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Direct emergence of the conus artery from an independent ostium. A cadaveric study on a Spanish sample

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SUMMARY

The main purpose of this study was to evaluate the frequency with which the conus artery originates from an independent ostium in the right aortic sinus. Twenty-five adult hearts (3 females, 5 males and 17 unknown sex), from the body donation program of the University of Girona, were analysed. After intravascular injection of natural coloured latex in the coronary ostia, the origin of the conus artery and its distribution pattern were analysed by microdissection. Three of the 25 hearts analysed (12.0%) displayed the direct emergence of the conus artery from a discrete ostium in the right aortic sinus: in two specimens (8%) showing a single ostium for the independent conus artery, and in one heart (4%) two ostia for two independent conus arteries. In all cases, the independent conus arteries were shorter than the coronary artery and extended up to the anterior wall of the right ventricle, coinciding with the observations of previous authors. The independent conus artery may be an important source of collateral blood flow to the infundibulum. It may be an important source of apex and interventricular septum collateral irrigation. To ascertain the origin of the conus artery and its distribution is clinically important, particularly in obstructions of the anterior interventricular artery. The independent conus artery's collateral perfusion can both obscure the detection of any ischaemic modification in the apex and septum regions, and serve as a therapeutic source. Consequently, interpretations of the coronary occlusion clinical test should take this vascular channel into account.

Key words: Coronary arteries – Conus branch – Heart – Anatomical variations – Anatomical population differences

INTRODUCTION

In recent years, the number of recorded anomalies and anatomical variations in coronary arteries has increased due to the development and improvement of diagnostic imaging techniques. The prevalence of congenital coronary artery malformations found in autopsy and angiography studies ranges from 0.3-1.3% (Yamanaka and Hobbs, 1990; Caglar et al., 2013). The prevalence of anatomical variations is higher than these given values. Depending on the anatomical variation, their prevalence can reach up to 50% (Angelini et al., 1999).

To identify the presence of coronary malformations and coronary anatomical variations is of great clinical importance. Some coronary malformations have been associated with sudden cardiac death (particularly in young individuals), myocardial ischaemia and infarction (De-Giorgo et al.,

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2013; Caglar et al., 2013). Although, in general, malformations have not clinical effects under normal circumstances, in some cases, its obstructive type of involvement can explain ischemic symptomatology and electrocardiography findings in situations of maximum physical stress. In addition, knowledge of coronary anatomical variations, apart from the well-known surgical implications (James, 1961; Reig-Vilallonga, 2003), has also yielded therapeutic effects (De Agustín et al., 2010). In some cardiac pathology, particular coronary anatomical variations, such as an independent conus artery - arising from and independent ostium different than that of the right coronary artery - can be a source of collateral perfusion, which is basic for the individual survival in cases of coronary obstruction (Sahni and Jit, 1990; Dhobale et al., 2015). However, standard approaches to coronary angiographies fail to visualize these variations in many cases (Levin et al., 1981; Dhobale et al., 2015; De Agustín et al., 2010). Therefore, sound knowledge of the presence of these cardiac malformations and anatomical variations is needed for accurate interpretation of symptoms and clinical tests such as coronary angiograms. This study will focus on cardiac anatomical variations, particularly on the origin of the conus artery.

The conus artery is normally defined as the first branch off the right coronary artery (James, 1961; Caglar et al., 2013). This artery is responsible for supplying the coronary blood flow of the conus, the right ventricular outflow tract and a large portion of the anterior free wall of the right ventricle. Furthermore, the conus artery frequently anastomoses with the corresponding branch of the left coronary artery, forming Vieussens' arterial ring (Sankari et al., 2001). Ever since the late 1940s, studies have indicated the existence of a morphological variant in the origin of the conus artery, whereby it emerges directly from a discrete ostium in the right aortic sinus (Schlesinger et al., 1949; Lippert and Pabst, 1985; Akçakoyun et al., 2010; Caglar et al., 2013). This occurs in between 7% and 50% of individuals, this percentage varying with the population of origin of the individuals (Olabu et al., 2007). Currently, there is information on the prevalence of the independent conus artery in populations such as the Japanese (36.8%) (Miyazaki and Kato, 1988), Kenyans (35.1%) (Olabu et al., 2007), English (15.8%) (Turner and Navaratnam, 1996) and Germans (7.1%) (Von Lüdinghausen and Ohmachi, 2001). However, in spite of its importance, there is no information on this anatomical variant in the current Spanish population.

Given the great clinical significance of information on anatomical variations in the coronary arteries and their branches, and the lack of information regarding the Spanish population on the prevalence of the variation in the conus artery in relation to its direct emergence from an accessory ostium, the objective of this study is to provide evidence for the prevalence of this anatomical variant in present-day Spaniards.

MATERIAL AND METHODS

Twenty-five adult human hearts of individuals aged between 53 and 86 years old were analysed. These were collected from 12 formalin-fixed and 13 fresh-frozen specimens (17 of unknown sex, 3 females and 5 males), belonging to the body donation program of the University of Girona. All of them were voluntary donors of this program. Hearts with macroscopic cardiac defects and gross congenital malformations were excluded. Fat and pericardium were removed in piecemeal fashion. The hearts were dissected to display the origin of the conus branch, and right and left coronary arteries. The ascending aorta was transversely sectioned approximately 0.5 cm above the aortic valves and natural coloured latex was injected intravascularly into the coronary ostia. We microdissected, photographed, and macroscopically examined both coronary (right and left) and conus arteries. In each heart, we focused our observations on the ostia in the aortic sinuses, on the distribution pattern of the conus artery, and also on the identification of independent conus arteries (conus branches that emerged directly from an independent ostium).

RESULTS

The prevalence of direct emergence of the conus artery from the aortic sinus is 12.0% (3/25) in total (these three independent conus arteries were observed in three unknown sex specimens and because of this, we could not evaluate possible sex differences). Two of these three specimens showed a single orifice for the conus artery in the right aortic sinus (Fig. 1A, B), separated from that of the right coronary artery (8%). The third of these three individuals showed two orifices separated from that of the right coronary artery (Fig. 1C), thus forming two independent conus branches (4%). The remaining 22 individuals showed a common orifice for the origin of the conus and right coronary arteries, the conus artery being a branch off the right coronary artery (88%). In all cases, the ostia of the independent conus arteries were located in the right aortic sinus adjacent to (left of) the ostium of the right coronary artery. The ostium diameter of these independent conus arteries was always smaller than that of the right coronary artery (Fig. 1B). In the case of the duplicated conus arteries, two independent ostia of different size were noted (Fig. 1C). In this case, the ostium nearest to the right coronary artery showed the lowest diameter of the three ostia (see Fig. 1C). In all three cases, the independent conus arteries extended up to the anterior wall of the right ventricle (see Fig. 1A). The number of branches from the four independ-

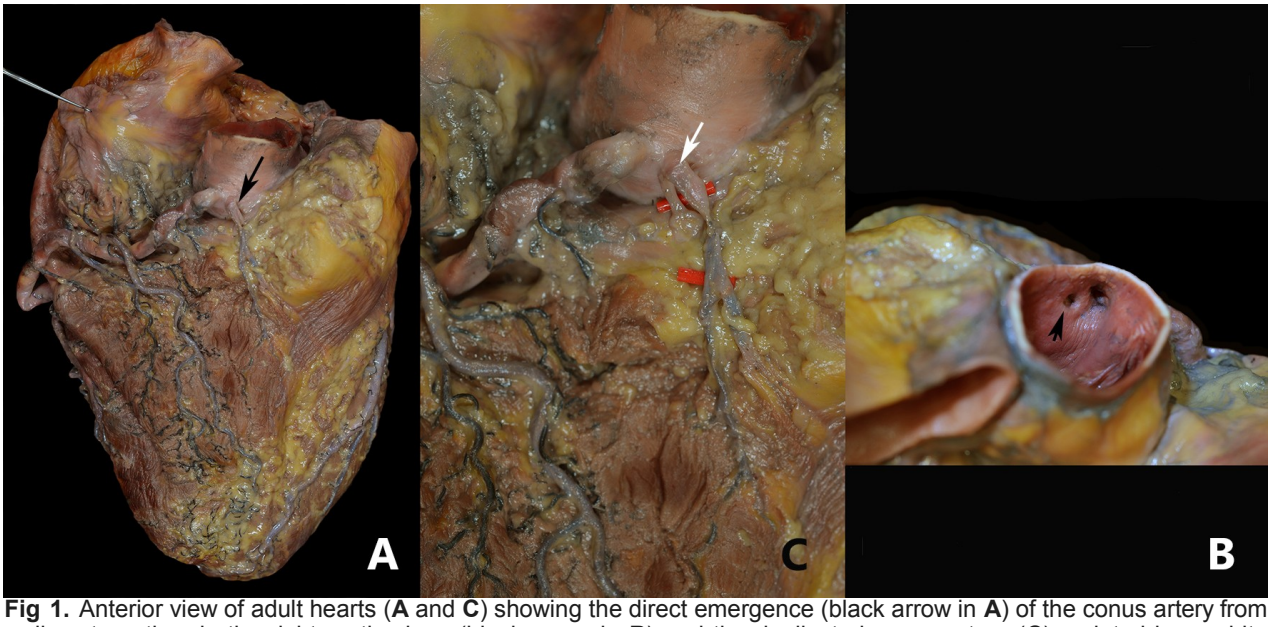

Fig 1. Anterior view of adult hearts (**A** and **C**) showing the direct emergence (black arrow in **A**) of the conus artery from a discrete ostium in the right aortic sinus (black arrow in **B**) and the duplicated conus artery (**C**), pointed by a white arrow.

ent conus arteries was 0 in one conus artery (see Fig. 1C), 3 in one conus artery, and 4 in two conus arteries (see Fig. 1A and C).

DISCUSSION

Based on a Spanish sample, the present study analysed the possible direct emergence of the conus artery from an independent ostium in the right aortic sinus, close to that of the right coronary artery. The results indicate a total incidence of 12.0% for the direct emergence of the conus artery from an independent ostium (three individuals out of 25): in two hearts (8%) a single ostium for the independent conus artery, and in one heart (4%) two ostia for two independent conus arteries.

Usually, there are two coronary arteries, the right and the left, and the conus artery, which contributes to the vascularization of the infundibulum, is a branch off the right coronary artery. However, sometimes the conus branch arises as an independent artery from the right aortic sinus. This has prompted some authors to call it the third coronary artery (Schlesinger et al., 1949; Dhobale et al., 2015). Several authors have also described the presence of supernumerary conus arteries, which arise independently from the right aortic sinus and pass though the subepicardial adipose tissue of the pulmonary conus and the anterior wall of the right ventricle (Schlesinger et al., 1949; Saidi et al., 2002; Dhobale et al., 2015). In our sample, the total incidence found for the independent conus artery (12%) is higher (see table 1) than that found in Germans (7.1%) and Iraqis (8%), and lower than that found in English (15.8%) and Indians (24%), and much lower than that found in Bulgarians (34.8%), Kenyans (35.1%) and Japanese (36.8%). In addition, Olabu et al. (2007) found no sex differences in the prevalence of the independent conus artery in their Kenyan sample. As has been suggested by previous authors (Schlesinger et al., 1949; Levin et al., 1981; Gupta et al., 1987; Stankovic and Jesic, 2004; Olabu et al., 2007; Dhobale et al., 2015), these differences between populations is consistent with the existence of wide population variability for this anatomical variation, which probably has a genetic basis. However, some authors (Miyazaki and Kato, 1988; Edwards et al., 1981) reported a lower incidence of an independent conus artery in individuals younger than two years of age, suggesting that these differences between adults and such very young individuals could be related with age.

The presence of separate ostia (two or multiple orifices) for the right coronary artery and the conus artery has been explained as being a result of the insufficient fusion of these vessels during their growth towards the ascending aorta (Reese et al., 2002; Wada et al., 2003). Until now, however, there has not been any explanation for the differ-

Table 1. Prevalence of independent conus artery in various populations

Author and year	Population	Prevalence
Miyazaki and Kato, 1988	Japanese	36.8%
Olabu et al., 2007	Kenyans	35.1%
Stankovic and Jesic, 2004	Bulgarians	34.8%
Kalpana, 2003	Indians	24%
Turner and Navaratnam, 1996	English	15.8%
Present study	Spaniards	12%
Kurjia et al., 1986	Iraqis	8%
Von Lüdinghausen and Ohmachi, 2001	Germans	7.1%

ences in the prevalence of this anatomical variation between adults and individuals younger than two years of age. Edwards et al. (1981) proposed three potential explanations for these differences. The first proposal was (i) a failure to identify the independent conus artery in foetal and infantile individuals younger than two due to the size of this anatomical structure at this age; the second was (ii) that during growth the diameter of the aorta increases, resulting in moulding of structures, so the initially independent conus artery is moved into the aorta; the third was (iii) postnatal budding of the conus artery from the aorta. However, the latter two potential explanations (ii and iii) are in disagreement with the observations of Reinecke and Hort (1992), who reported no or only insignificant new development of the coronary artery during growth.

The proximal branches of the four independent conus arteries observed in the three individuals in this study were distributed on the anterior wall of the right ventricle. This is in accordance with the observations of previous authors (Stankovic and Jesic, 2004; Ben-Gal et al., 1997; Von Lüdinghausen et al., 2003; Olabu et al., 2007). In fact, the independent conus artery is an important source of collateral blood flow through the circle of Vieussens, which is an anastomotic connection between the right and left coronary arteries (Schlesinger et al., 1949; Edwards et al., 1981; Olabu et al., 2007). In particular, the independent conus artery may make an important contribution to the supply of the conducting system, the anterior wall of the right ventricle, the interventricular septum and the apex of the heart (Olabu et al., 2007). This significant contribution to cardiac vascularization, particularly to the collateral circulation of the apex and septum perfusion, is vital in cases of anterior interventricular artery occlusion. In these cases, the independent conus artery can act as an important element in the perfusion of the apical and septal area protecting the interventricular septum (Olabu et al., 2007). In cases of anterior interventricular artery occlusion, this collateral perfusion from the conus artery is of great clinical importance, because it can obscure the detection of any ischaemic modification in the apex and septum regions by a diagnostic test, resulting in a better report (Hejmadi and Sahn, 2003; Olabu et al., 2007). In addition, this collateral perfusion can also be a therapeutic source, to be used in cases of arterial occlusion, as of the anterior interventricular artery. The possible contribution of this vascular channel should thus be taken into account in interpreting signs, symptoms and the coronary occlusion clinical test. In addition, it is essential for the surgeon to know the origin of the conus artery and its trajectory to avoid damaging it during surgery. Interventions involving manipulation of the right infundibulum present a risk of injury, especially if the independent conus artery is partially hidden by an intramyocardial path. It is also necessary to exercise particular caution during surgical procedures around the anterior wall of the right ventricle and infundibulum if the independent conus artery extends epicardially to irrigate the apex of the heart, since such a long, independent conus artery presents a particular risk in this type of surgery (Olabu et al., 2007). All of this evidences the necessity to characterize in detail the prevalence of the independent conus artery in the different populations and sexes. Currently, although we have information on the prevalence of the independent conus artery in different populations, there is very little information on sex differences in this anatomical variation. When a man or a woman is submitted to heart surgery or has an arterial occlusion, to know the probability of risk in the applied procedures related to the possible presence of an independent conus artery is essential. Therefore, to extend this research taking into account sexes is necessary.

CONCLUSIONS

This study has evaluated the prevalence of the direct emergence of the conus artery from an independent ostium in the right aortic sinus in a present-day Spanish sample. The results indicated a prevalence of 12.0%, which lies between that found in Germans (7.1%), Iraqis (8%) and English (15.8%), and is lower than that found in Indians (24%), Bulgarians (34.8%), Kenyans (35.1%) and Japanese (36.8%). In addition, among these three cases of independent conus arteries, we found a case of double conus arteries arising independently from the right aortic sinus (4%). These results agree with the observations of previous authors, indicating variation between populations, with a possible genetic basis.

The four independent conus arteries observed in three individuals in the present study were distributed on the anterior wall of the right ventricle. The independent conus artery is an important source of collateral blood irrigation. In particular, it may make an important contribution to the supply of the conducting system, the anterior wall of the right ventricle, the interventricular septum and the apex of the heart. This significant collateral contribution to heart vascularization makes the independent conus artery vital in cases of anterior interventricular artery occlusion. In these cases, the independent conus artery can serve as an important element in the perfusion of the apical and septal area. Consequently, the independent conus artery is of great clinical importance. It can hide the detection of any apex and septum ischaemic modification by a diagnostic test, providing better results. Furthermore, we can take advantage of this collateral perfusion by using it as a therapeutic source in cases of arterial occlusion.

For all of this, it is extremely important to in-

crease the research on the prevalence of the independent conus artery to characterise this anatomical variation in the different populations and sexes.

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