

Comparative Analysis of the Efficiency of Radiation Methods in the Diagnostics of Functional Parameters in Total Anomalous Pulmonary Venous Drainage

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Abstract Relevance. Total anomalous pulmonary venous drainage (TAPVD) is a malformation in which all pulmonary veins drain into the right atrium, vena cava, or a combination of both. The incidence of TAPVR ranges from 0.5% to 2% of all congenital heart defects (CHD), or 1/10000 of newborns. The prognosis and outcome of the clinical course of the defect depend largely on the variant anatomy of TAPVD and the functional state of the small circle. TAPVD has a mortality rate of up to 50% in the first 3 months of life and up to 80% by the end of 1 year of life. **Objective.** To improve surgical outcomes in patients with TAPVD by using modern diagnostic modalities, to evaluate the convergence and divergence between MSCT and ACG in patients with TAPVD. **Methods.** In-State Institution of Republican Scientific and Practical Medical Centre for Surgery named after Academician V. Vahidov the diagnostic interventions have been carried out on 59 patients from January 2008 up to December 2021. Male patients made up 41 (69.49%), female 18 (30.51%). The sensitivity, specificity, and overall accuracy of ASD and OFO in TAPVD were studied, and comparative correlation analysis between echocardiography, angiocardiology, and multislice computed tomography was performed. **Results.** We found the following correlation dependence on the left ventricular end-diastolic volume between findings of echocardiography and angiocardiology (Spearman's R 0.89; Kendall's Tau 0.77 and Gamma 0.79; Pearson's correlation coefficient 0.96). The obtained correlation relationship indicates high accuracy of EchoCG data about ACG data, which allows relying on echocardiography data for estimation of left ventricular volumetric and linear parameters. **Conclusions.** MSCT demonstrates outstanding diagnostic performance, which significantly affects the tactical aspects of the surgical treatment of the defect and its outcome. When assessing the state of the pulmonary circulation, there are significant problems regarding the effectiveness of the standard radiation methods used in assessing the throughput of the pulmonary circulation, which is due to their physical limitations and the difficulty in interpreting the obtained diagnostic information.

Keywords Total anomalous pulmonary venous return, Echocardiography, Angiocardiology, Computed tomography, Diagnostic efficiency, Open foramen ovale

1. Relevance

Total anomalous pulmonary venous drainage (TAPVD) is a defect in which all of the pulmonary veins return into the right atrium, vena cava, or a combination of both. The frequency of TAPVR is from 0.5 to 2% of all congenital heart diseases (CHDs), or 1/10,000 newborns. According to the literature, the defect is rare in isolated form, in most cases, it is accompanied by an atrial septal defect (ASD), or other intracardiac shunts [1].

According to Darling's classification, there are four types of TAPVD: Supracardial - where the pulmonary veins flow

into the superior vena cava system and account for up to 50% of all cases; Cardial - where the pulmonary veins flow into the right atrial cavity or coronary sinus and account for 25% of all cases; Infracardial - where the pulmonary veins flow into the inferior vena cava system in 20% of cases; Mixed type - characterized by a combination of different levels of TAPVR inflow and occurs in 5% of cases. In total abnormal pulmonary vein drainage (TAPVD), all pulmonary veins drain into the right atrium and vena cava system at different levels. The ratio of TAPVD in males to females is 3.6:1 respectively.

In TAPVR, pulmonary hypertension has a more aggressive course and is characterized by a severe clinical manifestation requiring urgent surgical care. About 60% of patients with TAPVD have hemodynamic abnormalities that are incompatible with life because of severe pulmonary hypertension and small or no intracardiac shunt (ASD). This

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causes the rapid development of critical conditions and the death of patients soon after birth, necessitating emergency surgery for vital indications.

The prognosis and outcome of the clinical course of the defect depend largely on the variant anatomy of TAPVD and the functional state of the pulmonary circle. In TAPVD, the mortality rate is up to 50% in the first 3 months of life and up to 80% by the end of 1 year of life. The average life expectancy in patients without pulmonary vein occlusion is 2.5 months and 3 weeks in those with occlusion.

The study aims to evaluate the convergence and divergence between MSCT and ACG in TAPVD patients.

2. Methods

In the Department of Congenital Heart Disease Surgery of the State Institution of Republican Scientific and Practical Medical Centre for Surgery named after Academician V.Vahidov from January 2008 to December 2021 diagnostic interventions were carried out in 59 patients with TAPVD, of which 52 patients with TAPVD underwent radical correction.

The age of patients at the time of inclusion in the study ranged from 1 month. up to 25 years (average 4.3 ± 5.6 years). The weight of the patients varied from 4.0 kg to 75 kg (average 16.94 ± 36.55 kg). The body surface area (BSA) ranged from 0.25 m² to 1.63 m² (0.6 ± 0.36 m² on average). Males were 41 (69.49%) patients, female 18 (30.51%) with a sex ratio (2.28:1) presented in Table 1.

Table 1. Distribution of patients by age and sex

| Sex | Males | | Females | | Overall | |
|-----------------------------|-----------|--------------|-----------|--------------|-----------|---------------|
| | n | % | n | % | N | % |
| Up to 1 year | 17 | 28,8% | 8 | 13,6% | 25 | 42,4% |
| 1 to 3 years old | 8 | 13,6% | 2 | 3,4% | 10 | 16,9% |
| 3 years old and over | 16 | 27,1% | 8 | 13,6% | 24 | 40,7% |
| Total: | 41 | 69,5% | 18 | 30,5% | 59 | 100,0% |

Our study involved both ultrasound and radiological methods such as EchoCG, ACG, and MSCT.

Using the principles of evidence-based medicine to assess sensitivity, specificity, overall accuracy, and prognosis of positive and negative results, we performed a comparative analysis of the radiological methods we used [2].

The method of comparative analysis used in our research work was carried out according to the generally accepted method of calculating the diagnostic method to understudy the reference method. This method is widespread due to its origin in statistics, particularly contingency tables. Its essence is to calculate the number of patients with confirmed and excluded features (i.e. defects) determined by a given method of investigation.

The contingency table on which the study of the diagnostic method was carried out with the reference

diagnostic method is built based on the four-field table 2 is presented below.

Table 2. 4-field table for assessing sensitivity and specificity

| Test | Disease exists | No disease | Total |
|-----------------|----------------|------------|-------|
| Positive | A | B | a+b |
| Negative | C | D | c+d |
| Total | a+c | b+d | |

These ratios of correctly diagnosed patients are called the sensitivity and specificity of the clinical examination: Sensitivity: the proportion of positive test results in a group of sick patients: Sensitivity = $a \div (a + c)$; Specificity: the proportion of negative test results in a group of healthy patients: Specificity = $d \div (b + d)$; Overall accuracy: the ratio of the sum of significant positive and negative test results to the total number of patients examined: Overall accuracy = $(a + d) \div (a + b + c + d)$; [4].

As only qualitative signs can be statistically evaluated with cross-tabulations, in the evaluation of quantitative signs, such as tensiometry and volume and linear parameters of the heart, a comparative analysis was made between echocardiography and angiocardiology by determining the correlation between the compared methods of investigation [5].

3. Results

Despite the importance of accurate preoperative diagnosis of TAPVD, these defect components, even detected as findings during intraoperative revision, do not significantly influence the surgical approach and can be successfully managed if the patient previously met the criteria for operability, including the degree of pulmonary hypertension, which often has a significant impact on the intra- and postoperative course [6].

We, therefore, performed a comparative analysis of our radiological methods, taking into account their main advantages and disadvantages to objectively assess their limitations in the diagnosis of TAPVD and its natural course complication of pulmonary hypertension. Due to the hemodynamic and pathophysiological features, TAPVD without Pulmonary Artery Stenosis is always complicated by pulmonary hypertension, which can be of key importance in establishing a contraindication for surgical treatment in grades IIIB-IV [7].

We assessed the correlation of tensiometry findings from echocardiography with angiocardiology and intraoperative tensiometry.

Considering that angiocardiology is now the "gold standard" in the diagnosis of pulmonary hypertension, we analyzed echocardiography for sensitivity, specificity, and overall accuracy in pulmonary hypertension presented in Table 3.

Table 3. Efficacy of echocardiography vs ACG tensiometry in the diagnosis of PH

| Established data | | Calculation data | |
|------------------|-----------|--------------------------------|-------|
| Positive | 33 | Sensitivity | 100% |
| False-positive | 3 | Specificity | 92,7% |
| False-negative | 0 | Overall accuracy | 95,9% |
| Negative | 38 | Prognosis of a positive result | 91,7% |
| Total: | 36 | Prognosis of a negative result | 100% |

Being an indirect imaging method, echocardiography in the diagnosis of PH takes into account the following criteria: 1) characteristics of the flow rate of regurgitation on the tricuspid valve allow indirect judgment of the pressure in the Right Ventricle and the degree of pulmonary hypertension; 2) displacement of the IVS towards the left ventricle due to severe hypervolemia of the right part of the heart accompanied by an extremely underloaded left ventricle of the heart [8].

Along with a comparative analysis of echocardiography data with ACG, we compared the same data with the results of intraoperative tensiometry presented in Table 4.

The data obtained look somewhat paradoxical, given that intraoperative and angiocardigraphic tensiometry essentially represents a direct measurement of pressure in the main vessels [9]. However, in our opinion, the decrease of such different specificity is because there are significant differences in the period of tensiometry during angiocardigraphy and intraoperative tensiometry in each specific patient, namely the effect of artificial ventilation with enriched oxygen mixture, vasodilators such as milrinone, which are administered protocol calls from the beginning of the operation, preoperative preparation with drugs aimed at reducing pulmonary hypertension such as phosphodiesterase 5 and 3 inhibitors, ACE inhibitors and bosentan.

Table 4. Effectiveness of echocardiography vs. intraoperative tensiometry in the diagnosis of PH

| Established data | | Calculation data | |
|------------------|-----------|--------------------------------|-------|
| Positive | 44 | Sensitivity | 97,8% |
| False-positive | 1 | Specificity | 0% |
| False-negative | 1 | Overall accuracy | 95,7% |
| Negative | 0 | Prognosis of a positive result | 97,8% |
| Total: | 46 | Prognosis of a negative result | 0% |

It is therefore clear that when it comes to the correct diagnosis of pulmonary hypertension in TAPVD, echocardiography is fully capable of replacing angiocardigraphy.

Even when TAPVD is combined with other intracardiac shunts, when a high degree of pulmonary hypertension is suspected and taking into account the urgency of the condition, there is no need for angiocardigraphy with an extension of the angiography program to determine PA/BP pressure ratios, Qp, Qs, Qp/Qs and total pulmonary vascular resistance [10]. Based on the data obtained, it is quite

acceptable based on the results of intraoperative tensiometry and justified based on the data obtained from echocardiography and multislice computed tomography with optional treatment between surgical correction of the defect or narrowing of the pulmonary artery, supplemented, if necessary, with atrioseptotomy by an operative or endovascular method. Due to the hemodynamic and pathophysiological features of TAPVD, there is a significant volume imbalance in the work of the heart, which characterizes severe hypervolemia of the right heart due to systemic and pulmonary venous return against the background of an underloaded left heart. The degree of filling of the latter is largely determined by the size of the intracardiac communication: open foramen ovale / ASD and/or VSD [11]. As a rule, such a condition in cardiac surgery practice is accompanied by a severe clinical course and significantly affects the outcome in the postoperative period. In this regard, we performed a comparative correlation analysis of the accuracy of left ventricular volumetric and linear parameters assessed by both echocardiography and angiocardigraphy. In particular, we investigated the correlation dependence on the left ventricular end-diastolic volume between echocardiography and angiocardigraphy findings. we obtained the following correlation relationships: Spearman $r=0.89$; Kendall tau 0.77 and Gamma 0.79, Pearson correlation coefficient 0.96. The obtained correlation dependence indicates the high accuracy of EchoCG data about EDV to ACG data, which allows us to confidently rely on echocardiography data in assessing the volume-linear parameters of the left ventricle in TAPVD. For clarity, the results obtained are presented in the form of a scatter plot of values in Figure 1.

At the same time, with a similar comparison of indexed indicators of LV EDV relative to body surface area, the following results were obtained: Spearman's R 0.75; Kendal's Tau 0.63 and Gamma 0.63; Pearson's correlation coefficient 0.83. Although the indexed correlation indicators for EDV were also close, as in the first case, it is seen that the strength of the correlation relationship in the analysis of the indexed values is somewhat lower, indicating less accuracy in the indexed indicators. For clarity, the results are presented as a graph of dispersion values in Figure 2.

4. Discussion

In this regard, despite rather close values on LV volume-linear values, it is obvious that the nominal value of LV volume according to echocardiography and angiocardigraphy has a more close value in comparison with the indexed one. We studied the volume-linear parameters of the LV because several studies on LV geometry in TAPVD state that the small LV volume differs significantly from the typical small, globular LV geometry in hypoplasia of the left heart and has a flattened or sickle-shaped shape, compressed by the dilated RV, which is overloaded by pressure and volume [12].

The authors suggest that intrauterine LV volume is normal or close to normal, whereas right ventricular overload with compression of the LV is formed postnatally. According to the authors, a small LV size does not affect the results of surgical correction of TAPVD [13]. Of interest is the fact that, according to some authors, the main reason for the preoperative decrease in LV EDV in patients with TAPVD is the anterior deviation of the interventricular septum due to high pressure in the RV, the so-called LV hypoplasia is determined not so much by compression as by its insufficient filling [14]. Our studies revealed that in patients with TAPVD the baseline LV dimensions correlate with the diameter of the interatrial communication, confirming the importance of the preoperative LV preload restriction mechanism (LV hypovolemia). Based on their findings, the authors believe that the preoperative decrease in LV EDV in patients with TAPVD is predominantly due to deviation.

In patients with TAPVD, in the early postoperative period, normalization of the size and increase in LV volume are noted after the elimination of the overload of the right heart by pressure and volume. The hemodynamic integrity of the LV and its ability to provide adequate systemic ejection is further confirmed by the absence of an alternative pathway for left heart chamber decompression in the patient group under study. Thus, based on the comparison of echocardiography data with angiocardiology, we concluded that a strong correlation between echocardiography and angiocardiology data will make it possible to accurately determine LV EDV, which, according to several authoritative studies, is important at the stage of preoperative assessment of TAPVD and in the postoperative period. Since, despite the initial reduction in LV size, elimination of compression and creation of adequate preload ensures 'hemodynamic rehabilitation' of the LV with normalization of its size in the early postoperative period.

Spearman's R 0.89; Kendall's Tau 0.77 and Gamma 0.79; Pearson's correlation coefficient 0.96

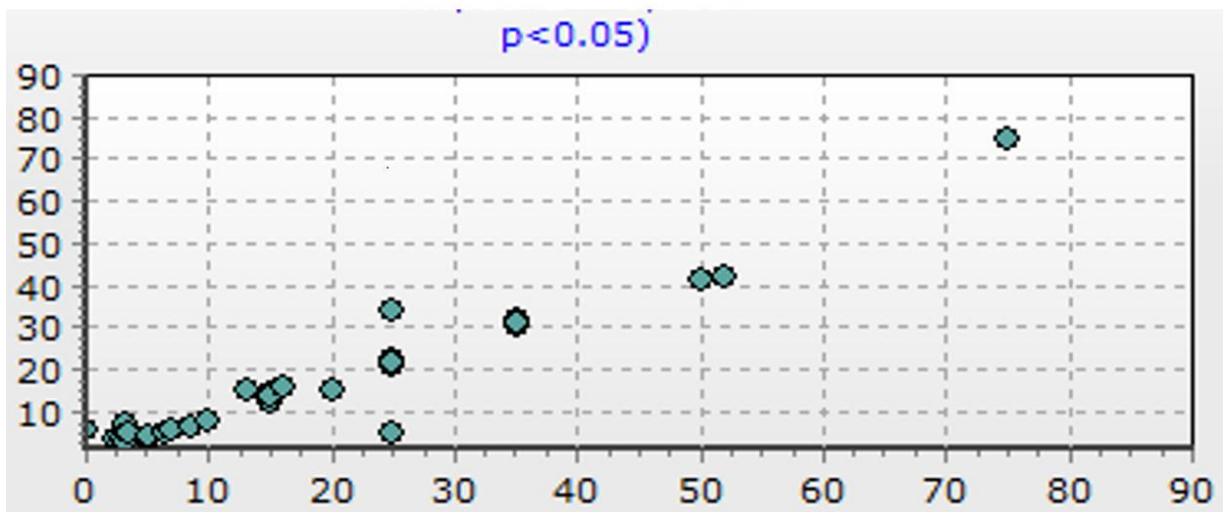


Figure 1. Scatterplot of correlation dependence on LV EDV between echocardiography and angiocardiology

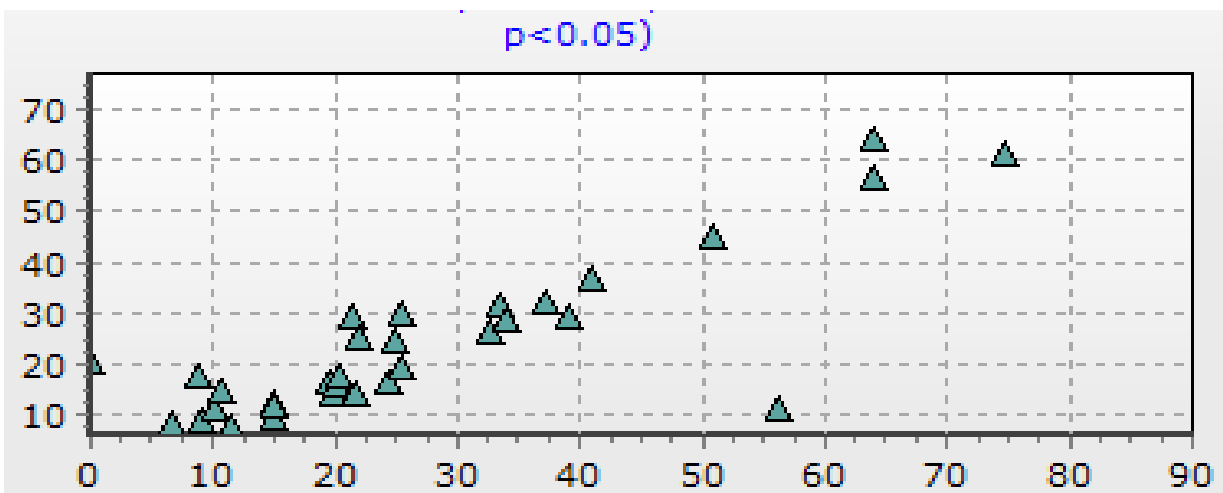


Figure 2. Scatterplot of the correlation between LV CDI between echocardiography and angiocardiology

5. Conclusions

Based on comparative correlation analysis, we found a strong correlation between the results of left ventricular assessment obtained from EchoCG and angiocardiology, which in turn also allows us to limit preoperative preparation to ultrasound to reduce preoperative preparation time due to severe TAPVD to optimize the study protocol without compromising the quality and completeness of clinical diagnosis of the defect. Despite the correlations identified in this analysis regarding the effectiveness of the radiological techniques, our results are not intended to be the final truth, but they can be recommended for clinical use with a degree of certainty.

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The study was not sponsored.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

- [1] Laux D, Fermont L, Bajolle F et al. Prenatal diagnosis of isolated total anomalous pulmonary venous connection: a series of 10 cases. *Ultrasound Obstet Gynecol.* 2013; 41: 291–297. Doi: 10.1002/uog.11186.
- [2] Ross FJ, Joffe D, Latham GJ. Perioperative and Anesthetic Considerations in Total Anomalous Pulmonary Venous Connection Seminars in Cardiothoracic and Vascular Anesthesia. 2017; 21(2): 138–144. Doi: 10.1177/1089253216672012. Epub 2016 Sep 29.
- [3] Darling RC, Rothney WB, Craig JM. Total pulmonary venous drainage into the right side of the heart: report of 17 autopsied cases not associated with other major cardiovascular anomalies. *Lab Invest.* 1957; 6: 44–64.
- [4] Sinzobahamvya N, Arenz C, Brecher AM et al. Early and long-term results for correction of total anomalous pulmonary venous drainage (TAPVD) in neonates and infants. *Eur J Cardiothorac Surg.* 1996; 10: 433–438.
- [5] Hines MH, Hammon JW. Anatomy of total anomalous pulmonary venous connection. *Oper Tech Thorac Cardiovasc Surg.* 2001; 6:2–7. Doi: doi.org/10.1053/otct.2001.22696.
- [6] Padalino MA, Cavalli G, De Franceschi M et al. Surgical outcomes of total anomalous pulmonary venous connection repair: a 22-year experience. *J Card Surg.* 2014; 29: 678–685. Doi: 10.1111/jocs.12399.
- [7] Seale AN, Uemura H, Webber SA et al. Total anomalous pulmonary venous connection: morphology and outcome from an international population-based study. *Circulation.* 2010; 122: 2718–2726. Doi: 10.1161/CIRCULATIONAHA.110.940825. Epub 2010 Dec 6.
- [8] Chowdhury UK, Airan B, Malhotra A, et al. Mixed total anomalous pulmonary venous connection: anatomic variations, surgical approach, techniques, and results. *J Thorac Cardiovasc Surg.* 2008; 135: 106–116. Doi: 10.1016/j.jtcvs.2007.08.028.
- [9] Hancock Friesen CL, Zurakowski D, Thiagarajan RR et al. Total anomalous pulmonary venous connection: an analysis of current management strategies in a single institution. *Ann Thorac Surg.* 2005; 79: 596–606. Doi: 10.1016/j.athoracsur.2004.07.005.
- [10] Haworth SG, Reid L. Structural study of the pulmonary circulation and heart in total anomalous pulmonary venous return in early infancy. *British Heart Journal.* 1977; 39: 80–92. Doi: 10.1136/hrt.39.1.80.
- [11] Haworth SG. Total anomalous pulmonary venous return. Prenatal damage to the pulmonary vascular bed and extrapulmonary veins. *Br Heart J.* 1982; 48: 513–524. Doi: doi.org/10.1136/hrt.48.6.513.
- [12] Brown DW., Geva T. Anomalies of the Pulmonary Veins. In: Moss & Adams heart disease in infants, children, and adolescents: including the fetus and young adult / Allen H.D. et al. 8th ed. by Lippincott Williams & Wilkins, 2013; 809–839.
- [13] Hlavacek AM, Shirali GS, Anderson RH. Pulmonary venous abnormalities. In: Anderson RH, Baker EJ, Redington A, Rigby ML, Penny D, Wernovsky G, editors. *Pediatric Cardiology.* London: Churchill Livingstone; 2009: 497–522.
- [14] Kalantre AA, Champaneri B, Kottayil B, Vaidyanathan B. «Hemodynamic vice» of the right-sided ascending vertical vein in the setting of supracardiac total anomalous pulmonary venous connection in a neonate: Anatomic-embryological correlation. *Ann Pediatr Cardiol.* 2017; 10(1): 104–106. Doi: 10.4103/0974-2069.187091.