

## WHITE PAPER

# MPI+, an automatic tool for measurement of fetal right ventricular myocardial performance index

Mi-Young Lee, M.D., Ph.D., So Yeon Kim, M.D.,  
Hye-Sung Won, MD., Ph.D.

Department of Obstetrics and Gynecology,  
University of Ulsan College of Medicine,  
Asan Medical Center, Seoul, Korea

## Abstract

### Objective

The aim of this paper was to evaluate the reproducibility of Right Ventricular Modified Myocardial Performance Index (RV Mod-MPI) calculations of fetuses measured automatically using “MPI+” on Samsung Medison’s ultrasound systems.

### Methods

MPI+ operated as follows: RV inflow and outflow pulsed-wave Doppler images were automatically synchronized based on the closure clicks of the pulmonary valve. The values of MPI and its components were automatically measured by the ultrasound system. Two experts measured the RV Mod-MPI manually twice and then they measured the RV Mod-MPI automatically twice for each case. Intra- and inter-operator reproducibility were evaluated using Intraclass Correlation Coefficient (ICC). The mean difference between manual and automated measurements was also compared.

### Results

Both operators successfully measured the RV Mod-MPI automatically in all cases. For both operators, intraoperator reproducibility was higher with automated measurements compared to manual measurements (ICC = 0.962 vs ICC = 0.913). Interoperator reproducibility was also higher with automated measurements compared to manual measurements (ICC = 0.961 vs ICC = 0.889). The mean difference of RV Mod-MPI between the manual and automated measurements was  $0.0002 \pm 0.0586$  (95% CI [confidence interval], -0.0095 to 0.0099).

### Conclusion

Automated measurement of RV Mod-MPI using MPI+ is a reliable technique for evaluating fetal RV function. MPI+ provides more detailed information about RV function with excellent intra- and inter-operator reproducibility as compared to manual measurements.

## Introduction

The importance of anatomical evaluation as well as functional assessment of the fetal heart has been thoroughly recognized<sup>1</sup>. Fetal cardiac function provides important information as a marker for early detection of fetal compromise in several diseases such as intrauterine growth restriction and twin-to-twin transfusion syndrome<sup>2</sup>.

The modified myocardial performance index (Mod-MPI) expresses global systolic and diastolic ventricular function using conventional pulsed-wave (PW) Doppler. This value is defined as the sum of isovolumetric contraction time (ICT) and isovolumetric relaxation time (IRT) divided by ejection time (ET)<sup>3</sup>. Because of the pulmonary tricuspid discontinuity, right ventricular (RV) inflow and outflow cannot be obtained from the same cardiac cycle. Therefore, MPI should be calculated as  $(a-b)/b$ ; 'a' is the time interval from the closure click of the tricuspid valve (TV) to the opening click of the next cardiac cycle, and 'b' is the ejection time of the outflow (Figure 1). This conventional method is limited to measure the ICT and IRT, which represents systolic and diastolic functions, respectively.

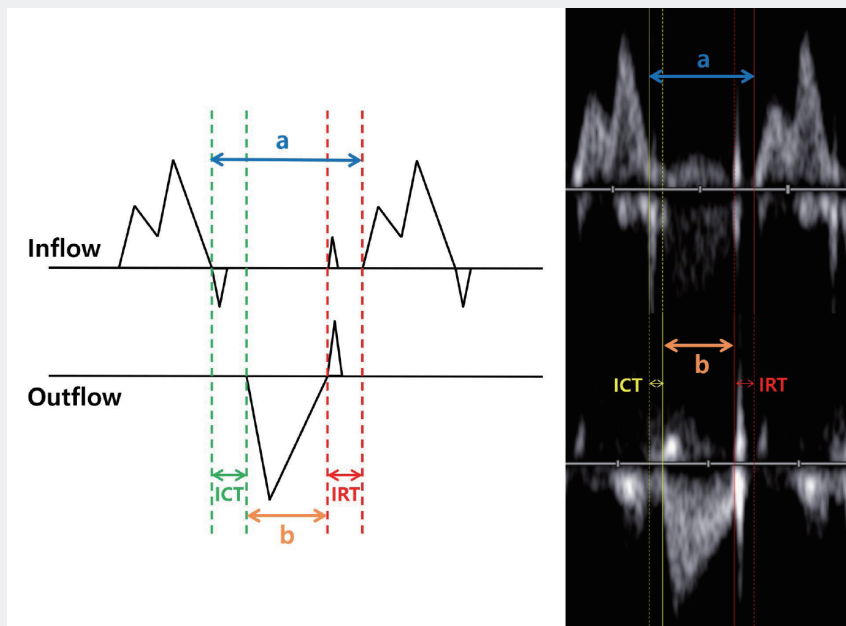


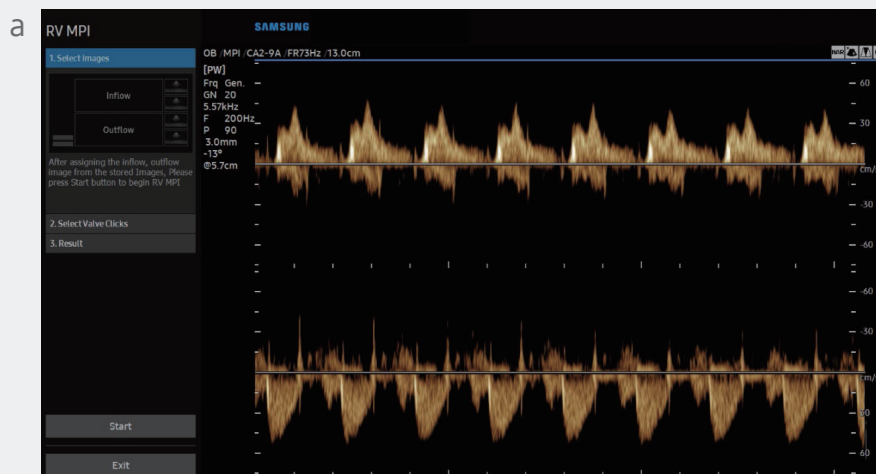
Figure 1. Measurement of modified myocardial performance index in the fetal right heart

Authors recently developed novel method for measuring the right Mod-MPI using synchronized images of RV inflow and outflow, which enable to measure not only MPI, but also ICT and IRT<sup>4</sup>. MPI+ was developed to automatically synchronize of the two separate RV inflow and outflow images and also measure of the Mod-MPI and its components (i.e., ICT, IRT, and ET) automatically. The purpose of this study was to evaluate the feasibility of MPI+.

## Materials and Methods

This was a prospective study of 70 normal singleton pregnancies with gestational ages between 20 weeks 0 days and 24 weeks 4 days examined at Asan Medical Center, Seoul, Korea, from May 2017 to December 2020. PW Doppler waveform images of RV inflow and outflow were obtained using HERA W10 ultrasound machines (Samsung Medison Co., Ltd, Seoul, Korea) and the associated transabdominal probes. The following ultrasound settings were used as previous recommended<sup>4</sup>: 3-mm sample volume size, 420-Hz Doppler sweep speed, a low Doppler gain (~20 dB), 200–400 Hz wall motion filter, and <15° angle of insonation. Only heart rate (HR) differences of  $\leq 5$  beats/min between RV inflow and outflow were included in the study.

MPI+ is a built-in, commercially available software installed on the high-resolution ultrasound system. RV Mod-MPI was measured using the synchronizing method based on pulmonary valve closure clicks in two separate RV inflow and outflow images<sup>5</sup>. MPI+ operated as follows (Figure 2): 1) the operator classified the images into inflow and outflow (Figure 2a); 2) when the operator selected one cardiac cycle each from inflow and outflow, the system automatically calculated the HRs of inflow and outflow (Figure 2b); 3) if the HR differed between inflow and outflow, the system automatically adjusted the outflow HR to inflow HR if it was within  $\leq 5$  beats/min; 4) the system automatically synchronized the inflow and outflow images based on the pulmonary valve closure clicks; 5) the system automatically placed the calipers at the beginning of each valve click; and 6) the system automatically calculated the RV Mod-MPI and its components (Figure 2c).



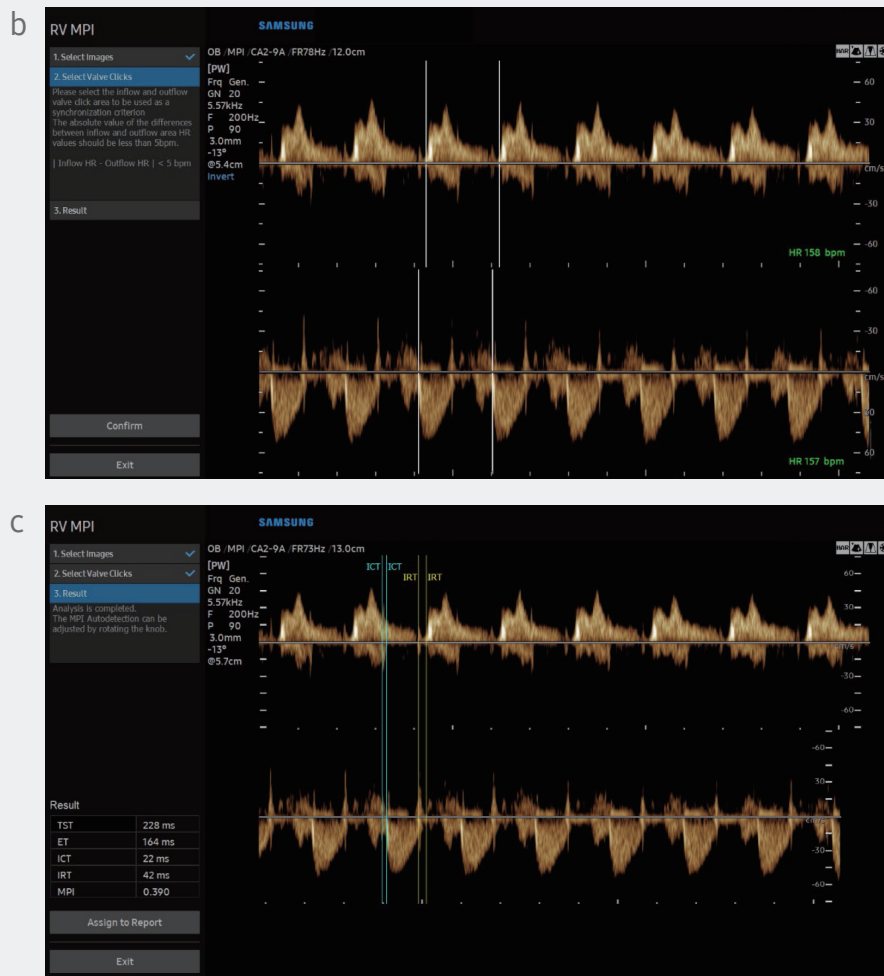


Figure 2. MPI+ main display. (a) Operator selects the inflow and outflow images. (b) Next, the operator selects one cardiac cycle each from inflow and outflow images, and then the system automatically calculates heart rates of inflow (158 bpm) and outflow (157 bpm). (c) When operator selects the ‘Confirm’ key, the system automatically synchronizes the inflow and outflow images based on the pulmonary valve closure clicks, automatically places the calipers at the beginning of each valve click, and automatically calculates the values of Mod-MPI and its components.

Two experienced operators independently measured the RV Mod-MPI manually and automatically, twice for each method. Intraclass correlation coefficients (ICCs) were calculated for intra- and inter-operator reproducibility. Mean differences between the manual and automated measurements were also compared.

## Results

Both operators successfully measured the RV Mod-MPI in all cases using MPI+. For both operators, the intra-operator reproducibility of the Mod-MPI was higher with automated measurements (MPI+) compared to manual measurements (Table 1). Among the components of Mod-MPI, ET showed the highest reproducibility, whereas IRT showed the lowest reproducibility. The inter-operator agreement of the Mod-MPI using automated method (MPI+) was also higher compared to manual measurements (Table 2). Among the Mod-MPI components, ET also showed the highest agreement. The mean differences of Mod-MPI, ICT, IRT and ET between the manual and automated measurements were  $0.0002 \pm 0.0586$  (95% CI,  $-0.0095$  to  $0.0099$ ),  $0.8575 \pm 8.4241$  (95% CI,  $-0.5410$  to  $2.2559$ ),  $1.4278 \pm 4.9515$  (95% CI,  $0.6058$  to  $2.2498$ ), and  $4.5203 \pm 7.4951$  (95% CI,  $3.2760$  to  $5.7645$ ), respectively.

Table 1. Intra-operator reproducibility of measurement of right ventricular modified myocardial performance index by manual and automated system

Value	Method	ICC	95% CI
Mod-MPI	Manual	0.913	0.879–0.941
	Automated (MPI+)	0.962	0.946–0.975
ICT	Manual	0.904	0.866–0.935
	Automated (MPI+)	0.964	0.949–0.976
IRT	Manual	0.863	0.812–0.906
	Automated (MPI+)	0.963	0.948–0.976
ET	Manual	0.940	0.916–0.960
	Automated (MPI+)	0.977	0.967–0.985

ICC (intraclass correlation coefficient); CI (confidence interval); Mod-MPI (modified myocardial performance index); ICT (isovolumetric contraction time); IRT (isovolumetric relaxation time); ET (ejection time).

Table 2. Inter-operator reproducibility of measurement of right ventricular modified myocardial performance index by manual and automated system

Value	Method	ICC	95% CI
Mod-MPI	Manual	0.889	0.862–0.912
	Automated (MPI+)	0.961	0.952–0.970
ICT	Manual	0.883	0.855–0.907
	Automated (MPI+)	0.964	0.955–0.972
IRT	Manual	0.843	0.806–0.874
	Automated (MPI+)	0.962	0.953–0.970
ET	Manual	0.928	0.910–0.943
	Automated (MPI+)	0.976	0.971–0.982

ICC (intraclass correlation coefficient); CI (confidence interval); Mod-MPI (modified myocardial performance index); ICT (isovolumetric contraction time); IRT (isovolumetric relaxation time); ET (ejection time).

## Discussion

RV Mod-MPI measurement by automatic synchronization of RV inflow and outflow images using MPI+ overcame the limitations of the conventional method, provided more detailed information of fetal cardiac function, and showed excellent reproducibility. Therefore, MPI+ is a reliable technology for evaluating fetal right cardiac function.

Most of the previous studies have addressed clinical applications of fetal left cardiac function using a relatively simple method of measurement. In left heart, simultaneous acquisition of inflow and outflow within the same cycle is possible. Considering that fetal cardiac circulation showed right ventricle dominancy, it is important to evaluate the cardiac function of the RV. However, in the right heart, obtaining of RV inflow and outflow simultaneously is not possible due to the complex anatomy of RV especially with advancing gestational age<sup>6</sup>.

To overcome the limitations of the conventional method, we proposed the novel technique for measurement of RV Mod-MPI using the synchronized images of the RV inflow and outflow based on the closure clicks of the pulmonary valve and provided the evidence of its feasibility for clinical practice<sup>5</sup>. The proposed synchronizing method not only provides information on the MPI value, but also provides information on ICT and IRT, thereby giving more detailed information on fetal cardiac function. Because the thickness and shape of valve clicks are highly variable, manual synchronization of inflow and outflow images may be operator dependent, which may result in intra- and inter-variability. Automatic synchronization of images and automatic placement of the calipers can minimize such variations.

## Conclusion

RV Mod-MPI measurement using MPI+ is reliable for evaluating right-sided fetal cardiac function. MPI+ helps physicians who are unfamiliar with the cardiac function evaluation to automatically calculate MPI and easily apply it in their clinical practice.

Supported system – HERA W10

MPI+ is available in the following systems – HERA W10, HERA I10, V8

## References

1. Crispi F, Gratacos E. Fetal cardiac function: technical considerations and potential research and clinical applications. *Fetal Diagn Ther* 2012;32:47-64.
2. Lee MY, Won HS, Park JE, et al. Fetal left modified myocardial performance index measured by the Auto Mod-MPI system: development of reference values and application to recipients of twin-to-twin transfusion syndrome. *Prenat Diagn* 2016;36:424-431.
3. Hernandez-Andrade E, Lopez-Tenorio J, Figueroa-Diesel H, et al. A modified myocardial performance (Tei) index based on the use of valve clicks improves reproducibility of fetal left cardiac function assessment. *Ultrasound Obstet Gynecol* 2005;26:227-232.
4. Meriki N, Izurieta A, Welsh AW. Fetal left modified myocardial performance index: technical refinements in obtaining pulsed-Doppler waveforms. *Ultrasound Obstet Gynecol* 2012;39:421-429.
5. Kang OJ, Kim SY, Lee MY, et al. Novel Technique for the Measurement of Fetal Right Modified Myocardial Performance Index Using Synchronized Images of Right Ventricular Inflow and Outflow and Clinical Application to Twin-to-Twin Transfusion Syndrome. *J Ultrasound Med* 2021; doi:10.1002/jum.15634.
6. Mahajan A, Henry A, Meriki N, et al. The (Pulsed-Wave) Doppler Fetal Myocardial Performance Index: Technical Challenges, Clinical Applications and Future Research. *Fetal Diagn Ther* 2015;38:1-13

## Disclaimer

- \* The features mentioned in this document may not be commercially available in all countries. Due to regulatory reasons, their future availability cannot be guaranteed.
- \* Do not distribute this document to customers unless relevant regulatory and legal affairs officers approve such distribution.
- \* Images may have been cropped to better visualize their pathology.
- \* This clinical practice review is a result of a personal study conducted by collaboration between Samsung Medison and Prof. Hye-Sung Won. This review is to aid customers in their understanding, but the objectivity is not secured.
- \* 본 자료는 삼성메디슨이 원혜성 교수님과 협업하여 산출된 개인 연구의 결과물입니다. 고객의 요청에 따라 이해를 돕기 위해 제공하는 자료일 뿐 객관성은 확보되지 않았습니다.

---

## SAMSUNG MEDISON CO., LTD.

© 2021 Samsung Medison All Rights Reserved.

Samsung Medison reserves the right to modify any design, packaging, specifications and features shown herein, without prior notice or obligation.

<https://www.samsunghealthcare.com/en/products/UltrasoundSystem>