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ORIGINAL ARTICLE

A rapid and Easy Objective Evaluation of the Three Vessel View to Enhance Diagnostic Confidence in Fetal Echocardiography

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Abstract The three vessel view (3VV) is an integral component of fetal cardiac screening. The evaluation of vessel size is subjective in this view. Not infrequently, however, there can be a doubt and a need arises for objective assessment. Our aim was to clarify which ratio (AO/PA, AO/SVC, PA/SVC) can most easily judge the 3VV. We measured the diameter of the aorta (AO), pulmonary artery (PA) and superior vena cava (SVC) in 85 fetuses that had been diagnosed with a normal heart (NH) by the spatiotemporal image correlation (STIC) method and calculated the AO/PA ratio, AO/SVC ratio and PA/SVC ratio. We then calculated a similar index using an offline videotape in 15 fetuses diagnosed with coarctation of the aorta (COA), and 15 fetuses diagnosed with Tetralogy of Fallot (TOF). TOF excluded pulmonary atresia and absent pulmonary valve. All of the AO/PA ratios, AO/SVC ratios and PA/SVC ratios recognized a significant difference in the CoA, TOF and the NH groups. When we calculated the ROC curve in each CoA group and TOF group about AO/PA ratio, AO/SVC ratio, PA/SVC ratio, AO/PA ratio showed the highest sensitivity and specificity in the CoA group and the TOF group. When the cut-off value of the CoA for the NH group is AO/PA ratio < 0.7, good results are obtained, sensitivity is 100% and specificity is 90.6%. When the cut-off value of the TOF from the NH group is AO/PA ratio > 1.2, good results are obtained, sensitivity is 100% and specificity is 98.8%. The method to measure AO/PA ratio during heart screening can judge the 3VV objectively. When it exceeds $0.7 <$ AO/PA ratio < 1.2, it is likely to be congenital heart disease.

Keywords Three vessel view · Fetal echocardiogram · Coarctation of the aorta · Tetralogy of Fallot

Introduction

The three vessel view (3VV) is a routine section for heart disease screening and is particularly useful for screening outflow tract disease [1, 2]. The normal vascular diameters are pulmonary artery (PA) ≥ aorta (AO) ≥ superior vena cava (SVC) (Fig. 1).

However, in cases of tetralogy of Fallot (TOF), the relationship becomes PA ≤ AO (Fig. 2a), and in cases of coarctation of the aorta (CoA), it becomes PA >> AO ≒ SVC (Fig. 2b) [1, 3].

A way of judging vascular dimensions is not infrequently needed, but at present, there is no index that can provide an objective numerical value of these relationships.

In the present study, we first measured the diameters of the PA, AO and SVC in normal fetuses. We then measured these diameter in cases of CoA and TOF. Using these values, we explored which of the ratios (AO/PA, AO/SVC, or PA/SVC) was most useful for predicting TOF and CoA.

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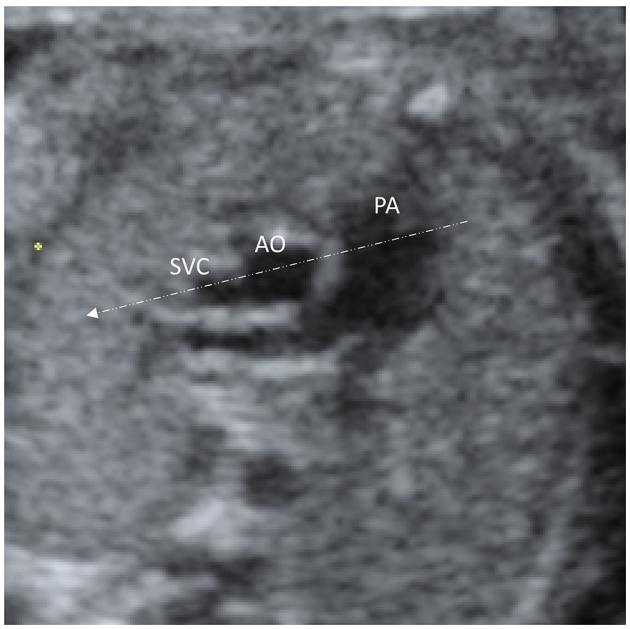

Fig. 1 The normal three vessel view. The normal vascular diameter relationship is PA ≥ AO ≥ SVC. PA: pulmonary artery, AO: aorta, SVC: superior vena cava

Patients and Methods

Eighty-five fetuses without congenital heart disease (gestational age 28.7 ± 3.2 weeks) were randomly selected. They had been screened using the spatiotemporal image correlation (STIC) method in a single maternity hospital in 4 obstetricians' offices (NH group). We included 15 consecutive cases each, diagnosed with tetralogy of Fallot (excluding PA atresia and deficiency; TOF group) and coarctation of the aorta (4 isolated cases and 11 complex cases; CoA group) in our hospital from 2007 to 2012. For coarctation of the aorta, we included cases that required surgery or catheter intervention for coarctation or needed at least one year of follow up.

We measured the diameter of the PA, AO and SVC in all three groups and then calculated the AO/PA ratio, AO/SVC ratio and PA/SVC ratio for each group. The measurement of each blood vessel in the three-vessel view was performed with a cross-section in which the left and right PA, AO, and SVC could be visualized, as shown in Fig. 1, on the short axis view. As for the measurement points, the major axis of the main PA above the pulmonary valve was measured for the PA, and the major axis of the minor axis was measured for the AO and SVC.

Next, we examined the most suitable ratio of 3VV for screening TOF or CoA. We determined the cut-off values using a receiver operating characteristics (ROC) curve of the AO/PA, AO/SVC, and PA/SVC ratios for the diagnosis CoA and TOF.

Statistical Analyses

All the echocardiographic measurements were expressed as the mean ± the standard deviation (SD). All the analyses were performed using professional statistical software (Stat View Ver. 5.0, SAS Institute Inc.) We used Student's *t*-test to assess the significant difference between the two groups. A P value of < 0.05 was considered to indicate statistical significance.

Results

All fetal echocardiographic data are shown in Table 1. The diameters of the AO, PA and SVC in the NH group were 5.15 ± 1.0 mm, 6.25 ± 1.34 mm and 3.88 ± 0.91 mm, respectively; those in the CoA group were 3.77 ± 0.79 mm,

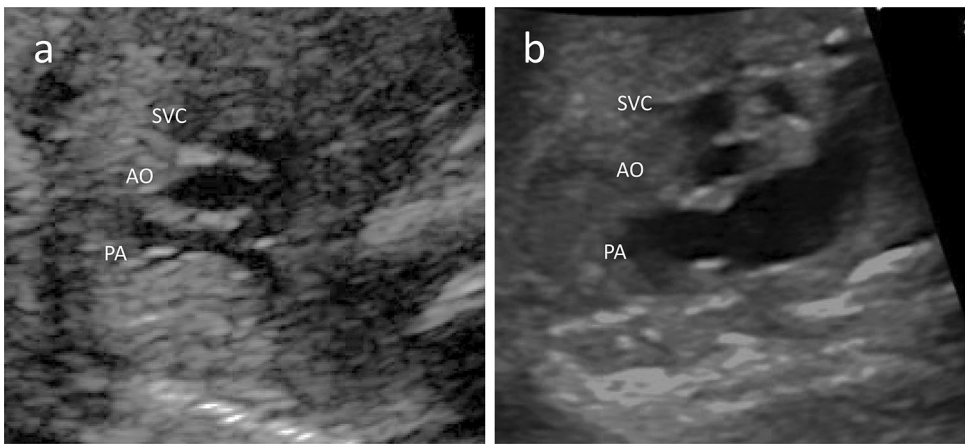

Fig. 2 **a** The three vessel view of Tetralogy of Fallot (PA ≤ AO). **b** The three-vessel view of coarctation of the aorta (PA >> AO ≒ SVC)

Table 1 Summary of measurement data

	CoA group	TOF group	NH group
AO(mm)	3.77 ± 0.79*[a]	6.34 ± 1.19[a]	5.15 ± 1.0
PA(mm)	7.34 ± 1.77*[a]	4.33 ± 0.87[a]	6.25 ± 1.34
SVC(mm)	3.82 ± 0.70	3.55 ± 0.56	3.88 ± 0.91
AO/PA	0.52 ± 0.08*[a]	1.47 ± 0.14[a]	0.84 ± 0.12
AO/SVC	1.00 ± 0.17*[a]	1.81 ± 0.33[a]	1.36 ± 0.29
PA/SVC	1.92 ± 0.31*[a]	1.23 ± 0.24[a]	1.66 ± 0.13

AO Aorta, *PA* Pulmonary artery, *SVC* Superior vena cava, *CoA* Coarctation of the aorta, *TOF* Tetralogy of Fallot, *NH* normal heart
*: vs TOF $p<0.05$, [a]: vs NH $p<0.05$

7.34 ± 1.77 mm and 3.82 ± 0.70 mm, respectively; and those in the TOF group were 6.34 ± 1.19 mm, 4.33 ± 0.87 mm and 3.55 ± 0.56 mm, respectively. The 3VV vascular diameter in the NH group was similar to that described in previous reports, showing the expected relationship of PA > AO > SVC. In the CoA group, however, the AO diameter was remarkably smaller than the PA diameter, and the AO and SVC diameters were similar. In the TOF group, the AO diameter was larger than the PA diameter.

The AO/PA ratio, AO/SVCratio and PA/SVC ratio were 0.84 ± 0.12, 1.36 ± 0.29 and 1.66 ± 0.13, respectively, in the NH group; 0.52 ± 0.08, 1.00 ± 0.17 and 1.92 ± 0.31, respectively, in the CoA group; and 1.47 ± 0.14, 1.81 ± 0.33 and 1.23 ± 0.24, respectively, in the TOF group. All three ratios showed significant differences among the groups.

When we calculated the ROC curves in the CoA and TOF groups for the AO-PA ratio, AO-SVC ratio and PA-SVC ratio, the AO/PA ratio showed the highest sensitivity and specificity in both groups (Fig. 3). When the cut-off value for detecting CoA was set at < 0.7(AO-PA ratio) it had a good correlation with CoA (Fig. 3a). Similarly, a cut off value of > 1.2(AO-PA ratio) correlated well in fetuses of TOF (Fig. 3b).

Discussion

Thanks to advances in fetal echocardiography screening technology, many more cases of congenital heart disease are now being diagnosed prenatally. However, the prenatal diagnosis rates of outflow tract diseases, such as CoA or TOF, remain unsatisfactory [4, 5].

3VV can be useful as a screening tool for identifying fetuses with TOF or TOF physiology, hypoplastic left heart syndrome, critical aortic stenosis with COA, or isolated COA. However, comparing three blood vessels at once is not always simple in daily practice. Furthermore, the 3VV is judged subjectively, as there is no normal value for the 3VV. It may, therefore, be difficult to conclusively determine if an abnormality is present or not.

Given this situation, we decided to determine what constituted a normal 3VV and explored which indices could most easily judge the 3VV. As target diseases, we used CoA as a representative left ventricular outflow tract disease and TOF as a representative right ventricular outflow tract disease.

When we compared the AO/PA ratio, AO/SVC ratio and PA/SVC ratios, the AO/PA ratio showed the highest sensitivity and specificity. We think this is because AO and PA originate directly from the ventricles and are most susceptible to the effects of blood flow. Specifically, when the PA diameter increases, the AO diameter decreases, and vice versa. In contrast, the SVC diameter is usually constant, with no marked influence by these vessels. We

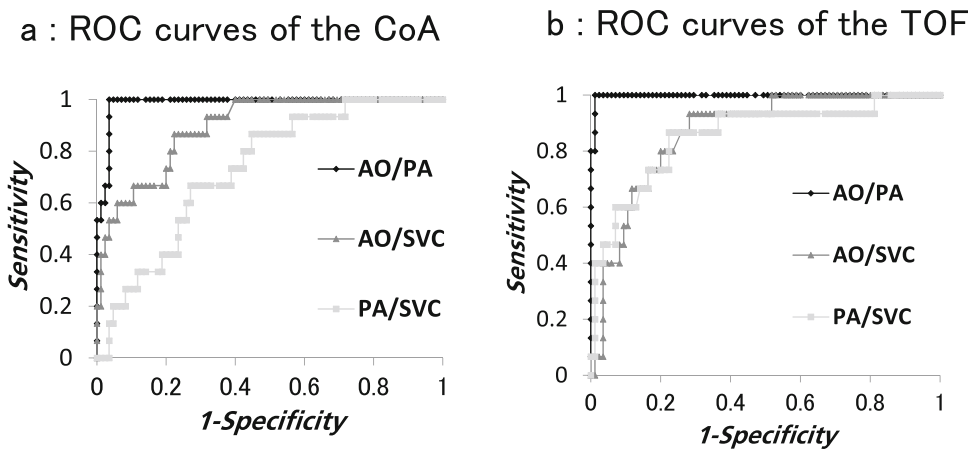

Fig. 3 The ROC curves of the CoA and TOF groups with respect to the AO/PA, AO/SVC, and PA/SVC ratios are shown. The AO/PA ratio showed the highest sensitivity and specificity in the CoA and TOF groups

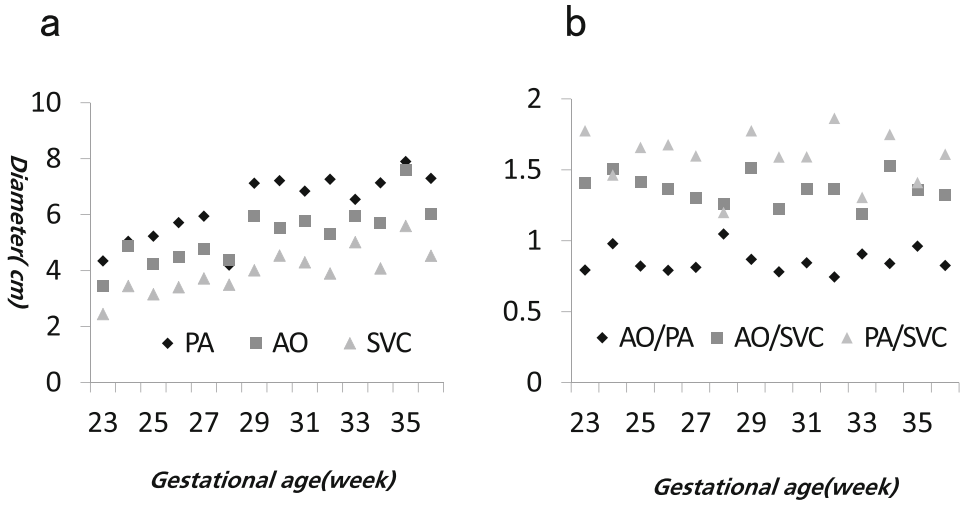

Fig. 4 **a** The graph on the left shows the correlation between the AO, PA, and SVC diameter and the gestational age in the NH group. There is a correlation. **b** The graph on the right shows the correlation between the AO/PA, AO/SVC and PA/SVC and the gestational age in the NH group. There is no correlation

therefore supposed that the ratio of the diameters of the AO and PA would be the most useful for screening for outflow tract disease. When the AO/PA ratio was > 1.2 in TOF and < 0.7 in CoA, the sensitivity of the diagnosis was 100% for both, and the specificity was 98.8% and 90.6%, respectively. We believe that the CoA group was slightly less sensitive than the TOF group because the CoA group includes cases that do not require treatment. For diagnosing CoA, it may be necessary to perform a reexamination or put depiction isthmus and shelf together in addition to AO/PA ratio [5, 6].

In their report, Robert et al. measured the AO/PA ratio of 2,797 fetuses and found an AO/PA ratio > 1 in 31 cases, including 25 TOF cases and 6 cases with aortic valve abnormality with AO expansion. Therefore, they concluded that a close inspection was necessary in cases with an AO/PA ratio > 1 [7]. In addition, in the report of Wong et al., the 95% confidence interval of the AO/PA ratio among 966 NH children was found to be 0.87–1.58 [8]. The AO/PA ratio of 0.7–1.3 in our study was not significantly inconsistent with these two reports.

Slodki et al. examined the PA/AO ratio of a case with a small left ventricle and suspected CoA. In their study, in cases with a PA/AO ratio > 1.6, corresponding to an AO/PA ratio of < 0.63, CoA was suspected with a sensitivity of 83% and specificity of 85% [9]. The cut-off for the AO/PA ratio in the present study was < 0.7, which was smaller to that of Slodki et al., and our study had relatively high sensitivity and specificity. We believe this is because our study included a comparison with a normal group, whereas Slodki's included a comparison with a CoA false positive group.

Study Limitations

Several limitations associated with the present study warrant mention. First, the vascular diameter is believed to increase with increasing gestational age. When we examined the test of correlation about vascular diameter and gestational ages of AO, PA, SVC in each of the NH groups, it became $p < 0.01$ with all AO, PA, SVC(Fig. 4a). This indicates the correlation of gestational age with vascular diameter. However, there were no significant differences in the test of correlation with gestational ages and AO/PA ratio, AO/SVC ratio, PA/SVC ratio (Fig. 4b). This shows that the vascular ratio is not affected by gestational age. Second, we used the STIC method to calculate the diameter in the NH group but analyzed scanned images offline in the CoA and TOF groups. While we believe that the analysis of the ratio (AO/PA, AO/SVC, PA/SVC) is not markedly affected by differences in the technique used, further examinations will be necessary to confirm this.

Conclusion

The detection of fetal CoA is difficult. The Z-score of each blood vessel and ventricle is often required to identify fetal CoA. The same is true for TOF. In this study, we investigated simple parameters for screening for abnormalities. We concluded that the AO/PA ratio, as determined by the

3VV, is useful in screening for congenital heart disease. Calculation of the AO/PA ratio in fetal screening may prevent outflow tract congenital disease being missed in antenatal cardiac evaluation.

Authors' contributions TT: Dr Tomohiko Tanaka analyzed the data and wrote the paper. NI: Dr. Noboru Inamura analyzed the data and wrote the paper. YK: Dr. Yukiko Kawazu collected the image of echocardiography. FK: Dr. Futoshi Kayatani calibrated the paper.

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Availability of data and material The data and material in the current study are available from the corresponding author on reasonable request.

Code availability Not applicable' for that section.

Declarations

Conflicts of interest There are no financial or other relations that could lead to a conflict of interest.

Ethics approval The study design was approved by the appropriate ethics review board.

Consent to participate Written informed consent was obtained from the pregnant mother for participate of this study. The doctors who collected the images used in this paper have also provided their written informed consent.

Consent for publication Written informed consent was obtained from the pregnant mother for publication of this study. The doctors who collected the images used in this paper have also provided their written informed consent.

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