Relationship between orifices of pulmonary and coronary arteries in common arterial trunk

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Received 18 November 2008; received in revised form 20 December 2008; accepted 30 December 2008; Available online 23 February 2009

Abstract

Objective: Variability in pulmonary arterial and coronary arterial origins in common arterial trunk has been investigated previously but only as separate entities. We hypothesise that combinations of relationships between the two arterial structures have important clinical implications.

Methods: We identified pulmonary arterial and coronary arterial origins in 56 heart specimens. The orifices were plotted according to the location on the circumference of the common trunk and distance from the level of the sinutubular junction.

Results: Pulmonary orifice was sinusal when the lowest margin of the orifice was below the sinutubular junction (n = 12, 21%). It was defined as low when located ≤2 mm above the sinutubular junction (n = 11, 20%). Pulmonary origin >2 mm above the sinutubular junction was designated as normal (n = 33, 59%). Circumferentially, there was a distinct predilection for sinusal origin to be located within the left-anterior segment of the common trunk, as opposed to low and normal origins that almost always resided within the left-posterior segment. Furthermore, hearts with sinusal origin (75%; 9 hearts out of 12) had significantly higher prevalence of proximity (defined as a distance of ≤2 mm) between pulmonary and coronary orifices than those with low origin (27%; 3 hearts out of 11) and normal origin (3%; 1 heart out of 33) (p = 0.039 and p < 0.001, respectively).

Conclusions: Owing to its unique location, frequently close to a coronary orifice, hearts with sinusal origin warrant special attention in both diagnostic and surgical management. At the same time, however, its peculiar pulmonary arrangement may facilitate direct right ventricular-pulmonary connection and dispense with the need for augmentation with an external conduit that inevitably will be outgrown by the patient.

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Keywords: Congenital heart disease; Common arterial trunk; Anatomy

1. Introduction

Common arterial trunk is usually categorised according to the pattern of pulmonary origin as described in the traditional classifications by Collet and Edwards [1] and Van Praagh and Van Praagh [2], and more recently the unified nomenclature system of the STS-Congenital Heart Surgery Database [3]. These traditional categorisations were useful for deciding whether to perform banding of the pulmonary artery in the days before the advent of surgical repair. Both categorisations were established before McGoon et al. succeeded in the first repair for this malformation in 1967 [4]. However, in the current era of surgical repair not only the pattern of pulmonary origin but also the location of the orifices and relationship to other surrounding structures are important because surgical repair entails detachment of pulmonary arteries from the common arterial trunk and closure of the resulting defect by direct suturing or with patch augmentation. Potentially, these manoeuvres could distort the surrounding structures, particularly the coronary arteries that may be nearby. Variability in pulmonary arterial and coronary arterial origins in common arterial trunk has been investigated previously but only as separate entities [5—12]. In this study, therefore, we revisited this malformation, with a special focus on pulmonary—coronary relationship and its relevance to clinical management.

2. Materials and methods

This study has been approved by our institutional ethics committee. From the archive of the Royal Brompton Hospital, we identified 65 heart specimens with common arterial trunk. For the purpose of this study, we excluded...
three foetal hearts and six hearts in which the location of either pulmonary or coronary orifices could not be determined because of previous surgery or dissection. The remaining 56 hearts were examined. The hearts were from patients ranging in age from 3 days to 35 years, with majority (90%) aged 3 months or younger.

The pulmonary orifices were assessed and expressed in three ways. Firstly, the origins of the left and right pulmonary arteries were assessed and categorised as from a common orifice (type I according to the Collet—Edwards classification [1]), separate and adjacent orifices (type II), separate and remote orifices (type III), or single orifice leading to only one pulmonary artery. Secondly, the location of pulmonary orifices was assessed as to whether there was a sinusual origin, low origin, or normal origin. A pulmonary orifice was considered sinusual when the lowest margin of the orifice was below the sinutubular junction and low origin when the lowest margin was ≤2 mm above the sinutubular junction (Fig. 1). Pulmonary origins >2 mm above the sinutubular junction were designated normal. Thirdly, the location of pulmonary orifices was mapped relative to the circumference of the common trunk using compass-like designations of anterior, left-anterior, posterior, and so on. Additionally, any atypical arrangements of pulmonary arteries were noted.

The origin of the coronary arteries and their relationship to the semilunar leaflets and sinuses of the truncal valve were examined following the methods previously described [9]. Again, the location of coronary orifices was assessed relative to the level of the sinutubular junction and to the circumference of the common trunk. Coronary origin immediately above the sinutubular junction was designated as upper margin of the sinutubular junction. When the coronary orifice was located well above the sinutubular junction with the distance equivalent to at least one-half of the sinus depth, it was considered high take-off of the coronary artery.

Particular attention was directed toward the relationship and distance between the pulmonary and coronary orifices. Close proximity is defined as a distance of ≤2 mm between the margins of the pulmonary and coronary orifices.

For comparison of the prevalence of close proximity between the pulmonary and coronary orifices, Fisher’s exact test was used. The data were analysed with SPSS 15.0.1 for Windows (SPSS Inc., Chicago, IL). A p value of 0.05 or less was considered statistically significant.

3. Results

3.1. Pulmonary arterial arrangement

3.1.1. Type of pulmonary origins

The pulmonary orifices were common (type I) in 36 hearts (64%), separate and adjacent (type II) in 13 (23%), and separate and remote (type III) in 5 (9%). In another two hearts (4%), only one pulmonary artery arose from the common trunk with the contralateral lung supplied by systemic-pulmonary collaterals from the descending aorta or via patent arterial duct.

3.1.2. Location of pulmonary orifices relative to sinutubular junction

In hearts with a common pulmonary orifice/trunk (type I: n = 36), almost half had either low (n = 9, 25%) or sinusual pulmonary origin (n = 8, 22%). In hearts with separate and adjacent pulmonary orifices (type II: n = 13) there was similar prevalence of sinusual origin (n = 3, 23%) but low origin was identified in only one (8%). In contrast to these two forms, none of the hearts with remote orifices (type III: n = 5) had low or sinusual origin. On the other hand, both hearts having a single pulmonary artery arising from the common arterial trunk had either low or sinusual orifice.

3.1.3. Location of pulmonary orifices relative to circumference of common trunk

Fig. 2 (left circle) shows the distribution of pulmonary orifices relative to the circumference of the common trunk in hearts with a common orifice or separate and adjacent orifices (types I and II). All the hearts with low or normal origin had the pulmonary orifices between left and posterior compass points. By contrast, all the hearts with sinusual origin had the orifice between anterior and left points irrespective of the type of orifices. In hearts with remote orifices (type III: n = 5), the right pulmonary artery arose from the right (n = 3) or posterior (n = 2) aspect of the trunk, whereas the left pulmonary artery took origin from the left (n = 4) or left-anterior (n = 1) aspect. In hearts with a single pulmonary artery directly originating from the trunk (n = 2), one of them had left-anterior (with sinusual) origin of the right pulmonary artery. The other had anterior (with low) origin of the left pulmonary artery.

3.1.4. Other arrangements of pulmonary arteries

In addition to the above-mentioned variations in the type and location of pulmonary orifices, there were some atypical

Fig. 1. Pulmonary orifice is categorised according to the level of the lowest margin of the orifice as either sinusual (below STJ), low (≤2 mm above STJ), or normal (>2 mm above STJ) (STJ, sinutubular junction).
arrangements of pulmonary arteries. One heart with a common orifice (type I) had a dilated pulmonary trunk giving rise to right and left pulmonary arteries that were in a cross-over relationship. This heart was associated with a patent arterial duct and tubular hypoplasia of the aortic arch. In another heart with separate and remote orifices (type III), the orifice of the right pulmonary artery was located at the relatively distal part of the trunk compared with its counterpart, thereby resulting in an oblique relationship of two pulmonary orifices.

3.2. Coronary arterial arrangement

3.2.1. Location of coronary orifices relative to sinutubular junction

The majority of coronary orifices were located below the sinutubular junction. The truncal valves had three leaflets in 31 (55%) hearts, four leaflets in 18 (32%), two leaflets in 6 (11%), and five leaflets in 1 (2%). In total, both the left and right coronary orifices resided below the sinutubular junction in 31 hearts (55%). In 21 hearts (38%), at least one orifice was located at the upper margin of the sinutubular junction: left coronary orifice in 9 hearts, right coronary orifice in 3, both orifices in 6, and single coronary arterial orifice in 3. The remaining four hearts (7%) had high take-off of the coronary arteries: left coronary artery in two hearts, and right coronary artery in the other two.

3.2.2. Location of coronary orifices relative to circumference of the trunk

Fig. 2 (middle and right circles) shows the distribution of right and left coronary orifices relative to the circumference of the common trunk. Although their circumferential locations were variable, the plots showed some clustering. The right coronary orifices were found mainly in the segment between anterior and right compass points, with fewer numbers between left-anterior and anterior points, and between right and right-posterior points. Right coronary orifices were not found on the left-posterior half of the circumference between left-anterior and right-posterior compass points. This segment of the circumference is where the majority of left coronary orifices were located. Even when the coronary arteries had high take-off origin, the locations of their orifices were within their corresponding preferred segments. All the three hearts with single coronary artery had their orifices between left and left-posterior margin.

3.2.3. Other abnormalities of coronary arteries

Nine (16%) hearts had a stenotic orifice of the coronary artery due to its slit-like shape (left coronary orifice in seven hearts, right coronary orifice in one, and single coronary arterial orifice in one). In four (7%) hearts, the right coronary artery gave rise to a large branch that descended in the anterior interventricular groove after crossing in front of the truncal root. One of them appeared to be an accessory anterior descending coronary artery.

3.3. Proximity of pulmonary and coronary orifices

Among the 56 hearts examined, 13 (23%) had close proximity of ≤2 mm between the pulmonary and coronary orifices (left and right coronary arteries in 12 and 1, respectively) (Fig. 3). The prevalence of this close proximity was significantly affected by the level of pulmonary orifices relative to the sinutubular junction.
Most of the hearts with sinusal origin had this proximity (9 hearts out of 12). By contrast, only one of the hearts with normal pulmonary origin had this relationship (1 heart out of 33). This exceptional case was associated with high take-off of the left coronary artery. Three hearts out of 11 with low pulmonary origin had close proximity to coronary orifices. Comparison between groups showed that hearts with sinusal origin had significantly higher prevalence of such proximity (75%) than those with low origin (27%) and normal origin (3%) \((p = 0.039\) and \(p < 0.001\), respectively). Furthermore, not only lower pulmonary origin but also its circumferential location appeared to have clear influence on this close proximity. All the four hearts with sinusal pulmonary origin at the left aspect of the truncum circumference had this proximity. Another four out of six hearts with sinusal pulmonary origin at the left-anterior aspect had this relationship. By contrast, the two hearts with sinusal location of pulmonary orifice at the anterior aspect were not close to the left coronary orifice but in one heart the right coronary orifice was in the immediate vicinity.

4. Discussion

Our observation on hearts with sinusal pulmonary origin has disclosed some morphologic features that had not been recognised in the past but might have important clinical implications. We believe that pre- and intra-operative detection of this atypical pulmonary origin could help in surgical management. The likelihood of a close proximity between pulmonary and coronary origins is highest in hearts with sinusal pulmonary origin.

This result should not be surprising considering the fact that coronary orifices are usually located below the sinutubular junction. Nevertheless, it must be emphasised that the likelihood of such proximity is also affected by the location of pulmonary orifice relative to the circumference of the common trunk. The left coronary orifice is nearest when the sinusal pulmonary orifice is located at the left aspect of the truncum circumference because most of the left coronary orifices cluster between the left and right-posterior aspects (Fig. 2). Consequently, the more anteriorly situated the pulmonary orifices, the less likely they are to be in close proximity to the left coronary orifice. But, anterior location of the pulmonary orifices potentially can be associated with proximity to the right coronary orifices, because right coronary orifices are occasionally located in the left-anterior margin (Fig. 2). Indeed, one heart with anterior and sinusal pulmonary origin in our series had close proximity to the right coronary orifice (Fig. 3). Nevertheless, although it rarely occurs, we should also take note that close proximity is possible even if the pulmonary orifice is located far above the sinutubular junction. We had such an example where the pulmonary origin was in typical location (above the sinutubular junction and on the left-posterior aspect of the common trunk) but the left coronary artery had high take-off (Fig. 3).

Whilst sinusal pulmonary origin might pose a risk of coronary arterial compromise during repair, the shorter distance between the pulmonary arteries and the right
ventricular outflow tract could be advantageous for the newer repair techniques that dispense with the need for augmentation with an external conduit [13–16]. Direct anastomosis technique, first described by Bailey and colleagues [13] and subsequently popularised by Barbero-Marcial and associates [16], uses the patient’s own tissues to reconstruct the posterior wall of the outflow and, if needed, a patch to augment the channel anteriorly. This has the potential for tissue growth that may delay or even avoid the need for further reconstruction of the right ventricular outflow tract as the child grows [16–18]. However, there are some drawbacks to this newer modification. The most important one is stenosis of one (or both) branch pulmonary artery [18]. This complication could be the result of tension in bringing the pulmonary bifurcation downward from its original position to the right ventricle for direct anastomosis. The right pulmonary artery is especially prone to being stretched since it has to pass around the side of the neo-aorta from its usual left-posterior or posterior location. In this regard, hearts with sinusal pulmonary origins would be the best candidates for the direct connection repair owing to this crucial distance being shorter. This is particularly true since all the sinusal pulmonary origins are more or less anteriorly located in our series and, therefore, most conveniently sited for direct connection (Fig. 4). In fact, the heart illustrated in the paper by Barbero-Marcial, who had popularised the direct anastomosis technique, showed sinusal and left-anterior pulmonary origin [16]. It is interesting that their illustration concurrently demonstrated another important feature of this particular condition, i.e. the proximity of the pulmonary orifice to the left coronary ostium. This proximity could increase the risk of injury to any nearby coronary artery when detaching pulmonary arteries from the common trunk or closing the resulting defect, especially if the surgeon needs to detach a large cuff of truncal wall around the pulmonary orifice so as to access adequate tissues for direct anastomosis [18]. Similarly, a surgeon detaching the separate and adjacent pulmonary orifices (type II) as a single pulmonary cuff may encroach upon a coronary artery. Two specimens in our series had the coronary ostium (left coronary artery in one and right coronary artery in another) incorporated in the suture lines used for patch closure. Any additional anomalies of the coronary artery like a slilt-like ostium might further impact on coronary perfusion.

Limitation of our study is a possible difference in the prevalence of atypical pulmonary arrangements between an autopsy series and clinical series. Nevertheless, the observation of close relationship between sinusal pulmonary orifices and coronary arteries should still hold true.

In conclusion, detection or suspicion of sinusal origins of pulmonary arteries in common arterial trunk is relevant to optimising surgical management and can alert the surgeon to the possibility of coronary arteries nearby.

Acknowledgements

The authors wish to express appreciation for statistical advice from Mr Joseph Eliahoo at the Statistical Advisory Service, Imperial College London. We also appreciate Ms Manveer Sroya and Ms Carina Lim for their technical and secretarial assistances.

References


Fig. 4. (A) A heart with sinusal and almost anterior origin of pulmonary trunk viewed from the front. The common arterial pathway is limited to a very short zone immediately above the truncal valve. Owing to the unique location of pulmonary origin, the pulmonary trunk is extremely close to the right ventricular cavity. (B and C) Another example of a heart with sinusal pulmonary origin. (B) View from the left showing the pulmonary trunk arising from the left-anterior circumference of the common arterial trunk. (C) The common trunk and right ventricle opened to show the locations of pulmonary and coronary orifices and the ventricular septal defect. The pulmonary orifice is within the left-anterior sinus of the truncal valve (open arrow). The level of pulmonary orifice is similar to that of the left coronary artery and even lower than that of the right coronary artery that has high take-off origin (LCA, left coronary artery; PA, pulmonary artery; RCA, right coronary artery).