Progress in Retinal and Eye Research xxx (2017) 1–26

Contents lists available at ScienceDirect

Progress in Retinal and Eye Research

journal homepage: www.elsevier.com/locate/prer

The chick eye in vision research: An excellent model for the study of ocular disease

C. Ellis Wisely [a, 1], Javed A. Sayed [a, 1], Heather Tamez [a, 1], Chris Zelinka [b, 1], Mohamed H. Abdel-Rahman [a, 1], Andy J. Fischer [b, *, 1], Colleen M. Cebulla [a, **, 1]

[a] Havener Eye Institute, Department of Ophthalmology and Visual Science, The Ohio State University Wexner Medical Center, 915 Olentangy River Rd, Columbus, OH 43212, USA
[b] Department of Neuroscience, The Ohio State University Wexner Medical Center, 333 West 10th Avenue, Columbus, OH 43210, USA

ARTICLE INFO

Article history:
Received 6 February 2017
Received in revised form
24 June 2017
Accepted 27 June 2017
Available online xxx

Keywords:
Chick
Eye
Ocular disease
Animal model
Stem cell
Optical coherence tomography
Mutant

ABSTRACT

The domestic chicken, *Gallus gallus*, serves as an excellent model for the study of a wide range of ocular diseases and conditions. The purpose of this manuscript is to outline some anatomic, physiologic, and genetic features of this organism as a robust animal model for vision research, particularly for modeling human retinal disease. Advantages include a sequenced genome, a large eye, relative ease of handling and maintenance, and ready availability. Relevant similarities and differences to humans are highlighted for ocular structures as well as for general physiologic processes. Current research applications for various ocular diseases and conditions, including ocular imaging with spectral domain optical coherence tomography, are discussed. Several genetic and non-genetic ocular disease models are outlined, including for pathologic myopia, keratoconus, glaucoma, retinal detachment, retinal degeneration, ocular albinism, and ocular tumors. Finally, the use of stem cell technology to study the repair of damaged tissues in the chick eye is discussed. Overall, the chick model provides opportunities for high-throughput translational studies to more effectively prevent or treat blinding ocular diseases.

Contents

* Corresponding author. Department of Neuroscience, The Ohio State University Wexner Medical Center, 333 West 10th Avenue, 3020 Graves Hall, Columbus, OH 43210, USA.
** Corresponding author. Havener Eye Institute, Department of Ophthalmology and Visual Science, The Ohio State University Wexner Medical Center, 915 Olentangy River Rd, Suite 5000, Columbus, OH 43212, USA.
E-mail addresses: fischer.412@osu.edu (A.J. Fischer), Colleen.cebulla@osumc.edu (C.M. Cebulla).
[1] Percentage of work contributed by each author in the production of the manuscript is as follows: Wisely: 22%, Sayed: 12%, Tamez: 5%, Zelinka: 3%, Abdel-Rahman: 8%, Fischer: 25%, Cebulla: 25%.

http://dx.doi.org/10.1016/j.preteyeres.2017.06.004
1350-9462/

1. Introduction

Animal models are critical to vision research for numerous ocular diseases and conditions, including retinal detachment, retinal degeneration, glaucoma, and corneal injuries. Currently, multiple species including non-human primates, rodents, felines, and certain avian species are being used for ocular research purposes; all have advantages and disadvantages. However, the chick is perhaps an underutilized model animal with many advantages in cost, size, and ease of handling compared to other models. This review will focus on our experience with modeling human retinal disease using the chick model system and discuss its advantages and disadvantages for vision research.

2. Basic anatomy and physiology

2.1. Overview

The chick is a diurnal bird originating from jungle fowl (Eriksson et al., 2008). Like most avian species, the chick relies heavily on vision for everything from predator evasion to food acquisition. With this highly developed visual system, the chick eye is relatively large compared to its overall size. The mean axial globe length of the chick eye, 12–13 mm (Montiani-Ferreira et al., 2003; Troilo et al., 1995), is approximately half that of the human eye. Avian species exhibit this relatively large eye size by dedicating up to 50% of the cranial volume to the eye, compared to approximately 5% in humans (Waldvogel, 1990). Table 1 provides anatomical comparisons between chick and human eyes, and Fig. 1 compares the chick to several other species used in vision research. Figs. 2 and 3 are images of hemisected chick eyes, also allowing for an overview of anatomical structures. Specific categories of chick ocular anatomic and physiologic details are presented in sections 2.2 through 2.9.

2.2. Cornea

The chick cornea is a transparent structure composed of five distinct layers: epithelium (outermost), Bowman's layer, stroma, Descemet's membrane, and endothelium (innermost) (Jones et al., 2007; Kanski, 1994; Ritchey et al., 2011). The normal, average respective adult corneal diameter and thickness measurements are 9.1 mm and 405 μm (by histology and optical coherence tomography (OCT)) in chick (Fowler et al., 2004) compared with 11.5–12.5 mm (Rüfer et al., 2005) and 518–558 μm (as measured via ultrasound, Scheimpflug imaging, and OCT by Grewal et al. (2010)) in humans. Fig. 4 shows a representative anterior segment spectral domain OCT image of the chick. Bowman's layer has been shown to play a key role in corneal wound healing (Fowler et al., 2004), but rabbit and rodent models used in corneal wound healing studies have severely underdeveloped Bowman's layers (Hayashi et al., 2002). In contrast, the chick has a true Bowman's layer, which is an advantage for trauma or corneal refractive studies, particularly studies of epithelial debridement in which epithelial cell re-growth is evaluated (Fowler et al., 2004; Ritchey et al., 2011). Chick corneas are thinner than those of other animals, but the relative thickness ratios of chick corneal layers are very similar to those observed in human corneas (Fowler et al., 2004; Ritchey et al., 2011). Furthermore, the chick eye, like the human, has a more stable blood-aqueous barrier than some species, such as the rabbit, which produces prominent fibrin material with minimal tissue manipulation (Fowler et al., 2004).

2.3. Sclera

Extending laterally from the limbus, the avian sclera is in many respects analogous to the primate sclera. Distinguishing features include the presence of both fibrous and cartilaginous scleral layers and the presence of scleral ossicles (Coulombre and Coulombre, 1973; Koch, 1973; Rada et al., 1991). A layer of hyaline cartilage is located internally, with a thin fibrous layer of type I collagen and proteoglycans situated externally. The hypocellular fibrous layer is similar in composition to the primate sclera (Rada et al., 1991). The two layers respond differently during ocular growth, with the cartilaginous layer incorporating additional glycosaminoglycans

Please cite this article in press as: Wisely, C.E., et al., The chick eye in vision research: An excellent model for the study of ocular disease, Progress in Retinal and Eye Research (2017), http://dx.doi.org/10.1016/j.preteyeres.2017.06.004