A COMPARISON OF 2D ECHO AND COLOUR DOPPLER WITH ANGIOGRAPHIC ESTIMATION OF PDA SIZE

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ABSTRACT

BACKGROUND
PDA device closure is an important nonsurgical method of treatment. Device size estimation depends upon the accurate assessment of the morphology and size of the PDA. Although, angiography is the gold standard for estimation of the size of the PDA, 2D echo and colour Doppler are comparable noninvasive alternatives. Put together, the three modalities are useful in fairly accurate estimation of the PDA size and prevention of complications like device embolisation or incomplete ductal closure. The purpose of this study is to compare PDA measurements made by 2D echo and colour Doppler with those made by angiography in the cardiac catheterisation laboratory.

MATERIALS AND METHODS
15 cases of PDA referred to Osmania General Hospital between August 2013 and August 2016 were included in the study. All the cases were assessed with 2D echo, colour Doppler and angiography and underwent device closure. PDA size estimated by 2D echo colour Doppler and angiography were compared and statistically analysed.

RESULTS
The patient ages ranged from 5 yrs. to 32 yrs. with a mean age of 14±8.5 yrs. There were 10 females and 5 males. As regards the type of PDA, all of them belonged to the A type based on Krichenko's classification. The mean diameter of pulmonary end measured 6.1±2.56 mm by 2D echo, 5.03±1.9 mm by colour Doppler, 5.32±2.17 mm by angiography. The mean diameter of aortic end measured 9.4±2.3 mm by 2D echo, 8.1±2.19 mm by colour Doppler, 8.4±2.29 mm by angiography. Both 2D echo and colour Doppler measurements correlated significantly with angiographic measurements at both pulmonary and aortic ends. The Pearson correlation coefficient for 2D echo and colour Doppler are 0.927 and 0.977 respectively at the pulmonary end indicating that CDE correlates marginally better than 2D echo with angiographic measurements at the pulmonary end. However, a larger sample size is needed to prove this. At the aortic end (ampulla), the Pearson correlation coefficient for 2D echo and colour Doppler are 0.896 and 0.969 respectively indicating that CDE correlates with angiography better than 2D echo.

CONCLUSION
The M:F ratio in the present study. The commonest type of the ductus in the present study is the type A based on Krichenko's 1 classification. Both 2D echo and colour Doppler correlated significantly with angiographic estimation of PDA size, but colour Doppler correlated slightly better than 2D echo. A larger sample size is needed to prove the same. Measurement of the aortic end of the ductus with colour Doppler when compared to pulmonary end correlated more significantly with angiography than 2D echo.

KEYWORDS
2D Echo, Colour Doppler, PDA Size.

HOW TO CITE THIS ARTICLE: Srinivas R, Venkata Subba Reddy Y, Adikesava Naidu O. A comparison of 2D echo and colour Doppler with angiographic estimation of PDA size. J. Evid. Based Med. Healthc. 2016; 3(88), 4782-4786. DOI: 10.18410/jebmh/2016/1007

BACKGROUND

Transcatheter closure of PDA is an established procedure. The device selection is typically based on ductal morphology and dimensions. Inaccurate measurements and, therefore, device selection may result in adverse events, including systemic or pulmonary embolisation, incomplete ductal closure and haemolysis. Thus, when transcatheter occlusion is considered in the treatment of PDA acquiring accurate ductal dimensions is necessary for appropriate device selection and sizing to ensure complete occlusion and to prevent inappropriate embolisation. The primary purpose of this study was to compare angiographically derived minimum ductal diameter measurements to that obtained in both 2D and colour Doppler.

Financial or Other, Competing Interest: None.
Submission 13-10-2016, Peer Review 20-10-2016,
Acceptance 26-10-2016, Published 02-11-2016.
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DOI: 10.18410/jebmh/2016/1007

MATERIALS AND METHODS

15 cases of PDA referred to Osmania General Hospital between August 2013 and August 2016 were included in the study.

Exclusion Criteria

1. Patients weighing less than 6 kg.
2. Age less than 6 months.
3. Active endocarditis or other infections producing bacteraemia.
4. Presence of thrombus at the intended site of implant or documented evidence of thrombus at the vessels through, which access is gained.
5. Patients whose vasculature through, which access to the defect is gained is inadequate to accommodate the appropriate sheath size.
6. Patients with pulmonary hypertension with PVR >8 Wood units or Rp/Rs>0.4.
7. Echocardiographic and angiographic estimations of the PDA sizes were made independently by the respective paediatric cardiology echocardiographer and interventionist who were blinded to each other's' findings.

Echocardiographic studies were performed using Phillips IE 33. The echocardiographic examination included sequential scanning from subcostal, apical, parasternal and suprasternal windows. The patent ductus arteriosus was imaged from the parasternal short axis at the base of the heart, suprasternal long axis and high left parasternal views. The 2-D measurements were made at the narrowest inner echocardiographic dimension; optimal colour flow gain was achieved by increasing the gain until it just became saturated (speckled) and the Nyquist limit adjusted to the maximum. The narrowest colour "waist" was measured. The PDA diameters were measured to the nearest 0.5 mm because of equipment precision limitations. The narrowest inner echocardiographic dimension was used to measure the PDA minimal diameter. The ductal ampulla was defined as the vascular structure between the narrowest diameter and the ductal aortic end. The distance between the mid position of narrowest diameter and the mid position of the ductal aortic end was defined as the ductal ampulla length. The diameter of the ductal end at the descending aorta, ampulla diameter was visualised from the long axis suprasternal or high parasternal views. The angiographic PDA classification proposed by Krichenko et al[1] was used. An echocardiographic classification of PDAs was based on the same criteria. In type A, the narrowest segment was at the pulmonary insertion, whereas in type B, the ductus was short and narrowed at the aortic insertion. Type C comprised tubular ductus without constriction, and in type D, there were multiple constrictions. Type E ductus was defined as a long tortuous duct that required more than 1 echocardiographic plane to be completely imaged. Angiographic estimations of the minimum PDA diameters were obtained with ascending aortograms by using 1 mL/kg of nonionic contrast through an appropriate pigtail catheter in the straight lateral camera position. The angiographic measurements were made to the nearest 0.1 mm offline calibrated to the catheter size.

STATISTICAL ANALYSIS METHODS

Summary measures like mean, standard deviation were calculated for continuous variables. Percentages were used for describing the categorical variables. Unpaired 't' tests was used to assess the significance of difference between means of two independent groups. Pearson correlation coefficient (r) was calculated for studying the relationship between two continuous variables, the significance of which was tested with a 't' test. P value <0.05 was considered as statistically significant.

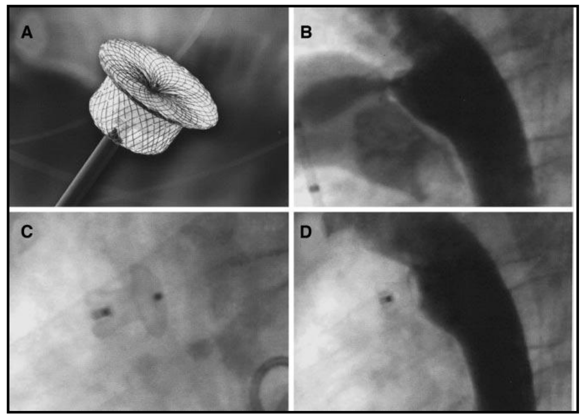

Figure 1

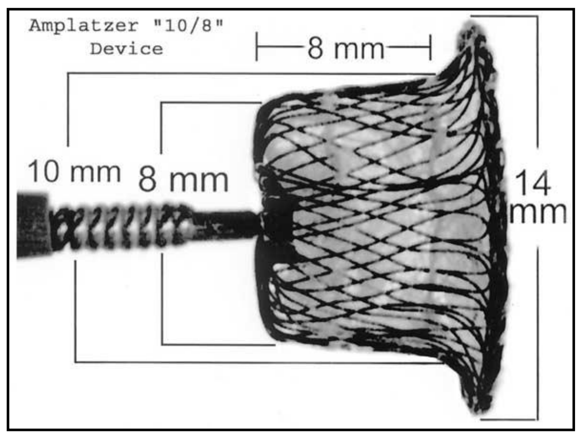

Figure 2

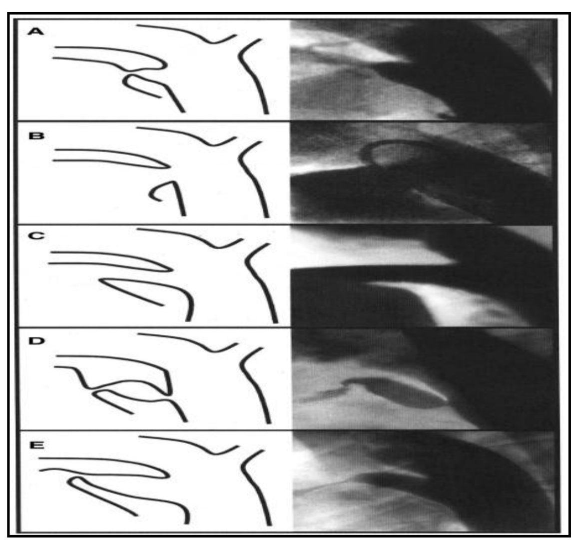

Figure 3

Based on these features, PDAs were classified into 5 common shapes;

1. Saucer shaped-total length of ductus <6 mm, ampulla at the aortic end;
2. Cylindrical (tubular)-length of ductus _>_6 mm with narrowing at the PA end by <50% of the ampulla width;
3. Conical (cup)-length _>_6 mm, narrowing at the PA end by >50% of the ampullary size and length of the narrowest portion (stem) one-third of the length of the ductus;
4. Hourglass shaped-ampulla at both the aortic and PA ends. The mean length of the PDAs in the present study was 7.06±1.76 mm with a mean ampulla width of 10.67±2.34 mm. The mean narrowest portion of the ductus was 2.25±1.05 mm and the mean depth of the ampulla was 5.50±1.98 mm. The mean angle of the ductus with the descending aorta was 143.74±23.2°.

The frequency with which various shapes were encountered was: conical 47.3% (/n/=72), funnel 25.8% (39), saucer 16.12% (25), tubular 7.5% (11) and hourglass 3.2% (5).

The following differences from Krichenko's classification were noted in the present study. Group B PDA, which accounted for almost 17% of Krichenko's description were not encountered in the present study.

Though PDAs with an ampulla at the PA end constituted 3.2% of the study group, all had an additional dilatation at the aortic end and were hence labeled hourglass-shaped. Moreover, PDAs with shapes conforming to groups D and E (altogether about 10% of Krichenko's study) were not noted in the present study. The commonest types of ductii in the present study could be classified as group A of Krichenko. However, 3 distinct shapes (saucer, conical and funnel-shaped) constituted this group. Hence, this study found significant differences in the angiographic appearance of PDAs from the classification originally proposed by Krichenko. Awareness of these morphological shapes is of importance before attempting percutaneous closure of the PDA and in the choice of closure hardware (coils versus occluder device).

Vascular resistance and PDA with low velocity or right-to-left flow, the ductus arteriosus may be very difficult to demonstrate with colour flow Doppler, even if it is large.

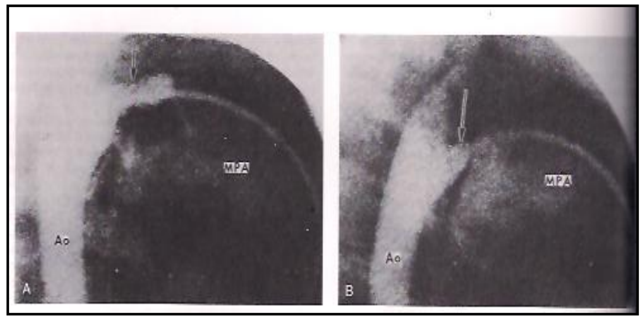

Figure 4. Angiograms in the Lateral Position in Two Children with Ductus Demonstrating the Variable Anatomy

RESULTS

The patient ages ranged from 5 yrs. to 32 yrs. with a mean age of 14±8.5 yrs. There were 10 females and 5 males. As regards the type of PDA, all of them belonged to the A type based on Krichenko's classification. The mean diameter of pulmonary end measured 6.1±2.56 mm by 2D echo, 5.03±1.9 mm by colour Doppler, 5.32±2.17 mm by angiography. The mean diameter of aortic end measured 9.4±2.3 mm by 2D echo, 8.1±2.19 mm by colour Doppler, 8.4±2.29 mm by angiography. Both 2D echo and colour Doppler measurements correlated significantly with angiographic measurements at both pulmonary and aortic ends. The Pearson correlation coefficient for 2D echo and colour Doppler are 0.927 and 0.977 respectively at the pulmonary end indicating that CDE correlates marginally better than 2D echo with angiographic measurements at the pulmonary end. However, a larger sample size is needed to prove this. At the aortic end (ampulla), the Pearson correlation coefficient for 2D echo and colour Doppler are 0.896 and 0.969 respectively indicating that CDE correlates with angiography better than 2D echo. An agreement in a 1 mm range with angiography was found in 12 of the 15 patients (79%) in case of colour Doppler and 5 of the 15 patients (40%) in 2D echo at the pulmonary end (Chart 2). An agreement in a 1 mm range with angiography was found in 15 of the 15 patients (100%) in case of colour Doppler as compared to 5 of the 15 patients (33%) with 2D echo at the aortic end (chart 3). The commonest size of the device used in this study was 8/10 (5) followed by 10/12 (4), 6/8 (3), 12/14 (1), 14/16(1), 16/18 (1).

Sl. No.	Age	Sex	Type	Pulmonary End (mm)			Aortic End (Ampulla)(mm)			Device Size
				2DE	CDE	ANGIO	2DE	CDE	ANGIO	
1	24	F	A	12	10	11	15	14	14.5	16/18
2	5	M	A	4	3.5	3	7	4	4	8/10
3	5	F	A	4.5	3	3	11	9.8	10	6/8
4	5	F	A	5	4	4	9	7.2	7	6/8
5	5	F	A	4	3.8	3.4	7	7.2	7	6/8
6	10	F	A	6	4.3	4.5	9	7.5	8	8/10
7	28	F	A	7	6	6.5	10	8.5	8.5	12/14
8	30	F	A	12	9	8.8	14	10.6	11	14/16
9	5	M	A	6	4.6	5	9	7.2	7	10/12
10	22	F	A	7	5.8	6	9.5	9.2	9	10/12
11	14	F	A	5	4.2	4.5	8.5	7.7	7.5	8/10

12	16	F	A	5.1	5	6	10	8.6	9	10/12
13	12	M	A	5	3.8	4	7	7.4	7.5	8/10
14	10	M	A	4.4	4	5	9	8.6	8	8/10
15	11	M	A	4.8	4.5	5.2	7	6.8	7.7	10/12

Chart 1

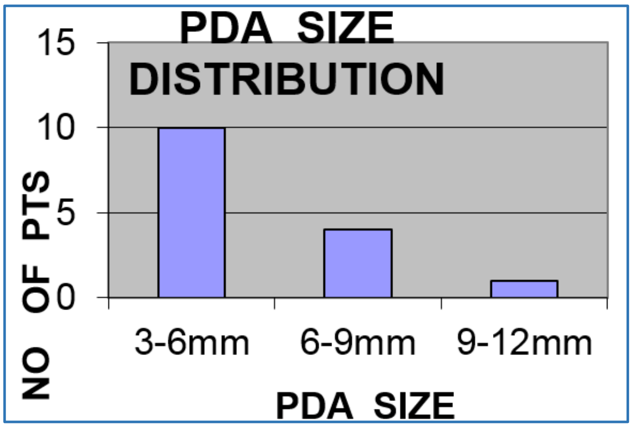

Chart 2

2D Echo vs. Colour Doppler (Pulmonary End) Within 1 mm, 1-2 mm and >2 mm Range of Angiographic Measurements

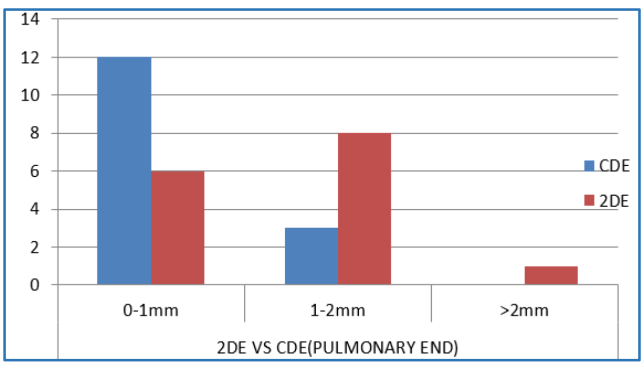

Chart 3

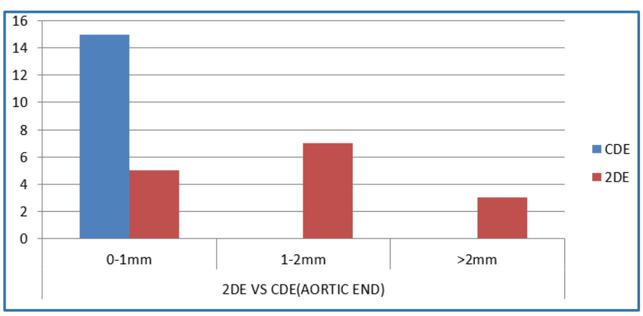

Chart 4

2D Echo vs. (Aortic End) Within 1 mm, 1-2 mm and >2 mm Range of Angiographic Measurements

DISCUSSION

In our study, the measurements made by 2D echo and colour Doppler correlated well with angiographic measurements. The colour Doppler measurements correlated better than 2D echo with the angiographic measurements at the aortic end marginally so at the pulmonary end. The 2D echo imaging tended to overestimate the minimum diameter of a PDA to a significant degree. These findings were similar those found by Sahn et al[2] though in their study, the minimum PDA diameters tended to be smaller than those found in ours (approximate range 2.3 to 7.2 mm, mean 4.1±1.7 mm vs. range 3 to 11 mm mean 5.32±2.17 mm). Sahn et al did note that 2D echocardiography did tend to overestimate the minimum PDA size when the PDA was smaller, which they attributed to represent some lack of endocardial visualisation because of echo dropout. Clearly, as the lumen of the PDA becomes less than the lateral resolution of the echocardiographic transducer used, the accurate assessment of the minimum PDA diameter by 2-D echocardiography cannot be reliably made. Although, our data support these issues of echo dropout and inadequate lateral resolution in smaller PDAs. The number of patients that we were able to study was small. Further study into this area needs to be performed before further conclusions can be made about the usefulness of 2D echocardiography in the assessment of minimum PDA sizes.

Wong et al[3] concluded that both colour Doppler and the 2D echo tended to overestimate the minimum diameter of a PDA to a significant degree. These findings differed from our study, though in their study, the minimum PDA diameters tended to be smaller than those found in ours (approximate range 3 to 11 mm, mean 5.2±2.7 mm, vs. range 0.4 to 3.3 mm, mean 1.6±0.7 mm).

The potential pitfalls of this technique was the inability to image and evaluate the narrowest portion of the PDA (particularly in the straight lateral position as used in angiography) and oversaturation of the colour filters secondary to improper colour Doppler sensitivity or gain settings ("bleeding" of the colour flow over the anatomic borders). With the difficulty in acquiring adequate 2D images, these errors are more likely to occur. These difficulties result in the overestimation of the true minimum PDA diameter. Ramaciotti et al showed that 2D echo estimation of the pulmonary end diameter and aortic end (ampulla) diameter correlated well with angiographic measurements. The 2D echo estimation of aortic end correlated less significantly with angiographic measurements. The reason was thought to be due to junction between the PDA and the descending aorta involved round edges with no sharp angulation. This feature could have made the precise demarcation of the ampulla diameter more troublesome by echocardiography and can also provide a potential source of error.

Sl. No.	Study	Conclusion
1.	Sahn et al	2D echo correlated with angiographic measurements with overestimation at smaller diameters.
2.	Wong et al[3]	Both 2 echo and colour Doppler overestimated the minimum diameter of PDA to a significant degree.
3.	Hameed Amoozgar et al[4]	The colour Doppler overestimated the pulmonary side by 33.6% and underestimated the aortic side by 7.8% compared to angiography.
4.	Ramaciotti et al[5]	2D echo measurements at both pulmonic and aortic sites showed good correlation with angiographic estimation.
5.	Alimohammad Hajizeinali et al[6]	They found that the TTE measurement of the aortic end diameter of the PDA showed a good linear regression correlation with the size of the implanted duct occluder.
6.	Present study	Both 2D echo and colour Doppler correlated well with angiographic measurements with colour Doppler correlating with angiography better at the aortic end than the pulmonary end.

CONCLUSION

1. The M:F ratio in the present study is 1:2.
2. The commonest age group involved in the present study is 5 yrs. Device closure done at this age can go a long way in preventing many of the long-term complications of persistent patent ductus arteriosus.
3. The commonest type of the ductus in the present study is the type A based on Krichenko's classification.
4. Both 2D echo and colour Doppler correlated significantly with angiographic estimation of PDA size, but colour Doppler correlated slightly better than 2D echo. A larger sample size is needed to prove the same.
5. Measurement of the aortic end of the ductus with colour Doppler when compared to pulmonary end correlated more significantly with angiography than 2D echo.
6. Commonest size of the PDA observed is 3-6 mm.
7. In the present study, the device was oversized up to 4 mm in most of the cases and in few up to 6 mm, but still we did not encounter any problem due the fact that the ductus is an elastic structure.

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