

doi: 10.13241/j.cnki.pmb.2021.10.038

## 胎儿心脏超声对足月胎儿出生后血液动力学变化的影响 \*

仲丽美<sup>1</sup> 贾红娥<sup>2</sup> 薛红红<sup>2Δ</sup> 姜 珏<sup>3</sup> 淡 敏<sup>1</sup>

(1 西北妇女儿童医院医学超声中心 陕西 西安 710016; 2 延安大学附属医院超声医学科 陕西 延安 716000;  
3 西安交通大学第二附属医院超声科 陕西 西安 710004)

**摘要 目的:**探讨胎儿心脏超声对足月胎儿出生后血液动力学变化的影响。**方法:**2018年7月1日到2020年6月30日选择在本院分娩的足月胎儿22750例,其中高危分娩组872例,正常分娩组21878例。所有胎儿都给予心脏超声,记录血液动力学变化情况并进行相关性分析。**结果:**所有胎儿的超声图像评分 $\geq 2$ 分,平均 $2.87 \pm 0.14$ 分,符合诊断要求。高危分娩组的主动脉与肺动脉FHR值高于正常分娩组( $P < 0.05$ ),PTV值低于正常分娩组( $P < 0.05$ )。高危分娩组的脐动脉RI与PI值高于正常分娩组( $P < 0.05$ ),而大脑中动脉RI与PI值低于正常分娩组( $P < 0.05$ )。在高危分娩组中,随访确诊先心病45例,发生率为5.2%;正常分娩组随访确诊32例,发生率为0.1%,对比差异有统计学意义( $P < 0.05$ )。在足月胎儿22750例中,Pearson相关分析显示先心病与脐动脉RI、PI值、主动脉和肺动脉FHR值、PTV值都存在相关性( $P < 0.05$ )。**结论:**胎儿心脏超声可反映足月胎儿出生后血液动力学变化情况,可指导临床医师及时对高危分娩作出适当处理。

**关键词:**足月胎儿;心脏超声;血液动力学;高危分娩;相关性

**中图分类号:**R714.5;R445.1 **文献标识码:**A **文章编号:**1673-6273(2021)10-1978-04

## The Effects of Fetal Cardiac Ultrasound on Hemodynamic Changes of Full-term Fetus after Birth\*

ZHONG Li-mei<sup>1</sup>, JIA Hong-e<sup>2</sup>, XUE Hong-hong<sup>2Δ</sup>, JIANG Jue<sup>3</sup>, DAN Min<sup>1</sup>

(1 Medical Ultrasound Center, Northwest Women and Children's Hospital, Xi'an, Shaanxi, 710016, China;

2 Department of Ultrasound Medicine, Affiliated Hospital of Yan'an University, Yan'an, Shaanxi, 716000, China;

3 Department of Ultrasound, Second Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi, 710004, China)

**ABSTRACT Objective:** To investigate the effects of fetal cardiac ultrasound on the hemodynamic changes of full-term fetuses after birth. **Methods:** A total of 22,750 full-term fetuses, who were delivered in Northwest Women and Children's Hospital from July 1, 2018 to June 30, 2020, were selected and were divided into high-risk delivery group ( $n=872$ ) and normal delivery group ( $n=21,878$ ). All the fetuses were examined by cardiac ultrasound, and their hemodynamic changes were recorded and analysed. **Results:** The ultrasound image scores of all fetuses were  $\geq 2$  points, with the average of  $2.87 \pm 0.14$  points, which accorded with the diagnostic requirements. The FHR values of the aorta and pulmonary artery in the group ( $P < 0.05$ ), and the PTV values were lower than those in the normal delivery group ( $P < 0.05$ ). The RI and PI values of the umbilical artery in the high-risk delivery group were higher than those in the normal delivery group ( $P < 0.05$ ), while the middle cerebral artery RI and PI values were lower than the normal delivery group ( $P < 0.05$ ). High-risk delivery group were higher than those in the normal delivery. In the high-risk delivery group, there were 45 cases of congenital heart disease diagnosed by followed-up, the incidence rates were 5.2%; and in the normal delivery group, there were 32 cases of congenital heart disease diagnosed by followed-up, the incidence rates were 0.1%, with statistically significant differences ( $P < 0.05$ ). In the 22,750 full-term fetuses, Pearson correlation analysis showed that congenital heart disease was correlated with umbilical artery RI, PI, aortic and pulmonary artery FHR, and PTV values ( $P < 0.05$ ). **Conclusions:** Fetal echocardiography can reflect the hemodynamic changes of full-term fetuses after birth, and can coach clinicians in dealing promptly with high-risk delivery.

**Key words:** Full-term fetus; Echocardiography; Hemodynamics; High-risk delivery; Correlation

**Chinese Library Classification (CLC):** R714.5; R445.1 **Document code:** A

**Article ID:** 1673-6273(2021)10-1978-04

### 前言

当前每年出生的先天残疾儿童约占总出生人口总数的5.0%左右,也是新生儿死亡的最主要原因之一<sup>[1]</sup>。先天性心脏病简称

\* 基金项目:陕西省社会发展基金项目(2019SF072)

作者简介:仲丽美(1982-),女,硕士,住院医师,研究方向:产前筛查、儿科,电话:18182620409, E-mail: zlm091011@163.com

Δ 通讯作者:薛红红(1982-),女,本科,副主任医师,研究方向:超声诊断及治疗,电话:15909214038, E-mail: 307139169@qq.com

(收稿日期:2020-11-04 接受日期:2020-11-27)

先心病,发生率与致病率均位于出生缺陷的首位<sup>[23]</sup>。目前先心病的具体发病机制还不明确,不过病因包括免疫溶血性疾病、感染性疾病糖尿病、结缔组织疾病、遗传基因缺陷、丙酮尿症、慢性酒精中毒、不正常妊娠史、高龄孕妇等,特别是有先心病家族史的胎儿先心病的发生率可高达 15.0%左右<sup>[45]</sup>。随着影像学仪器分辨率的不断提高及对胎儿病理生理知识认识的深化,在胎儿出生后进行胎儿疾病的筛查已越来越广泛<sup>[67]</sup>。特别是当前超声具有安全、简便、科学、有效、可重复等优点,也是胎儿先心病诊断的首选方法<sup>[89]</sup>。胎儿在生长过程中,血液通过脐静脉进入胎儿;在胎儿临足月时,血液通过静脉导管分流到右心房的脐静脉血占总量的 1/4 左右,到肝左、右叶的脐静脉血分别占总量的 1/2 和 1/4 左右,从而保证了营养丰富的血液进入到大脑、左心室、心肌,促进与胎盘进行再氧合及物质交换<sup>[1011]</sup>。本文具体探讨了胎儿心脏超声对足月胎儿出生后血液动力学变化的影响,希望为胎儿预后估计及临床处理等提供参考。现总结报道如下。

## 1 资料与方法

### 1.1 研究对象

2018 年 7 月 1 日至 2020 年 6 月 30 日选择在本院分娩的足月胎儿 22750 例,纳入标准:得到医院伦理委员会的批准;所有产妇均知情检查内容,并签署胎儿超声检查知情同意书;胎儿分娩孕周 $\geq 37$ 周;单胎分娩;临床、超声与随访资料完整。排除标准:临床资料缺乏者;具有超声检查禁忌者;外院引产或自然流产,无法确定最终诊断者;失访者。

其中男 11983 例,女 10767 例;孕周最短 37 周,最长 42 周,平均孕周  $39.14 \pm 2.77$  周;平均孕妇年龄  $31.27 \pm 2.43$  岁。其中高危分娩组 872 例,包括重度妊娠高血压综合征 231 例、重度妊娠肝内胆汁淤积症 322 例、重度贫血 123 例、胎儿宫内发育迟缓 196 例。正常分娩组 21878 例,表现为胎儿无结构和染

色体异常。

### 1.2 心脏超声方法

美国 GE E8 彩色多普勒超声诊断仪,探头频率 2~7 MHz。选用功率不超过 100 mW/cm<sup>2</sup> 的胎儿超声检查程序,检查者先对胎儿心脏各个常规诊断切面的二维超声扫查,然后进行经腹三维超声容积探头扫查,观察胎儿、胎儿器官、胎盘、心脏的位置。采用彩色多普勒观察胎儿左、右心内血流方向、血流束宽度,室间隔、各瓣环处等血管的血流情况。采集图像整理后存储于系统配套的采集图像工作系统中。

### 1.3 观察指标

(1)从瓣膜远端记录主动脉、肺动脉的血流速度波形,记录相关血流动力学参数,包括胎心率 (FHR)、收缩期峰值速度 (PTV)等参数。(2)记录胎儿的外周血流参数,包括脐动脉与大脑中动脉的 RI 与 PI 值。S/D 为收缩期峰值速度与舒张末期血流速度之比,阻力指数 $[RI=(S-D)/S]$ ,搏动指数 $[PI=(S-D)/M]$ 。(3)超声评分标准:3 分:胎儿心脏结构显示非常清晰,易于辨认;2 分:胎儿心脏结构显示清晰,可以辨认;1 分:胎儿心脏结构显示欠清晰,无法辨认。(4)以尸检、随访观察所得数据为金标准,记录最终诊断情况。

### 1.4 统计方法

选择 SPSS19.00 软件对本研究所有数据进行分析,计量数据选择均数 $\pm$ 标准差的形式表示(对比为 t 检验),计数数据选择率(%)的形式表示(对比为卡方  $\chi^2$  检验),各参数之间的相关性用 Pearson 相关分析, $P<0.05$  认为统计学存在差异性。

## 2 结果

### 2.1 胎儿心脏血流参数对比

所有胎儿的超声图像评分 $\geq 2$ 分,平均  $2.87 \pm 0.14$  分,符合诊断要求。高危分娩组的主动脉与肺动脉 FHR 值高于正常分娩组( $P<0.05$ ),PTV 值低于正常分娩组( $P<0.05$ ),见表 1。

表 1 两组胎儿心脏血流参数对比( $\bar{x} \pm s$ )

Table 1 Comparison of fetal heart blood flow parameters between two groups ( $\bar{x} \pm s$ )

| Groups                   | n     | Aorta              |                      | Pulmonary artery   |                     |
|--------------------------|-------|--------------------|----------------------|--------------------|---------------------|
|                          |       | PTV(cm/s)          | FHR(bpm)             | PTV(cm/s)          | FHR(bpm)            |
| High risk delivery group | 872   | $65.20 \pm 3.29^*$ | $141.76 \pm 11.82^*$ | $55.49 \pm 4.01^*$ | $141.48 \pm 3.84^*$ |
| Normal delivery group    | 21878 | $70.87 \pm 4.14$   | $136.09 \pm 8.77$    | $63.56 \pm 5.55$   | $134.98 \pm 2.75$   |

Note: Compared with the normal delivery group,  $*P<0.05$ .

### 2.2 外周血液动力学参数对比

高危分娩组的脐动脉 RI 与 PI 值高于正常分娩组( $P<0.05$ ),

而大脑中动脉 RI 与 PI 值低于正常分娩组( $P<0.05$ ),见表 2。

表 2 两组外周血液动力学参数对比( $\bar{x} \pm s$ )

Table 2 Comparison of peripheral hemodynamic parameters between two groups ( $\bar{x} \pm s$ )

| Groups                   | n     | Umbilical artery  |                   | Rteria cerebri media |                   |
|--------------------------|-------|-------------------|-------------------|----------------------|-------------------|
|                          |       | RI                | PI                | RI                   | PI                |
| High risk delivery group | 872   | $0.78 \pm 0.08^*$ | $1.76 \pm 0.14^*$ | $0.70 \pm 0.14^*$    | $1.67 \pm 0.09^*$ |
| Normal delivery group    | 21878 | $0.56 \pm 0.05$   | $0.86 \pm 0.11$   | $0.74 \pm 0.12$      | $1.71 \pm 0.15$   |

Note: Compared with the normal delivery group,  $*P<0.05$ .

### 2.3 先心病发生率对比

在高危分娩组中,随访确诊先心病 45 例(心内膜垫缺损 13 例,室间隔缺损 9 例,三尖瓣下移缺陷 6 例,左心发育不良 6 例,法洛四联症 5 例,心脏占位性病变 5 例,心室扩大 1 例),发

生率为 5.2 %;正常分娩组随访确诊 32 例(心内膜垫缺损 9 例,室间隔缺损 8 例,三尖瓣下移缺陷 2 例,左心发育不良 7 例,法洛四联症 4 例,心脏占位性病变 2 例),发生率为 0.1 %,对比差异有统计学意义( $P<0.05$ ),见表 3。

表 3 两组先心病发生率对比(例,%)

Table 3 Comparison of the incidence of congenital heart disease between two groups (n, %)

| Groups                   | n     | Congenital diseases | Incidence |
|--------------------------|-------|---------------------|-----------|
| High risk delivery group | 872   | 45                  | 5.2*      |
| Normal delivery group    | 21878 | 32                  | 0.1       |

Note: Compared with the normal delivery group, \* $P<0.05$ .

### 2.4 相关性分析

在足月胎儿 22750 例中,Pearson 相关分析显示先心病与

脐动脉 RI、PI 值、主动脉和肺动脉 FHR 值、PTV 值都存在相关性( $P<0.05$ ),见表 4。

表 4 足月胎儿出生后心脏超声血液动力学指标与先心病的相关性(n=22750)

Table 4 Correlation between cardiac ultrasound hemodynamic indexes and congenital heart disease after birth of full-term fetus (n=22750)

| Index | Umbilical artery |       | Aorta |        | Pulmonary artery |        |
|-------|------------------|-------|-------|--------|------------------|--------|
|       | RI               | PI    | FHR   | PTV    | FHR              | PTV    |
| r     | 0.566            | 0.475 | 0.498 | -0.563 | 0.511            | -0.586 |
| P     | 0.005            | 0.013 | 0.010 | 0.005  | 0.008            | 0.003  |

## 3 讨论

出生缺陷即各种原因引起的胎儿在出生时所伴随的结构或功能异常,可严重影响人口素质的提高,也影响社会的发展<sup>[12,13]</sup>。先心病为出生缺陷的一种,病因不明,但是发病因素众多。超声为筛查胎儿先心病的主要方法,不仅能清晰显示胎儿解剖结构,而且安全性好,对孕妇和胎儿无明显影响,也具有简便、可重复、科学、有效等优势<sup>[14,15]</sup>。其中彩色多普勒超声是通过检测胎儿心脏与外周血的血流量、血流速度及阻力大小等血流动力学指标来判断胎儿的发育情况<sup>[16]</sup>。本研究显示所有胎儿的超声图像评分 $\geq 2$ 分,平均 $2.87\pm 0.14$ 分,符合诊断要求。高危分娩组的主动脉与肺动脉 FHR 值高于正常分娩组,PTV 值低于正常分娩组。从机制上分析,PTV 受胎儿后负荷、心率、体重、心率和左右心室的固有收缩功能等多种因素影响,高危分娩组胎儿右心室容易出现受损,导致右心输出量下降而左心输出量相对增加<sup>[17,18]</sup>。胎儿期肺无呼吸功能,左心输出血主要直接通过主动脉到大脑与心脏,右心输出血主要通过肺动脉再分布到身体其他部位。而随着胎儿到足月,胎儿的右心优势已随胎龄增加而减弱,可使得左右心功能趋向一致<sup>[19,20]</sup>。

彩色多普勒超声检查的基本指标包括 PI、RI 值等,脐动脉是母体与胎儿血液循环互通的重要枢纽,随着胎儿的发育,脐动脉血管腔面积增大,血流量增加<sup>[21]</sup>。大脑中动脉是颈内动脉的主要分支,当胎儿发生缺氧时,可优先保护大脑的血流供应,因此大脑中动脉的血流状况可以直接反映胎儿颅内供血状况<sup>[22,23]</sup>。本研究显示高危分娩组的脐动脉 RI 与 PI 值高于正常分娩组,而大脑中动脉 RI 与 PI 值低于正常分娩组。当前也有研究表明当胎儿宫内缺氧时,可表现为为脐动脉 R 阻力增加,

同时伴有左心输出量下降<sup>[24,25]</sup>。并且彩色多普勒超声能清晰显示大血管的离断或异位状况,对大血管的血流动力学显示更为可靠,可间接推断心脏的运动功能,能够在实时条件下观察血流动力学信息<sup>[26,27]</sup>。

当前超声检查在孕产妇中广泛应用,但只有约 1/3 的胎儿先心病在产前做出准确诊断<sup>[28,29]</sup>。本研究显示在高危分娩组中,随访确诊先心病 45 例,发生率为 5.2 %;正常分娩组随访确诊 32 例,发生率为 0.1 %,对比差异有统计学意义;Pearson 相关分析显示先心病与脐动脉 RI、PI 值、主动脉和肺动脉 FHR 值、PTV 值都存在相关性。不过超声诊断除受客观条件等因素影响外,还受超声检查医生的培训程度、循证经验等因素的影响<sup>[30]</sup>。并且胎儿的心脏结构极其复杂,特别是具有复杂心血管结构异常的胎儿,标准心脏结构的识别与心脏切面的获得比较困难<sup>[31]</sup>。本研究也存在一定的不足,血流动力学观察指标比较少,且相关性分析不够深入,将在后续研究中进行探讨。

总之,胎儿心脏超声可反映足月胎儿出生后血液动力学变化情况,可指导临床医师及时对高危分娩作出适当处理。

### 参考文献(References)

- [1] Bayoumy S, Habib M, Abdelmageed R. Impact of maternal diabetes and obesity on fetal cardiac functions [J]. Egypt Heart J, 2020, 72(1): e46
- [2] Bolin EH. Implementation of a statewide, multisite fetal tele-echocardiography program: evaluation of more than 1100 fetuses over 9 years [J]. J Turk Ger Gynecol Assoc, 2020, 40(10): 1524-1530
- [3] Clark R, Raghuraman N, Macones GA, et al. Fetal arrhythmias: prenatal evaluation and intrauterine therapeutics [J]. J Perinatol, 2020, 46(1): e21
- [4] Downe S, Lempers C. The standardized 12-lead fetal electrocardio-

- gram of the healthy fetus in mid-pregnancy: A cross-sectional study [J]. *PLoS One*, 2020, 15(4): e0232606
- [5] Drukker L, Staines-Urias E, Villar J, et al. International gestational age-specific centiles for umbilical artery Doppler indices: a longitudinal prospective cohort study of the INTERGROWTH-21 (st) Project [J]. *Ultrasound Obstet Gynecol*, 2020, 222(6): 602-609
- [6] Ferraz MM. Aortic Isthmus Doppler Velocimetry in Fetuses with Intrauterine Growth Restriction: A Literature Review [J]. *Physiol Rep*, 2020, 42(5): 289-296
- [7] Gyselaers W. Preeclampsia Is a Syndrome with a Cascade of Pathophysiologic Events[J]. *J Clin Med*, 2020, 9(7): 112-118
- [8] Jacques R, Almond T, Rosser MH, et al. Prenatal hypoxia increases susceptibility to kidney injury[J]. *PLoS One*, 2020, 15(2): e0229618
- [9] Kikuchi H, Noda S, Katsuragi S, et al. Evaluation of 3-tier and 5-tier FHR pattern classifications using umbilical blood pH and base excess at delivery[J]. *PLoS One*, 2020, 15(2): e0228630
- [10] Kluckow M, Hooper SB, Mandalà M. Influence of Estrogens on Uterine Vascular Adaptation in Normal and Preeclamptic Pregnancies [J]. *Arch Dis Child Fetal Neonatal Ed*, 2020, 21(7): 99-105
- [11] Renshall LJ, Cottrell EC, Cowley E, et al. Antenatal sildenafil citrate treatment increases offspring blood pressure in the placental-specific Igf2 knockout mouse model of FGR [J]. *Am J Physiol Heart Circ Physiol*, 2020, 318(2): 252-263
- [12] Sun L, Marini D, Saini B, et al. Understanding Fetal Hemodynamics Using Cardiovascular Magnetic Resonance Imaging [J]. *Fetal Diagn Ther*, 2020, 47(5): 354-362
- [13] Lin SM, Chou YC, Huang SP, et al. Assessment of the Association Between Congenital Heart Defects and Brain Injury in Fetuses through Magnetic Resonance Imaging [J]. *PLoS One*, 2020, 22(1): 27-31
- [14] Sun L, Zhang L, Zhang N, et al. Evaluation of Hemodynamic Changes in Fetuses With Isolated Mild-to-Moderate Ventriculomegaly by Transabdominal Ultrasound [J]. *Int J Mol Sci*, 2020, 39(3): 453-461
- [15] Tan CMJ, Lewandowski AJ. The Transitional Heart: From Early Embryonic and Fetal Development to Neonatal Life[J]. *Fetal Diagn Ther*, 2020, 47(5): 373-386
- [16] Varcoe TJ, Darby JRT. Fetal cardiovascular response to acute hypoxia during maternal anesthesia [J]. *BMC Med Imaging*, 2020, 8(3): e14365
- [17] Wang Y, Zhao L, Zhang Y. Strategies for diagnosis of fetal right atrium dilation: based on fetal cardiac anatomy and hemodynamics[J]. *PLoS One*, 2020, 20(1): e76
- [18] Weissmann-Brenner A, Mitlin A, Hoffman C, et al. Assessment of the Association Between Congenital Heart Defects and Brain Injury in Fetuses through Magnetic Resonance Imaging[J]. *Isr Med Assoc J*, 2020, 22(1): 27-31
- [19] Wong FY. Induction of left ventricular hypoplasia by occluding the foramen ovale in the fetal lamb [J]. *J Cardiovasc Magn Reson*, 2020, 10(1): e880
- [20] Zakko J, Blum KM, Drews JD, et al. Development of Tissue Engineered Heart Valves for Percutaneous Transcatheter Delivery in a Fetal Ovine Model[J]. *Rev Bras Ginecol Obstet*, 2020, 5(8): 815-828
- [21] Lu JW, Lu D, Zhang XL, et al. Clinical outcomes of prenatal diagnosis of the fetal micrognathia: A case report [J]. *Ultrasound Obstet Gynecol*, 2020, 99(4): 18648-18654
- [22] Meister M, Axt-Flidner R, Graupner O, et al. Atrial and Ventricular Deformation Analysis in Normal Fetal Hearts Using Two-Dimensional Speckle Tracking Echocardiography [J]. *Rev Bras Ginecol Obstet*, 2020, 47(9): 699-710
- [23] Nyrnes SA, Fadnes S, Wigen MS, et al. Blood Speckle-Tracking Based on High-Frame Rate Ultrasound Imaging in Pediatric Cardiology [J]. *J Am Soc Echocardiogr*, 2020, 33(4): 493-503
- [24] Wang J, Wang A, Cui Y, et al. Diagnosis and treatment of infective endocarditis in pregnancy: a case report [J]. *J Cardiothorac Surg*, 2020, 15(1): e109
- [25] Carrilho MC, Bravo-Valenzuela NJ. Congenital Complete Atrioventricular Heart Block in a Pregnant Woman with Sjögren Syndrome: Prenatal Care Follow-Up and the Challenge of Intrauterine Treatment [J]. *Rev Bras Ginecol Obstet*, 2020, 42(4): 228-232
- [26] Chaberek K, Witwicki J, Debski R, et al. Successful treatment of neonatal atrial flutter by synchronized cardioversion: case report and literature review[J]. *J Clin Med*, 2020, 20(1): e370
- [27] Dong SZ, Zhu M, Ji H, et al. Fetal cardiac MRI: a single center experience over 14-years on the potential utility as an adjunct to fetal technically inadequate echocardiography[J]. *Sci Rep*, 2020, 10(1): e12373
- [28] Adams AD, Aggarwal N, Fries MH, et al. Neonatal and maternal outcomes of pregnancies with a fetal diagnosis of congenital heart disease using a standardized delivery room management protocol [J]. *J Perinatol*, 2020, 40(2): 316-323
- [29] Axt-Flidner R, Black MJ, Schranz D, et al. Cerebral hemodynamic response to short-term maternal hyperoxygenation in fetuses with borderline small left hearts[J]. *Sci Rep*, 2020, 20(1): e411
- [30] Atiyah M, Kurdi A, Al Tuwaijry O, et al. Fetal aortic valvuloplasty: first report of two cases from Saudi Arabia [J]. *J Cardiothorac Surg*, 2020, 15(1): e150
- [31] Zhao N, Xu J, Li XG, et al. Hemodynamic characteristics in preeclampsia women during cesarean delivery after spinal anesthesia with ropivacaine[J]. *World J Clin Cases*, 2020, 8(8): 1444-1453