ORIGINAL ARTICLE

INCIDENCE AND MORPHOMETRIC ANALYSIS OF PATENT FORAMEN OVALE IN HUMAN CADAVERS

INCIDÊNCIA E MORFOMETRIA DO FORAME OVAL PATENTE EM CADÁVERES HUMANOS

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ABSTRACT

Objective: Considering the influence of the diagnostic method and their accuracy in estimating the patent foramen ovale (PFO) incidence, this study aimed to investigate the incidence and morphometry of PFO in human cadaveric hearts. **Methods:** Ninety human hearts were randomly selected from the cadaveric specimen collection of the Department of Anatomy of the Federal University of Pernambuco. Inclusion criteria comprised human hearts with dissected right and left atria that allowed visualization of the internal structures and an intact interatrial septum (without dissection). Hearts with removed atria exposing the valvular plane or those without dissection were excluded. The study was carried out in three phases: (1) screening and selection of suitable human hearts; (2) investigation of the presence of PFO; and (3) morphometric analysis of PFO. A total of 40 cadaveric human hearts were analyzed for PFO incidence. Morphometric parameters analyzed comprised the interatrial septum, oval fossa, and limb, and the presence or absence of PFO was determined from right and left atrial perspectives. Morphometric parameters of PFO (vertical and horizontal diameters) were obtained using a digital caliper. **Results:** PFO was registered in six out of 40 human cadaveric hearts (incidence of 15%). The maximum potential diameter of the PFO ranged from 1 to 5 mm, with a mean of 3.5 mm. In addition, one heart presented two PFO. **Conclusion:** This study showed a 15% PFO incidence, with a mean of 3.5 mm of maximum potential diameter.

Keywords: Anatomy; Cadaver; Cardiology; Surgery; Foramen Ovale

RESUMO

Objetivo: Investigar a incidência e morfometria do forame oval patente (FOP) em corações humanos cadavéricos, sabendo que o método e a acuidade do exame diagnóstico interferem na estimativa da incidência do FOP. **Métodos:** Noventa corações humanos foram selecionados da coleção de partes de cadáveres do Departamento de Anatomia da Universidade Federal de Pernambuco. Incluídos no estudo estavam corações humanos que apresentavam os átrios direito e esquerdo dissecados para visualização das estruturas internas, bem como o septo interatrial intacto (sem dissecção). Corações cujos átrios foram removidos para visualização do plano valvar ou os átrios, não foram dissecados, foram excluídos. O estudo foi dividido em três etapas, a saber: (1) triagem e seleção de corações humanos; (2) investigação da presença de FOP em corações humanos selecionados; e (3) morfometria do FOP. Após a triagem, 40 corações humanos cadavéricos foram selecionados para estudar a incidência e a morfometria do FOP. Em cada coração humano cadavérico, o septo interatrial, a fossa oval e seu limbo foram analisados, e a presença ou ausência do FOP pelo átrio direito e pelo átrio esquerdo. Para realizar a morfometria, foi utilizado um paquímetro digital e medidos os diâmetros vertical e horizontal do FOP. **Resultados:** Dos 40 corações humanos selecionados, apenas seis apresentavam o FOP, indicando uma incidência de 15%. O FOP variou de 1 a 5 mm no diâmetro potencial máximo (média = 3,5 mm). Além disso, em um dos corações foi observada a existência de dois forames ovais. **Conclusão:** Com base nos resultados, foi observada uma incidência de 15% do FOP, com uma média de 3,5 mm de diâmetro potencial máximo.

Palavras-chave: Anatomia; Cadáver; Cardiologia; Cirurgia; Forame Oval

INTRODUCTION

The foramen ovale is a critical embryological structure for fetal survival. It is formed by the overlapping free edges of the primum and secundum septa, creating a virtual opening that allows blood to pass from the right to the left atrium[1-3]. The foramen closes after birth because it is no longer required.

With the expansion of lungs, pulmonary venous return to the left atrium increases, leading the primum and secundum septa to adhere, and to the closure of the foramen ovale[1]. When closure fails, a patent foramen ovale (PFO) persists, allowing right-to-left interatrial blood flow.

In some cases, primum and secundum septa may fail to adhere, forming a tunnel that allows continuous interatrial shunting (including at rest), which may be classified as high-risk PFO[2].

In 1877, the German pathologist Cohnheim described the presence of a foramen ovale during the autopsy of a young woman who died from a cerebrovascular accident (CVA). He hypothesized that the cause was embolic passage through the foramen, representing the first documentation of paradoxical embolism[3]. Subsequent studies established the association between paradoxical embolism and atrial septal defects[4,5].

PFO occurs in 25% to 30% of the general population and is benign in most cases. However, it has also been linked with cerebral thromboembolic events and migraine with aura, some of which are classified as cryptogenic due to the difficulty in identifying an embolic source[5]. One proposed mechanism of embolism in PFO is thrombus formation within the foramen itself, resulting from blood stasis under low-pressure gradients between atria during certain phases of the cardiac cycle[3,5].

The diagnostic method of choice for confirming PFO is transesophageal echocardiography, which provides high sensitivity and enables visualization of cardiac regions inaccessible via the transthoracic approach. Color Doppler with saline contrast also allows direct visualization and documentation of right-to-left shunting[6]. Another confirmatory method is transcranial doppler[3,7], which detects microbubbles in the cerebral circulation after intravenous injection of saline contrast[3,7]. The optimal therapeutic approach for patients with PFO and cerebrovascular events remains under discussion.

Several case-series studies suggest that percutaneous closure may be more effective than medical therapy for the secondary prevention of recurrent cerebrovascular events in patients with ischemic CVA or transient ischemic attack related to PFO[2].

Several devices have been developed to solve PFO, and high-risk PFO should be identified and assessed on a case-by-case basis. Percutaneous closure of PFO is currently performed in most hemodynamic laboratories worldwide, and has been demonstrated to be safe, effective, and reproducible, with excellent outcomes largely attributable to improved prosthetic devices technology[1,3].

Considering the influence of the diagnostic method and their accuracy in estimating PFO incidence, this study aimed to investigate the incidence and morphometry of PFO in human cadaveric hearts.

METHODS

Ninety human hearts were randomly selected from the cadaveric specimen collection of the Department of Anatomy of the Federal University of Pernambuco. Hearts with dissected right and left atria that allowed visualization of the internal structures, and preserved interatrial septum (without dissection) were included. Specimens with removed atria exposing the valvular plane, or those without dissection, were excluded. The study was carried out in three phases: (1) screening and selection of suitable human hearts; (2) investigation of the presence of PFO; and (3) morphometric analysis of the PFO. Forty hearts from human cadavers were analyzed for PFO incidence and subjected to morphometric evaluation. The interatrial septum, fossa ovalis (and its limbus), and the presence of PFO from the right and left atrial perspectives were examined. Morphometric measurements were obtained using a digital caliper, with vertical and horizontal diameters of the PFO recorded.

RESULTS

PFO was identified in six out of 40 human cadaveric hearts, corresponding to an incidence of 15%. The maximum potential diameter ranged from 1 to 5 mm, with a mean of 3.5 mm. Additionally, one heart presented two PFO.

Table 1. Morphometry of the patent foramen ovale.

Hearts					
1	2	3	4	5	6
0.3	0.5	0.3	0.5	0.1	0.3 and 0.4

Morphometric measurements in mm

Figure 1. Hearts with patent foramen ovale.

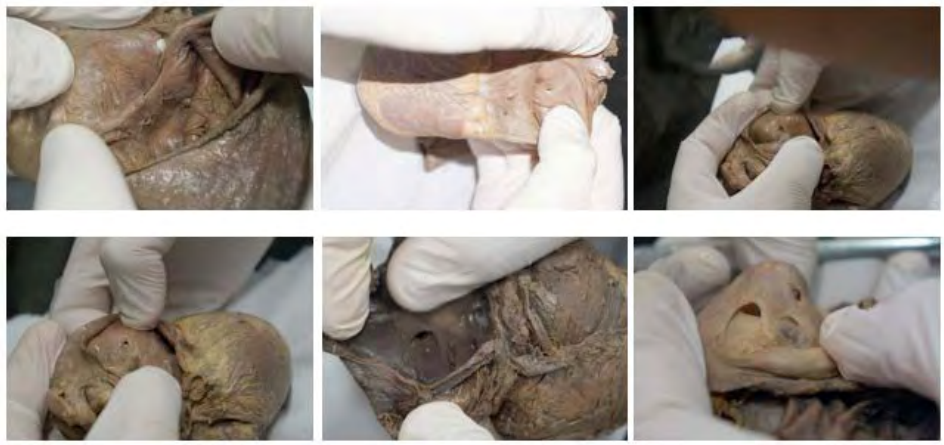

Figure 2. Patents foramen ovale.

DISCUSSION

The PFO consists of a functional, but not anatomical, closure. In this case, the interatrial septum is sustained by pressure-dependent apposition rather than fibrous adhesion between the primum and secundum septa[1]. Morphological variations of PFO include differences in septum primum thickness and shape, atrial septal flexibility, tunnel length, a multiperforated membranes with spontaneous left-to-right shunting, atrial septal aneurysms, and the presence of various anatomical structures within both atria, such as the Chiari network, Eustachian valve, and incompletely subdivided left atrium. A prominent Eustachian valve, when present, is thought to contribute to paradoxical embolism in PFO by facilitating right-to-left atrial flow and allowing thrombi to pass from venous to arterial circulation[3]. The presence of an atrial septal aneurysm is strongly associated with an increased incidence of CVA in patients with PFO. Paradoxical embolism refers to the passage of thrombi or other embolic particles from venous to arterial circulation through a right-to-left shunt. Our findings indicated a mean diameter of PFO of 3.5 mm, a dimension sufficient to allow emboli to occlude cerebral arterial branches, such as the middle cerebral artery and large cortical branches. Randomized studies have demonstrated a stronger causal association between CVA, increased PFO diameter, and atrial septal hypermobility[8].

The incidence of PFO in the general population is 25%, with a mean diameter of 4.9 mm[2]. However, the exact incidence varies depending on the diagnostic method and its respective accuracy[8], and the reference standard for PFO diagnosis remains controversial. PFO may account for up to 50% of cryptogenic CVA. Patients younger than 55 years show an increased relative association between PFO and cryptogenic stroke compared with older patients[8]. Nonetheless, this association has also been observed in older patients, whose PFO diameter tends to decrease with age. No consistent data currently correlate PFO prevalence with race or sex. The absence of epidemiological data on the individuals is a limitation of this study, as specimens were selected from the cadaveric collection of the Federal University of Pernambuco. Cryptogenic CVA is an exclusion diagnosis; however, topographic findings, such as cerebral infarcts in multiple vascular territories in young patients, reinforce the likelihood of an embolic cause. Therefore, documentation of a pos-

sible PFO should be considered in the differential diagnosis, given its high prevalence in the general adult population.

CONCLUSION

The incidence of PFO was 15% with an average of 3.5 mm of maximum potential diameter.

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