

## Study of Oval Foramen Anatomy in the Heart of Iranian One Humped Camel (*Camelus Dromedarius*) Fetuses

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### Abstract

This study was carried out to investigate the morphology of the oval foramen in the fetal stage of dromedary camel fetuses by routine dissection. The hearts were obtained from 21 fetuses that were collected from Yazd slaughter house of Iran. The Crown Vertebral Rump Length (CVRL) of fetuses were from 10.1 to 85 cm and estimated gestational age calculated from 81.9 to 270 days old. The results showed that anatomical structures of oval foramen in fetal camels concluded of septum primum (valve of oval foramen), foramen secundum, septum secundum and a large passageway called oval foramen (foramen ovale). The septum primum was a flat, long thin, white color and unfenestrated membrane (fold) in all fetuses. The thin fold was in the lower portion of foramen secundum and constituted about %75 to %100 of the lumen of the oval foramen in the small to large fetuses, respectively. So, it constituted a large proportion of lumen and was large enough to cover the opening of oval foramen, specially in large fetuses. The septum secundum was a thick, short and crescent-shaped fold above of ovale foramen. The oval foramen showed like an oval passage way between free border and arms of septum secundum. It was concluded that despite of size of heart and oval foramen, all structural arrangements of heart oval foramen in fetus of camel are similar to reports about other mammals and human.

**Key words:** Oval Foramen, Heart, Fetus, Dromedary Camel

### Introduction

One humped camel (*Camelus dromedarius*) lives in eastern and south western area of Iran and also in Africa and Arabian countries deserts. The camel is an important source of meat, milk and hides in several countries and there is growing interest in its meat and milk products (Smut et al. 1987). There are many reports about heart anatomy of adult dromedary camels (Smut et al. 1987; Ewshy et al. 1981). Sabah and Osman (2013) reported some information about great vessels of circulatory system in fetal period of camels. However, there are very rare studies about

development of heart and its specialisations like foramen ovale. So, this study was performed to establish the details of heart oval foramen structure in fetuses of Iranian one humped camel (*Camelus dromedaries*). The mammal's cardiovascular system is complex and consists of a four chambered heart (pump) with extensive pathways of blood vessels (arteries and veins) and a separate lymphatic vascular system to distribute and collect blood from every part of the human body. The heart is the first organ to form during embryogenesis (Zaffran and Frasch, 2002).

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During development of primary heart, at the end of the fourth week, a sickle crescent-shaped crest grows from the dorsal region of the common atrium into the lumen. This crest is the first portion of the septum primum (primary wall). These two limbs of septum directed toward the endocardial cushions in the atrioventricular canal. The distance between the lower rim of the septum primum and the endocardial cushions is the ostium primum (primary foramen). Then, due to grow extensions of the superior and inferior endocardial cushions along the edge of the septum primum, the ostium primum closes. However, before complete closure, due to cell death processes several perforations produces in the upper portion of the septum primum. These perforations Coalesce and form the ostium secundum (secondary foramen), that allows free blood flow from the right to the left primitive atrium (Sadler, 2015). In the horse, this event occurs at a crown-rump length of 11.5–12 mm, i.e., around Day 30-32 of gestation (Hyttel et al. 2010). With further development, the lumen of the right atrium expands and a new sickle-shaped fold appears on the right side of septum primum. This new fold, the septum secundum (secondary wall), However does not form a complete wall in the common atrial cavity. Its cranial crest direct down to the septum in the atrioventricular canal. By further development, the free curve edge of the septum secundum begins to overlap the ostium secundum. The opening left by the septum secundum is called the oval foramen (foramen ovale). When the upper part of the septum primum gradually disappears, the remaining part becomes the valve of the oval foramen. Also, the passage between the two atrial cavities that consists of an obliquely elongated foramen, transmits blood from the right atrium to the left atrium (right-left shunt). After birth, when respiration and circulation of lung begins and pressure in the left atrium increases, the valve of the oval foramen (septum primum) is pressed against the

septum secundum, closing the oval foramen and separating the right and left atria. When closure does not occur properly, neonatal mortality is high (MacGeady et al. 2017; Carlson, 2014; Schoenwolf, 2015).

### **Materials and Methods**

In present study, the hearts from 21 dromedary fetuses (10 females and 11 males) were studied. The fetuses collected after slaughter of pregnant camels at the slaughter house of Yazd city in Iran (Fig. 1, 2, 3 and 4). After recognition the sex of fetuses, the age estimation of them was calculated through Crown Vertebral Rump Length (CVRL) measurements and by use of formula for one humped camel fetus (Hussein et al., 1991). The CVRL of fetuses were from 10.1 to 85 cm, and gestational age estimated from 81.9 to 270 days old, respectively. The fetuses which showed no obvious cardiovascular abnormalities, not only injected via umbilical vein by 5 percent buffered formalin solution, but also immersed in 5 percent formalin solution, too. (Nanbo, 1990; Tomsett, 1970; Hildebrand, 1968). After one week, a large window was cut in the right wall of the thorax to expose pericardium and heart. Then, the right lung and pericardium cut and the wall of right atrium removed (fig.5). Finally internal structures of right atrium and anatomy and topography of oval foramen studied by routine dissection and photographed.



**Figure 1. Some of camel fetuses used in present study**



Figure 2. The smallest camel fetus (CVRL= 10.1 cm, male)



Figure 3. Camel fetus (CVRL= 25.2 cm, male)



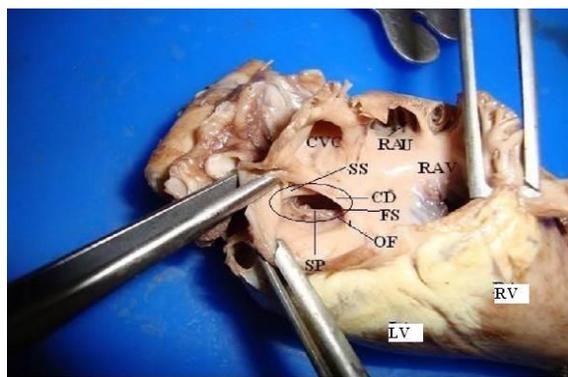
Figure 4. Camel fetus (CVRL= 40 cm, male).



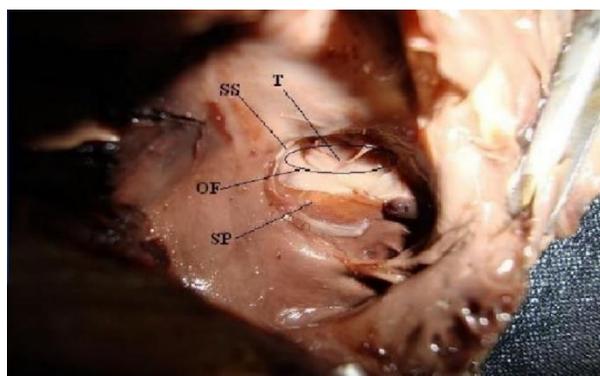
Figure 5. The hearts of some fetal Dromedary Camels (CVRL= 10.1 – 85 cm.).

## Results

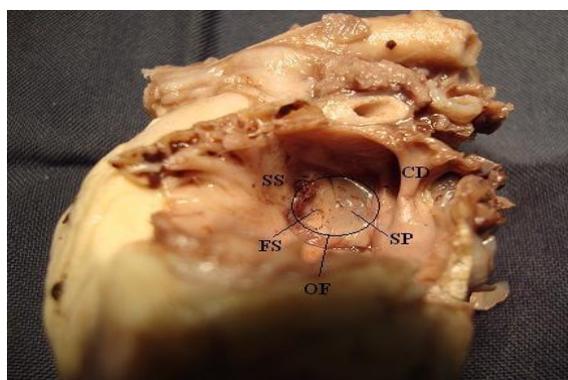
At present study, the gross anatomy of passageway between right and left atrium (foramen ovale) in 21 heart camel fetuses was studied using the routine dissection. On the basis of our observations, this passageway consisted of septum primum (valve of oval foramen), foramen secundum, septum secundum and oval foramen. The septum primum was a thin, flat, nonfenestrated and white membrane on the left side of passage way (Fig. 6, 7 and 8). Except for heart of biggest fetus (CVRL= 85 cm) a large thread of tissue arose from its free edge, and a large hole were found in the valve of oval foramen (Fig. 7). Septum primum started from down of passage way and floor of interatrial septum (endocardial cushions), and continued to up of interatrial septum and on the left side of foramen secundum. The septum primum showed short size and smooth in small fetal hearts but long and folded in large fetuses. This thin fold was in the lower portion of foramen secundum and constituted about %75 to %100 of lumen of oval foramen in the small to large fetuses, respectively. So, it constituted a large proportion of lumen and was large enough to cover the opening of oval foramina, specially in large fetuses (Fig. 7, 8 and 9). The septum secundum was a thick, short and crescent-shaped fold at roof of right atrium and above of oval foramen and also on the right side of passageway. The oval foramen showed like an oval passageway and its position was between free border and arms of septum secundum. From anatomical stand points, there were no differences between oval foramen arrangements in the males and female's camel fetuses.



**Figure 6.** The oval foramen and right atrial structures around it, after removing right atrial wall (CVRL= 47.2 cm. male). FS= foramen secundum, CD= crista dividance, SS= septum secundum, SP = septum primum, folded (oval foramen valve), OF= oval foramen, CVC= cranial vena cava, RAV= right atrio-ventricular foramen, RA= right ventricle, LA= left ventricle.



**Figure 7.** The oval foramen of the largest fetus after removing of right atrial wall (CVRL=85 cm, male). SP= septum primum, OF= oval foramen, SS= septum secundum, T= thread of tissue branched from septum primum.



**Figure 8.** The oval foramen of male fetal heart after removing atrial septum (CVRL= 58.4 cm.). SP= septum primum, FS= foramen secundum, SS= septum secundum, OF= oval foramen, CD=crista dividance.

## Discussion

One the basis of embryology literatures, the fetal circulation is different from that of the adults, because lungs are not functional and gas exchange occurs in the placenta. So, in fetal circulation there are a number of special structures which transmute oxygenated blood of the placenta to the fetal tissues without passing through the lungs. One of these structures is the oval foramen which directs the blood of caudal vena cava to the left atrium and so, blood to be shunted from the right atrium to the left atrium of the fetal heart. After parturation, oval foramen closes during the first three months. Following the lungs become functional at birth, the pulmonary pressure decreases and the left atrial pressure increases more than the right atrium. So, increasing of pressure in the left atrium, forces the valve of oval foramen (septum primum) against the septum secundum, functionally closing the oval foramen. Soonly the two septums eventually fuse, leaving a remnant of the oval foramen, the oval fossa (Sadler, 2015, Sabah and Osman, 2013, Dyce, 2010, Macdonald et al. 1988). The objective of this study was investigation of anatomical structures of oval foramen in the dromedary camel fetuses. There are many reports about anatomy of oval foramen in human and animals. Of them, the gross anatomy of the oval foramen is described for human (Yen Ho et al. 2003; Mandartim, 1993) and a number of animal species including the horse (Macdonald et al., 2010; Machida et al. 1988), the pinnipedia (Macdonald et al. 1995), the suina (Macdonald et al. 1988), in the babirusa (*Babyrousa babyrussa*), (Macdonald et al. 1994), cat, dog, bears and hyaens (Macdonald and johonstone, 1995), rat (Mommba et al. 1992) mouse (Cole-Jeffrey, 2012, Webb et al. 1996; Kiserud and Acharya, 2004), and the cetaceans (Macdonald et al. 2007). However, through the extensive study of literature, no data were found regarding the detailed structures of the oval foramen in the dromedary camel fetuses. Although, Sabah and Osman

(2013) reported foetal circulation of the dromedary camel, but they did not consider the structures of fetal hearts and oval foramen in dromedary camel. On the basis of our results, during fetal period, there is a passageway on the interatrial septum and its structures were consisted of septum primum (valve of oval foramen), foramen secundum, septum secundum and oval foramen. Our findings were in agreement with the reports of other authors about structure details of oval foramen in other animals (MacGeady et al. 2017; Hyttel et al. 2010) and human kind (Schoenwolf, 2015, Sadler, 2015; Carlson, 2014).

Unless, in the heart of biggest fetus (CVRL= 85 cm), a large thread of tissue arose from free border of septum primum, and a large hole were detected in the valve of oval foramen. This finding is supported with observations of MacDonald et al. (1998) in the oval foramen of some breeds of pigs, and also in heart of fetal horse, too (MacDonald et al, 2010). They suggested

that after postnatal days, this thread play a possible role in mechanism of closure of the oval foramen. On the other hand, MacDonald et al. (2007) postulated that only in the hearts of fetal horses the oval foramen, when viewed from the bottom of caudal vena cava shows imaging of the inlet to a short tunnel. This inlet was formed in part (caudally) by atrial wall plus the caudal vena cava and in part (cranially) by the curved crista dividens. We did not observe such tunnel like structure between caudal vena cava and oval foramen in the heart of camel fetuses. The results of this research showed that despite of size of hearts and oval foramina of them, all structural details of oval foramen in fetus of dromedary camel are similar to observations made previously in other mammals and human. However, due to absence of neonate specimens, it could not to determine the closure time of oval foramen and also the structural changes that occur during the perinatal period.

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### Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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## مطالعه آناتومی سوراخ بیضی قلب جنین شتر یک کوهانه ایرانی

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## چکیده

در این مطالعه مورفولوژی سوراخ بیضی قلب جنین شتر یک کوهانه ایرانی بررسی شد. بدین منظور ۲۱ جنین شتر از کشتارگاه‌های منطقه‌ی یزد جمع‌آوری گردید. طول CVRL جنین‌ها ۱۰/۱ الی ۸۵ سانتی‌متر و سن تخمینی آن‌ها ۸۱/۹ الی ۲۷۰ روز محاسبه گردید. نتایج نشان داد که ساختار آناتومیکی سوراخ بیضی قلب جنین شتر شامل دیواره‌ی اولیه، سوراخ ثانویه، دیواره‌ی ثانویه و یک مجرای بزرگ به نام سوراخ بیضی می‌باشد. در تمام جنین‌ها دیواره‌ی اولیه به صورت یک چین نازک پهن، طویل و بدون منفذ مشاهده شد ولی در قلب بزرگترین جنین یک رشته باریک از لبه‌ی آزاد دیواره‌ی اولیه جدا می‌گردید و یک سوراخ بزرگی بین این رشته و دیواره‌ی اولیه ایجاد می‌شد. دیواره‌ی اولیه در سمت پایینی سوراخ ثانویه قرار داشت و حدود ۷۵ درصد تا ۹۰ درصد از دهانه‌ی سوراخ بیضی را در جنین‌های کوچک تا بزرگ تشکیل می‌داد. بنابراین نسبت بزرگی از دهانه‌ی حفره را در بر می‌گرفت و قادر به پوشاندن سوراخ ثانویه بود. دیواره‌ی ثانویه به صورت یک چین کوتاه، ضخیم و هلالی شکل بود که در ناحیه‌ی بالایی سوراخ بیضی بزرگ قرار می‌گرفت. در نهایت نتیجه گرفته شد که صرف نظر از اندازه‌ی قلب و سوراخ بیضی، تمام ساختارهای تشکیل دهنده‌ی سوراخ بیضی در شتر مشابه دیگر پستانداران و انسان است.

کلمات کلیدی: سوراخ بیضی، قلب، جنین، شتر یک کوهانه

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