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RESEARCH ARTICLE

EARLY EMBRYONIC DEVELOPMENT OF THE NASOLACRIMAL DUCT OF THE COMMON QUAIL *COTURNIX COTURNIX* (PHASIANIDAE, GALLIFORMES)

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Abstract

The development of the nasolacrimal duct was studied in the common quail (*Coturnix coturnix*) at 6,7,8,9 and 10 days of incubation. The nasolacrimal duct started its development, as one or two solids ectodermal cords of cells (the nasolacrimal duct primordium) from superior conjunctival fornix of the lower eye lid. After that, the nasolacrimal duct primordium proceeded in its ontogeny forming bifurcated structure (anterior, posterior rami). Cavities appeared within duct and two rami as development proceeded. The nasolacrimal duct approached the olfactory organ gradually, and then it fused with its wall.

Introduction

The orbital and nasal regions of most tetrapod vertebrates are connected by the nasolacrimal duct (Hillenius and Rehorek, 2005). Also, its function remains poorly understood. The nasolacrimal duct carries “surplus fluids” away from the medial corner of the eye to the nasal cavity (Hillenius et al., 2001). The nasolacrimal duct passes not only the eye secretion but also, the secretion of the olfactory organ into the nasal cavity. Most of the nasal gland secretion goes into the mouth or the pharynx (Bang, 1960).

In anurans, the nasolacrimal duct terminates distally in the cavum medium of the nasal cavity (Michael, 1961). Unlike the condition in urodeles, caecilians and lepidosaur reptiles, there is no direct association between the nasolacrimal duct and the vomeronasal organ in frogs. However, it was postulated that the nasolacrimal fluid may reach the vomeronasal organ of frogs. On the other hand, Hillenius et al. (2001) stated that these fluids can nevertheless reach the vomeronasal organ epithelium in frogs. In lepidosaur, caecilians, urodeles and amphibians, the nasolacrimal duct opens rostrally in or near the entrance of the vomeronasal organ which is an accessory olfactory organ. It is lacking in turtles; however, in lizards and most snakes it empties into the vomeronasal organ (Rehorek et al., 2000 a&b). It appears that fluids from the Harderian gland (and perhaps even the lacrimal gland) may play some roles in the vomeronasal sense (Rehorek et al., 2000 c). In birds the nasolacrimal duct joins the nasal cavity of the middle concha and they open together in the choana. The two choanae open in the oral cavity via the median palatal fissure. Rehorek et al. (2005) examined the lacrimal apparatus of the crocodilian *Alligator mississippiensis* anatomically, histologically and histochemically and studied the embryogenesis of this system. They found that the nasolacrimal duct begins development as a non- patent duct that connects the nasal cavity to the rostral palpebral region.

Little is known about the organogenesis of the nasolacrimal duct in animals. In humans, it originates as an ectodermal thickening from the nasooptic furrow between the lateral nasal and the maxillary processes. In Rabbit (*Oryctolagus cuniculus*) little is known about the development of the nasolacrimal duct. Where, the duct first appears as an incomplete primordium in the subcutaneous region of the primordial eyelid and subsequently elongates to reach the naris (Rehorek et al., 2010). The ontogeny of the nasolacrimal ducts and canals are investigated in strepsirrhine and haplorhine primates (Rossie and Smith, 2007). In humans, many authors agreed that the gland arises from the superior conjunctival fornix of the human embryo. However, Tripathi and tripathi (1990) and De la Cuadra-Blanco et al. (2003) affirmed that the gland arose from the neural crest. Many authors studied other mammals and confirmed the ectodermal origin of the lacrimal gland (Lovicu et al., 1999). In avian species Johnston et al. (1979) stated that the mesenchymal surrounding the glandular primordium derives from the neural crest and not from the gland itself.

There is comparatively little published literature that details the development of the nasolacrimal duct. The available descriptions indicate that there are marked differences in nasolacrimal duct development among the few amniotes studied. Nevertheless, despite its varied development origins. It develops relatively early in fetal growth.

MATERIAL AND METHODS

The species chosen for this study is the common quail, *Coturnix coturnix Linn*. In Egypt, the quail inhabits the Nile Valley and Delta as well as El-Fayoum governorate (100 km, south of Cairo). It feeds on vegetations and small invertebrates. The nests are built on hollows in the ground among vegetation.

The fertilized eggs of *Coturnix coturnix* were provided from the Quail Unit at the Faculty of Agriculture, University of Cairo. The embryos were daily extracted from the incubated eggs. Extracted embryos were classified into different developmental stages corresponding to days of incubation. The total body length (T.B.L.) and the head length (H.L.) of each stage of development were measured. Days of incubation, developmental stages and lengths are listed in table 1.

Table 1

Days **Stages**	6^{th} **1**	7^{th} **2**	8^{th} **3**	9^{th} **4**	10^{th} **5**
T.B.L.(cm)	3.6	4.1	4.5	5.3	5.6
H.L.(cm)	1.9	2.0	2.4	3.1	3.0

As soon as embryos were extracted from the eggs, they were quickly fixed in aqueous Bouin's solution for 24 hours. Large embryos were treated with EDTA solution for decalcification of their bones. After that, the embryos were followed by washing it with 70% ethyl alcohol several times.

The embryos were treated with ascending series of ethyl alcohol and then cleared with xylene. The specimens were transferred into a melted paraffin wax. After changing the paraffin wax twice (one hour for each), specimens were transferred outside the oven and oriented in paraffin wax for blocking. This was followed by sectioning of the embryos transversely at 8 micrometer thickness.

The sections of each specimen were mounted serially on microscopic slides and prepared for staining. The mounted sections were stained with haematoxylin and counter stained by eosin.

Several sections were chosen for photography to demonstrate the early developmental stages of the nasolacrimal duct of the common quail.

RESULTS

Stage 1 (the sixth day of incubation: T.B.L: 3.6 cm, H.L: 1.9 cm):

The nasolacrimal duct started its origin from the ectoderm of the superior conjunctival fornix of the eye (E), an ectodermal short cord of cells which sink into the mesoderm. It represented the nasolacrimal duct primordium (Fig.1, NLD.PR). In other embryos at the same day of incubation, the primordial nasolacrimal duct appeared as two masses of cells (Fig. 2). They had the same ectodermal origin from the conjunctival surface of the lower eyelid (L.EL). Both of them united with each other distally and approached the olfactory organ (Fig.3).

Stage 2 (the seventh day of incubation: T.B.L: 4.1cm, H.L: 2.0 cm):

The primordial nasolacrimal duct appeared as two masses of cells. It became bifurcated into two rami; anterior, posterior (AR, PR). These rami were directed internally and ventrally towards the olfactory organ, but it was not attached to it (Fig.4).

Stage 3 (the eighth day of incubation: T.B.L: 4.8 cm, H.L: 2.4 cm):

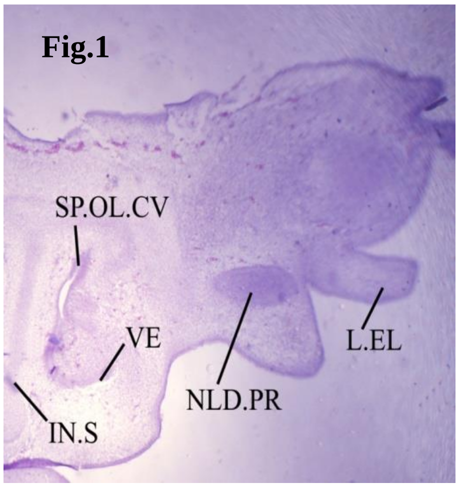
The solid anterior (AR), posterior rami (PR) of the primordial nasolacrimal duct increased in their growth. The primordial nasolacrimal duct approached the olfactory organ, fused with its wall and project into its cavity (Figs. 5&6.). The duct opened into the internal naris (IN.NR). In turn, the two choanae opened together medially in the oral cavity (OR.CV) at the region of the median palatal fissure (Figs 5&6.).

Stage 4 (the ninth day of incubation: T.B.L: 5.3 cm, H.L: 3.1 cm):

In this stage (Fig.7), the two rami increased in its development than previous stages. On the other side, the solid masses of cells begin to develop a lumen distally. It was the primordium lacrimal passage or cavity (Figs. 7&8, NLD.C) of the developing nasolacrimal duct (NLD).

Stage 5 (the tenth day of incubation: T.B.L: 5.6 cm, H.L: 3.0 cm):

A remarkable change taked place in the developing nasolacrimal duct. The lacrimal cavity primordium (Fig.9, NLD.C) proceeded in their development towards the two rami of the nasolacrimal duct. Also, the anterior ramus (AR) became enlarged and a cavity begin to appear on it (Fig.10). While, the posterior ramus (PR) became more elongated than previous stages. Still, the anterior ramus was larger than the posterior one.



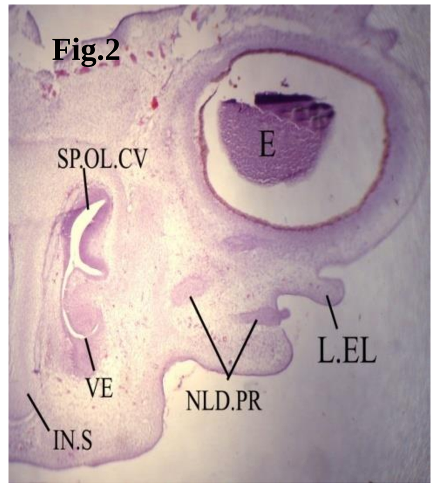
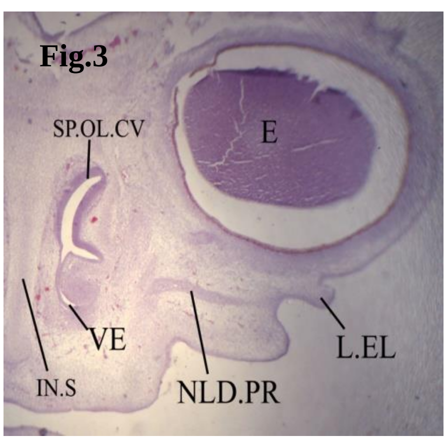


Fig.(1): A phtomicrograph of a transverse section through the head region of the sixth days of incubation common quail, showing the nasolacrimal duct primordium originates from the conjunctival surface of the lower eyelid. Also, different parts of olfactory cavity appear (superior olfactory cavity proper; vestibule).H & E., x 80.

Fig.(2): A phtomicrograph of a transverse section through the head region of the sixth days of incubation common quail, showing the primordium of nasolacrimal duct appears as two masses of cells. Also, vestibule appears. H & E., x 80.



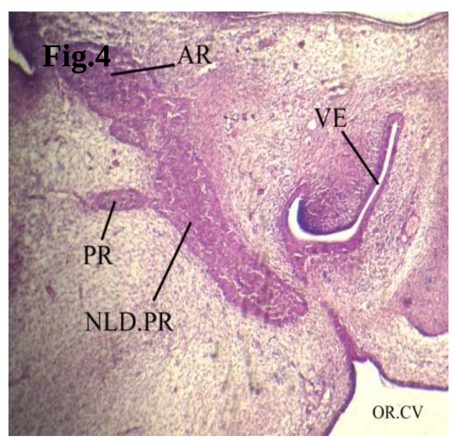
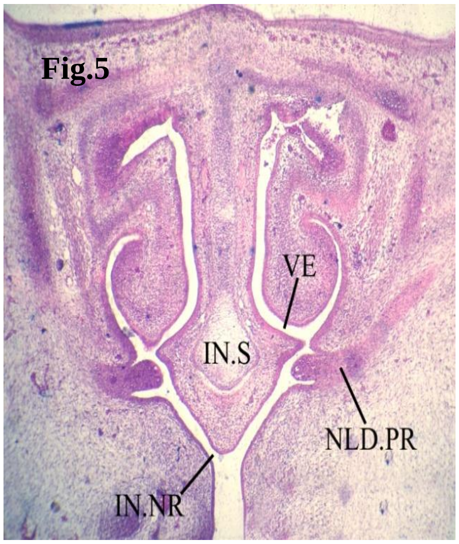


Fig. (3): A phtomicrograph of a transverse section through the head region of the sixth days of incubation common quail, showing that the nasolacrimal duct primordium approaches the olfactory organ (vestibule). H & E., x 80.

Fig. (4): A phtomicrograph of a transverse section through the head region of the seventh days of incubation common quail, showing that the two rami of nasolacrimal duct primordium are directed towards the olfactory organ (vestibule), but it is not atteached to it. H & E., x 112.



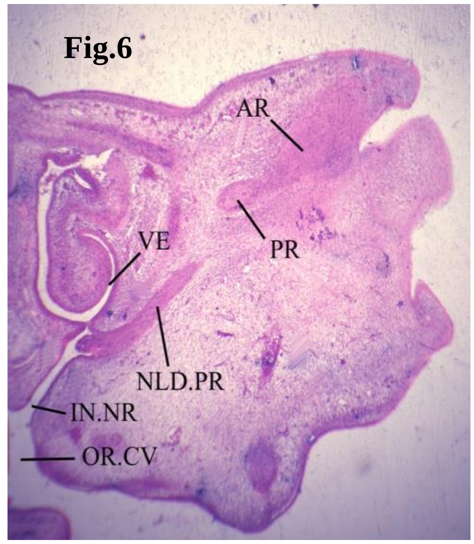
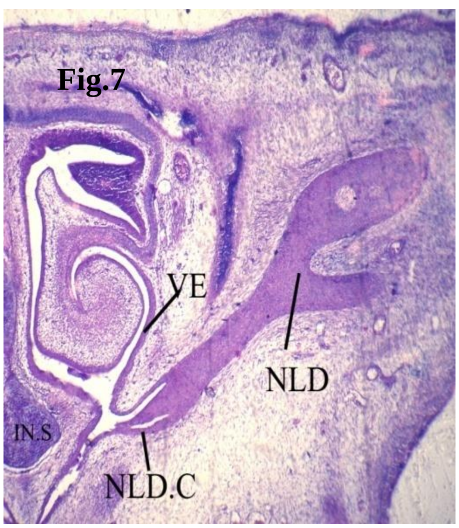


Fig.(5): A phtomicrograph of a transverse section through the head region of the eighth days of incubation common quail, showing that nasolacrimal duct primordium approach with olfactory cavity (vestibule) and fused with its wall. H & E., x 160.

Fig.(6): A phtomicrograph of a transverse section through the head region of the eighth days of incubation common quail, showing the two rami of nasolacrimal duct primordium approach with olfactory cavity (vestibule) and fused with its wall. H & E., x 80.



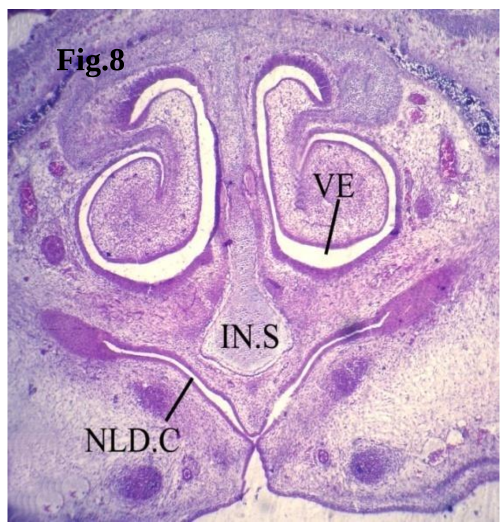


Fig. (7): A phtomicrograph of a transverse section through the head region of the ninth days of incubation common quail, showing the two rami of nasolacrimal duct and lacrimal cavity primordium. H & E., x 80.

Fig. (8): A phtomicrograph of a transverse section through the head region of the ninth days of incubation common quail, showing first appearance of a cavity within nasolacrimal duct forming the lacrimal cavity primordium. H & E., x 80.

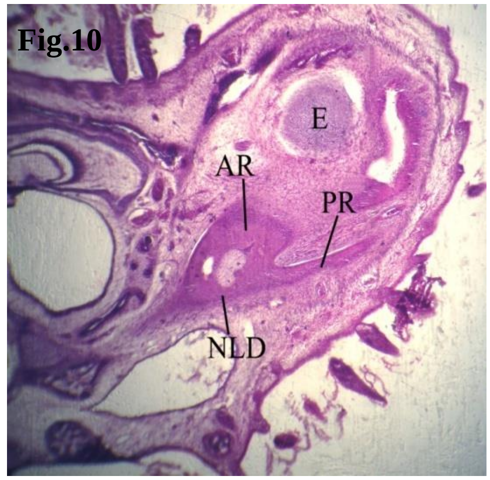


Fig. (9): A phtomicrograph of a transverse section through the head region of the tenth days of incubation common quail, showing increase in growth of the lacrimal cavity primordium. H & E., x 160.

Fig. (10): A phtomicrograph of a transverse section through the head region of the tenth days of incubation common quail, showing appearance of a cavity within two rami of nasolacrimal duct. H &E., x 80.

LIST OF ABBREVIATIONS
AR: Anterior ramus.
E: Eye.
IN.NR: Internal naris.
IN.S: Internasal septum.
L.EL: Lower eye lid.
NLD: Nasolacrimal duct.
NLD.C: Lacrimal cavity primordium.
NLD.PR: Nasolacrimal duct primordium.
OR.CV: Oral cavity.
PR: Posterior ramus.
SP.OL.CV: Superior olfactory cavity.
VE: Vestibule.
VE.CO: Vestibular concha.

DISCUSSION

In terrestrial vertebrates, epidermal orbital gland (the nasolacrimal gland) was developed. Its usual function was to secrete fluids for moistening and cleaning the cornea. In mammals, the nasolacrimal gland was characteristic. While in amphibians, the lacrimal gland was often poorly developed or absent.

Inception points for the nasolacrimal duct in amniotes, in rabbit (Rehorek et al., 2011) the duct originated subcutaneous as in snakes (Rehorek, 1998) and alligators (Rehorek et al., 2008). The present result was acceptance with them. While, in mice (Tamarin and Boyde, 1977) and human (Sadler, 2000) this duct originated from nasolacrimal groove. The nasolacrimal duct had different timing in its appearance; in common quail (sixth day of incubation) - in rabbit (Day 19) – in mice (Day 11) – in human (Week five) – in snakes (Stage 28) - in alligators (Before Stage 16). Also, the duct was different in its mode of growth within amniotes; in common quail, it originated in the lower eyelid and grew towards the olfactory chamber. In rabbit (Burling et al. 1991), it originated in the lower eyelid and grew towards the nose. It opened partway in the lateral aspect of the narial wall. In mice and human, a complete nasolacrimal groove connected the nasal and orbital regions at a very early stage. It Sank into the underlying dermis and canalizes. In snakes, it originated from the lateral side of the duct for the VNO and grew towards the orbit. In alligators, it originated in the lower eyelid and grew grew towards the nose. It opened partway in the nasal cavity proper.

As regarded, the development of the nasolacrimal duct in the common quail, it appeared at sixth days of incubation, while in the chick embryo (Ibrahim, 2008), and it appeared at 7 days-embryos as a solid cord of cells or two masses of cells. They had the same ectodermal origin from the conjunctival surface of the lower eyelid. Also, (Ibrahim, 2008) stated that, the nasolacrimal duct was probably suggested being originated from mesoderm as a result of active cell proliferation or migration. Epithelial - mesenchymal interaction may be essential in the development of the nasolacrimal duct as the case that presents in the development of the human lacrimal gland (Denny et al., 1997 and Kammandel et al., 1999).

The present results were in agree with the histological studies of Baccari et al. (1990) and Ibrahim (2008) on the lacrimal glands of the lizards. The authors mentioned that, the nasolacrimal duct originated from the conjunctival epithelium. In humans, the nasolacrimal duct resulted from a thickening of the ectoderm in the nasooptic furrow between the lateral nasal and the maxillary processes. This thickening formed a solid cord of cells which sank into the mesoderm. Then, the central cells of the cord broke down and a lumen of the nasolacrimal duct was established. In addition, Rehorek et al. (2005) studied the embryogenesis of it in the crocodilian *Alligator mississipiensis* and found that the nasolacrimal duct appeared as a non patent duct that connected the nasal cavity to the rostral palpebral region. Then it opened into the nasal cavity posteroventral to the inferior concha. Later on, the entire nasolacrimal duct appeared to be patent, including the two lacrimal puncta in the lower eyelid.

The present result was accepted with Ibrahim (2008) that, the primordial nasolacrimal duct became bifurcated into two rami. Only difference in timing of appearance, at seventh day of incubation in common quail and at 10 days-embryo of chick.

The nasolacrimal duct was opened only unilaterally in the direction of the nasal passage. The same result was found in Ibrahim (2008).

It was well known that the nasolacrimal duct was a duct which passed not only the eye secretion but also the secretion of the olfactory organ to the oral cavity. Bang (1960) stated that in birds, some of the mucous secretion of the nasal gland had been directed into the nasal vestibule through most of it went into the mouth or the pharynx. He added that the middle concha of the olfactory organ was covered with mucus-producing and ciliated cells. Also, many authors found intraepithelial mucus-secreting glands in the posterior concha of the chick olfactory organ (Street, 1937; EL-Hawary, 1979 and Micheal et al., 1997). In addition, there were paired lateral and medial nasal glands which opened into the septal wall of the vestibular concha. Bang and Bang (1968) indicated that the secretion of the eye was discharged via the lacrimal duct into the mouth to be swallowed or expectorated. Also, the lateral nasal glands secertions discharged into the nasal vestibule, to be inhaled or to crystallize at the rim of the nares.

The nasolacrimal duct was lacking in turtles; however, in lizards and most snakes it emptied into the vomeronasal organ (Hillenius et al., 2001).In humans, tears drained through the lacrimal puncta, via lacrimal canaliculi into the lacrimal sac. Then they passed via the nasolacrimal duct to the lateral side of the inferior meatus of the nose. The lacrimal fluid had thus accessory function in moistening the nasal mucous and forming an addition to the salivary fluid on reaching mouth via the nose.

In conclusion, the results of this study showed that the development of the nasolacrimal duct in common quail related to their adaption to its environmental condition. Where, not all birds had nasolacrimal duct.

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