatric cardiac surgeons open joint clinic sessions to consult women with pregnancy complicated by prenatally diagnosed CHDs. The sessions started in 2013, and the patients were usually referred from local hospitals. In these special sessions, which usually lasted for more than half an hour, the patients sat around a table with the three specialists with different backgrounds and discussed the diagnosis, treatment and prognosis of the fetus based on the echocardiogram performed by the pediatric cardiologists (**Fig. 1**). No more than 4 patients were consulted each day, and the patients were allocated to these Saturday sessions when the time slots were available, and



Fig. 1. Special outpatients' session in Samsung Medical Center where pediatric cardiology specialists, obstetricians and pediatric cardiac surgeons open joint clinic sessions to consult women with a pregnancy complicated by prenatally diagnosed congenital heart diseases. In this session, the patient meets with the three specialists simultaneously.

without any specific selection criteria. Other than these special Saturday sessions, normally the patients could only meet each specialist once at a time. Among 261 subjects included in the study, 121 subjects were initially seen at these Saturday sessions and were classified as the multidisciplinary group. The remaining 174, who were consulted by at most two of the three specialists non-simultaneously, were classified as the non-multidisciplinary group.

The subjects were also divided into 10 different groups based on their initial fetal echocardiography results; transposition of the great arteries group (group 1), tetralogy of Fallot group (group 2), pulmonary atresia or interrupted aortic arch group (group 3), coarctation of aorta group (group 4), anomalous pulmonary venous return group (group 5), functional single ventricle group (group 6), atrioventricular septal defect group (group 7), hypoplastic left heart syndrome group (group 8), simple valvar stenosis group (group 9) and undetermined group (group 10). For further analysis, groups 1 through 5, which could be repaired in biventricular manner, were categorized into biventricular group, whereas groups 6 to 8, where functional single ventricle repair, including Fontan procedure, should be considered, were categorized as the Fontan repair group.

Chi-square analysis was used to compare the demographic characteristics between the two groups as well as the delivery rate between the multidisciplinary group and the non-multidisciplinary group, overall and within the 10 different echocardiography groups. Logistic regression analysis was used to analyze if the change in delivery rate when multidisciplinary approach was taken was significantly different between the echocardiography groups. A two-sided P value of < 0.05 was considered statistically significant.

Ethics statement

This study was approved for exemption of subject consent by Samsung Medical Center Institutional Review Board (IRB File No.2019-03-047-002) and was conducted in accordance with the Declaration of Helsinki.

RESULTS

Of the 261 subjects included in the study, the multidisciplinary group consisted of 121 subjects. The 64.5% of the multidisciplinary group were born in our institute or were referred to another hospital, while 68.6% of those in the non-multidisciplinary group were born here or elsewhere, and the difference between the two groups was insignificant ($P = 0.48$).

Table 1 shows the number of subjects in each echocardiography group. Tetralogy of Fallot group was the largest consisting of 68 subjects (26%); functional single ventricle group (n = 38, 14.6%), and coarctation of aorta group (n = 36, 13.8%) followed. The delivery rate after multidisciplinary approach were 69.2% in the transposition of the great arteries group, 63.6% in the tetralogy of Fallot group, 68.8% in the pulmonary atresia or interrupted aortic arch group, 62.5% in the coarctation of aorta group, 70% in the functional single ventricle group, 60% in the atrioventricular septal defect group, 55.6% in the hypoplastic left heart syndrome group; there were no significant differences between the multidisciplinary group and the non-multidisciplinary group in each echocardiography group.

In **Table 2**, we compared other factors that might influence the decision to deliver the baby or not. Approximately 5 subjects in each group had suspicious heterotaxy, and the differences were not significant between the multidisciplinary and the non-multidisciplinary groups ($P = 0.74$) as well as within the group, that is between the delivered group and not delivered group. As an indirect measure of socioeconomic status of the subjects, the medical insurance coverage of the subjects was reviewed. 95% of the subjects were enrolled in the National Health Insurance, 2.9% were international cases, and none of the subjects required medical beneficiary from the country. There were no significant differences in the type of medical insurance enrolled between the multidisciplinary group and non-multidisciplinary group

Table 1. Percentage of delivery and OR comparing the odds of delivery when multidisciplinary approach is taken or not

Groups	Multidisciplinary delivery/total (%)	Non-multidisciplinary delivery/total (%)	Total delivery/total (%)	OR	P value
1	9/13 (69.2)	13/15 (86.7)	22/28 (78.6)	0.346	0.273
2	21/33 (63.6)	24/35 (68.6)	45/68 (66.2)	0.802	0.668
3	11/16 (68.8)	10/14 (71.4)	21/30 (70)	0.880	0.873
4	10/16 (62.5)	15/20 (75.0)	25/36 (69.4)	0.556	0.421
5*	N/A	1/2 (50.0)	1/2 (50.0)	NA	NA
6	14/20 (70.0)	8/18 (44.4)	22/38 (57.9)	2.916	0.116
7	6/10 (60.0)	2/4 (50.0)	8/14 (57.1)	1.500	0.733
8*	5/9 (55.6)	1/7 (14.3)	6/16 (37.5)	7.498	0.113
9	1/1 (100.0)	7/8 (87.5)	8/9 (88.9)	NA	NA
10	1/3 (33.3)	15/17 (88.2)	16/20 (80.0)	0.067	0.596
Total	78/121 (64.5)	96/140 (68.6)	174/261 (66.7)	-	0.483

Group 1 (transposition of the great arteries), group 2 (tetralogy of Fallot), group 3 (pulmonary atresia or interrupted aortic arch; ductal dependent lesions), group 4 (coarctation of aorta), group 5 (anomalous pulmonary venous return), group 6 (functional single ventricle), group 7 (atrioventricular septal defect), group 8 (hypoplastic left heart syndrome), group 9 (simple valvar stenosis) and group 10 (undetermined).

OR = odds ratio.

*Groups 5 and 8 were excluded from the analysis due to small sample sizes.

Table 2. Comparison of other factors that might influence the decision to deliver the fetus or not

Variables	Multidisciplinary			Non-multidisciplinary			P value
	Delivery	Non-delivery	Total	Delivery	Non-delivery	Total	
Suspected heterotaxy							0.739
Yes	4	2	6	2	4	6	
No	74	41	115	94	40	134	
Health insurance							0.372
National health	76	41	117	93	37	130	
International	1	1	2	2	2	4	
Others	1	1	2	1	5	6	
Chromosome analysis (amniocentesis)							0.271
Yes			21			32	
Abnormal	2	0		3	1		
Normal	15	4		17	11		
No	61	39	100	76	32	108	

There were no significant differences when the total numbers in each category were compared between the multidisciplinary and the non-multidisciplinary groups ($P > 0.05$).

($P = 0.37$). In the multidisciplinary group, only 4 subjects of the 43 patients (9.2%) who did not deliver the baby had their chromosome analyzed via amniocentesis and all 4 turned out to be normal, whereas among 78 babies born, 17 had their chromosome tested (21.8%) prior to birth and 2 had abnormal chromosomes. In the non-multidisciplinary group, 12 of the 44 subjects (27.3%) who did not deliver the baby in Samsung Medical Center or elsewhere carried out amniocentesis for chromosome analysis and only 1 showed chromosome anomaly (Turner syndrome). The infants of 20 subjects out of 96 (20.8%) who delivered the baby in the non-multidisciplinary group, underwent chromosome studies via amniocentesis where 3 showed chromosomal abnormality, including CATCH 22 and Edwards syndrome.

Transposition of great arteries, tetralogy of Fallot, pulmonary atresia or interrupted aortic arch, coarctation of aorta, anomalous pulmonary venous return can be repaired in a biventricular manner while in functional single ventricle, atrioventricular septal defect and hypoplastic left heart syndrome, it is highly likely that the hearts need to be repaired into functional single ventricles, and these three groups were regrouped into the Fontan repair group. Unlike the biventricular repair group, the Fontan repair group showed a significant increase in birth rate when multidisciplinary approach was taken (Fig. 2).

DISCUSSION

The estimated number of CHD ranges from 5 to 8 per 1,000 live births^{1,3,4,9,10} and it is still considered the most common cause of major congenital anomalies. In the past, the diagnosis was mainly made after birth; however, nowadays with the advance of imaging techniques, the diagnosis is usually made antenatally. Prenatal diagnosis of CHD allows detailed planning of pre, peri- and post-natal care. For this reason, in certain countries, fetal cardiac scanning is gradually being incorporated into the routine fetal screening program.^{6,10} However, to be able to correctly assess the prognosis of fetuses with CHDs and to accurately identify those who require immediate intervention, a multidisciplinary team involving pediatric cardiologists, obstetricians, pediatric cardiac surgeons and other pediatric specialists is necessary. The quality and completeness of the information on what should

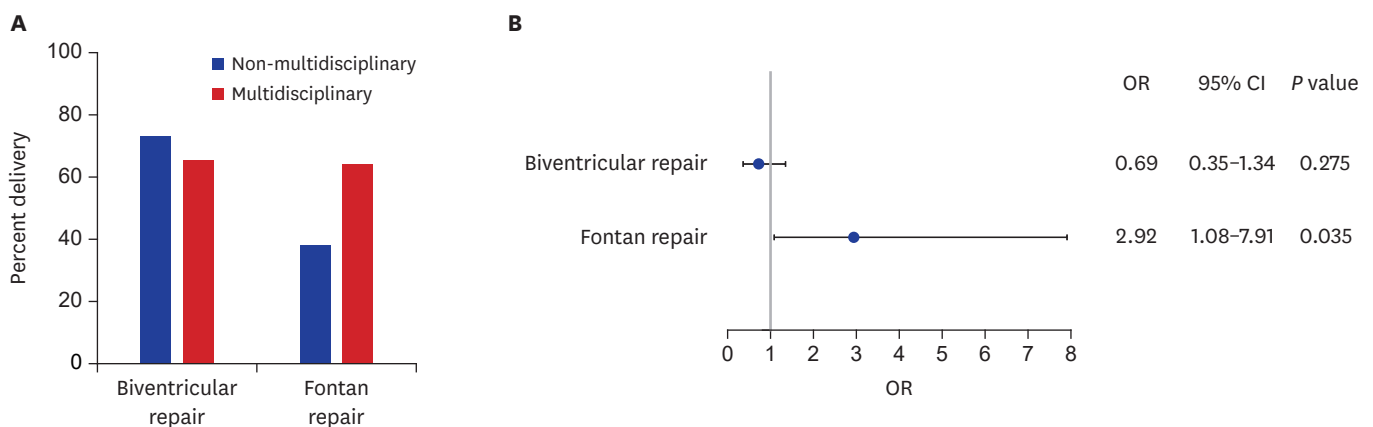


Fig. 2. The subjects were categorized into Fontan repair group and biventricular repair group for comparison. (A) The change in the percent delivery of biventricular and Fontan repair group depending on the mode of consultation. (B) The odds of delivery in biventricular repair group and Fontan repair group when multidisciplinary diagnostic approach was taken. Unlike the biventricular repair group, the single ventricular repair group showed a significant increase in birth rate when multidisciplinary approach was taken. OR = odds ratio, CI = confidence interval.

be expected of the child would likely influence the decisions the parents make: in some cases, whether to sustain the pregnancy or not.^{7,11} In this paper, the purpose was to assess the effect of multidisciplinary approach on delivery of infants with prenatally diagnosed CHDs by comparing the likelihood of giving birth to a child according to the specialists who participated in the initial assessment and according to the initial diagnosis made by the echocardiography examination.

To be able to provide accurate blueprints of the clinical course to the parents, and to devise a plan to safely deliver the baby, there had been attempts to develop severity scales for the CHD fetuses.^{2,5,8} Frequently, the fetuses are divided into different risk categories based on the expected hemodynamic status and necessity of immediate intervention at birth. Low-risk cardiovascular defects are expected to be hemodynamically stable and can be safely managed in an outpatient clinic or via tele-monitoring. Medium-risk patients have low risk of hemodynamic instability but can be ductal dependent and may require administration of prostaglandin E1. Such patients must be delivered in the presence of a neonatologist. High-risk groups are expected to have severe hemodynamic compromise requiring immediate intervention at birth.

In this paper, we assumed that if the baby was not born in our institute or was not formally transferred or referred to another hospital, it is more likely that the baby had been terminated or had died in utero rather than delivered in a different institution. This may have led to underestimation of the overall delivery percentage, especially in the low-risk group. To minimize such discrepancy, we excluded fetuses in the low-risk CHD group who could be safely delivered elsewhere; that is we excluded those with simple left-to-right shunts such as atrial septal defects or ventricular septal defects, or simple arrhythmia patients. Categorizing the remaining subjects into medium and high-risk groups was not meaningful for the study, because most of the subjects fell into the medium-risk group. Conventional stratification categorizes the patients who need intervention into medium-risk or high-risk groups regardless of whether the required intervention is surgical or transcatheter based. Surgical procedures are performed by cardiac surgeons while transcatheter procedures are performed by pediatric cardiologists. Since the definition of multidisciplinary approach in this paper included both specialists, categorizing the fetuses into groups who required a similar form of intervention was necessary. Thus, we divided the subjects into 10 different echocardiogram categories as mentioned in the methods section. The 10 echocardiography groups were further regrouped into Fontan repair group versus biventricular repair group, based on the type of surgical repair expected. The categorization was based on whether the possibility of Fontan repair was explained to the patients during the consultation or not. For atrioventricular septal defect patients, the possibility of surgery requiring single ventricle repair had been explained to the parents, since the possibility of such repair remains high even though in many of the balanced atrioventricular septal defect patients, biventricular repair may be the solution; the exact surgical repair necessary cannot be determined with certainty at the initial fetal echocardiography examination. The quality of the explanation of the possibility of Fontan repair did not differ in the multidisciplinary group and the non-multidisciplinary group.

Other comorbidities including the presence of chromosomal abnormality, heterotaxy as well as the socioeconomic status of the parents were retrospectively reviewed (**Table 2**). Hypothetically, subjects are more likely to give up delivery when they know that the fetus has chromosome abnormality or other comorbidities. However, when the amniocentesis results

of the subjects were reviewed, regardless of the consultation method taken, there were more chromosome abnormality in the delivery group rather than the non-delivery group, which is opposite to the hypothesis. Moreover, there was no significant difference between the two groups in the proportion of subjects who had their chromosome analyzed ($P = 0.271$). Thus, we concluded that the presence or absence of chromosomal abnormality or comorbidity was not a significant factor in our study.

As an indirect measure of the socioeconomic status of the subjects in the study, their medical insurance status was reviewed (Table 2). The 95% of the subjects were enrolled in the National Health Insurance, 2.9% were International cases, and most importantly, none of the subjects required medical beneficiary. There were no significant differences in the enrolled insurance between the multidisciplinary group and non-multidisciplinary group ($P = 0.37$).

In this study, around 65% were delivered in Samsung Medical Center or elsewhere. This falls within the reported range of 15% to 50% of termination of pregnancy complicated by prenatally diagnosed CHDs.^{3,6,9,12} The rate of termination usually increases in single ventricle hearts,^{6,12} however, such trend was not seen in our study with no significant differences in delivery rate between groups (Table 1).

In general, the difference in the likelihood of giving birth was unremarkable when modes of consultation, or diagnosis were considered. However, when diagnosed with functional single ventricle, atrioventricular septal defect or hypoplastic left heart syndrome, where surgical repair into single ventricle should be considered, multidisciplinary approach of pediatric cardiologists, obstetricians and pediatric cardiac surgeons resulted in increased possibility of delivering the baby (Fig. 2). This result can be expected because the treatment of such cardiac anomaly requires equal contribution from all three specialists: pediatric cardiac surgeons with specialized echocardiography skills would have to thoroughly understand the 3 dimensional structure of the fetal heart to estimate the hemodynamics and the need for intervention, pediatric cardiac surgeons to decide the timing and type of surgical procedures necessary, and obstetricians to decide with the other two specialists on the timing of delivery.² Multidisciplinary approach to congenital cardiac anomaly not only allows designing of proper management perinatally, but also allows development of in-utero management strategies in the future.^{13,14}

One limitation is that the study was based on retrospective reviews of the medical charts and that because it is illegal to terminate pregnancy because of fetal anomaly in Korea,⁴ other data acquisition methods, such as telephone interviews, for additional information, including pregnancy outcomes, were virtually impossible. However, there are not many tertiary medical institutions in Korea capable of taking full care of fetuses with complex CHDs requiring intervention at birth, and we have kept records of the subjects formally referred to another tertiary center for delivery. Based on these facts, if the baby was not born in our institute or was not formally transferred or referred to another hospital, we assumed that the baby had been terminated or had died in utero rather than delivered in a different institution. To minimize any possible underestimation of delivery, we excluded fetus in the low-risk CHD group who could be safely delivered in other primary or secondary medical facilities from the analysis.

Another limitation is that the study was based on data from a single tertiary hospital with a relatively short study period and small sample size. Regarding both limitations discussed

above, follow up population-based multicenter analysis with longer study period would be necessary to confirm the effect of multidisciplinary approach to prenatal detection of CHDs. Moreover, the effect on other parameters and clinical outcomes when multidisciplinary approach is taken should be explored.

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