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Comparative anatomy case study: differences in extrinsic eye muscles and dissection protocols

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Abstract:

There have been notable studies comparing the eye placement between predators and prey, which can be further categorized as omnivore, carnivore, and herbivore. The purpose of this study was to determine if eye placement correlated with extrinsic eye muscle differences among the classification of animals (predator vs. prey and omnivore vs. carnivore vs. herbivore). For an omnivore, a human orbit was dissected. A cat was dissected to represent a carnivore and a goat was dissected to represent an herbivore. Dissection protocol for the cat and goat were created due to the lack of dissections of these muscles. Unfortunately, data collection was incomplete due to the social distancing policy on Iowa State University's campus because of COVID-19. Even though the data was incomplete, dissection techniques, dissection of different tissue types, and next steps were learned. This case study should be continued, and a concrete protocol for extrinsic eye muscle dissection should be created for lateral eyed mammals.

Introduction:

This case study included dissections of an omnivore (human), a carnivore (cat) and an herbivore (goat). There have been notable studies comparing pupil shape and eye placement between predators and prey, which can also be further categorized as omnivore, carnivore and herbivore. Goats have monocular vision whereas humans and cats have binocular vision (Banks, Sprague, Schmoll, Parnell, & Love, 2015). The differences in vision are substantial when comparing predator and prey. Predators have binocular vision which allows for very good depth perception, but not very good range of view. Monocular animals (prey) have almost a panoramic view of their surroundings, but relatively poor depth perception. Binocular animals are typically front-eyed animals, while monocular animals are typically lateral-eyed animals. The purpose of this case study was to determine if eye placement correlated with muscle differences among the classifications of animals (omnivore, herbivore or carnivore and, predator vs. prey).

In mammals, there are six muscles that are responsible for voluntary and reflexive eye movement (Buttner-Ennever, 1988). As a group, these muscles are called extrinsic eye muscles. The six muscles in this group are: medial rectus, lateral rectus, superior rectus, superior oblique, inferior rectus and inferior oblique. However, some animals also have an accessory muscle that assists in eye movement. This muscle is called the retractor bulbi muscle and acts to retract the globe (Pasquini & Pasquini, 2009). In lateral-eyed mammals (i.e. goats), the actions and insertions of the extrinsic eye muscles differ from front-eyed mammals (i.e. primates).

The medial rectus muscle and lateral rectus muscle originate from the tendinous ring found in mammals at the apex of the orbit (Buttner-Ennever, 1988). This tendinous ring is also called the annulus of Zinn (Zampieri, Marrone, & Zanatta, 2014). The medial rectus also has an additional origin, the dura of the optic nerve. The names of these muscles describe the insertion point on the globe. Medial rectus inserts on the medial portion of the globe, and lateral rectus inserts laterally. These two muscles work antagonistically. The medial rectus muscle adducts the eye (or moves the globe toward the nose) while the lateral rectus muscle abducts the eye (or moves the globe away from the nose) (Purves, et al., 2001). Oculomotor and abducens innervate medial rectus and lateral rectus, respectively.

The superior rectus muscle originates from the tendinous ring as well as the dura of the optic nerve, and it inserts anteriorly to the equator of the globe (Zampieri, Marrone, & Zanatta, 2014). Due to the insertion point, the primary action of the superior rectus is elevation of the eye. In lateral eyed mammals, such as goats, the secondary actions of superior rectus are abduction and extorsion. In front-eyed mammals, such as primates, the secondary actions of superior rectus are adduction and intorsion. This difference is due to the angle at which the muscle inserts in these animals (Buttner-Ennever, 1988). In both lateral and front-eyed mammals, the superior oblique muscle is innervated by the oculomotor nerve.

The superior oblique muscle originates from the body of the sphenoid. It then proceeds anteriorly and courses through the trochlea, a fibrocartilaginous ring (Abdelhady, Bhupendra, Motlagh, & Al Aboud, 2019). After passing through the trochlea the superior oblique muscle turns laterally and inserts on the globe. In front-eyed mammals, the superior oblique muscle inserts on the superior globe, posterolateral to the central point. The primary action of superior oblique in front-eye mammals are depression and abduction of the eye. In lateral-eyed mammals, the superior oblique muscle inserts on the superior globe, anterolateral to the central point. This allows elevation and adduction of the eye in lateral-eyed mammals (Buttner-Ennever, 1988). Superior oblique is also responsible for torsional movement (Purves, et al., 2001). The trochlear nerve innervates the superior oblique muscle.

The inferior oblique muscle originates on the maxillary bone on the medial wall of the orbit and inserts on the lateral aspect of the globe (Purves, et al., 2001). Like the superior oblique muscle, the insertion point is different between front-eyed and lateral-eyed mammals. In front-eyed mammals the insertion is posterior to the equator. In lateral-eye mammals, the inferior oblique inserts anterior to the equator. The primary action of the inferior oblique muscle is extorsion. Secondary actions include elevation and abduction in front-eyed mammals, and depression and adduction in lateral-eyed mammals. Oculomotor is the nerve that innervates inferior oblique.

The inferior rectus muscle also originates from the tendinous ring and inserts on the inferior globe, anterior to the equator (Zampieri, Marrone, & Zanatta, 2014). The primary action of the inferior rectus muscle is depression. However, due to the differing angle of insertion, the secondary actions are different between lateral-eyed and front-eyed mammals. In front-eyed mammals the secondary actions include adduction and extrusion, while in lateral-eyed mammals abduction and intorsion are the secondary actions. Oculomotor innervates the inferior rectus muscle.

In veterinary sciences, the dissection protocol to access the extrinsic eye muscles is not one that could be used for this case study. Most dissectors instruct students to cut all attachments around the globe and extract it. For the intent of this case study, that was not an acceptable approach because the muscle had to be attached to both the origin and insertion to identify the length of each muscle. During the course of dissections, a protocol for extrinsic eye muscle dissections and observations was created.

Methods:

Figure 1: The length of superior rectus muscle of a human.

In order to compare the differences between species, dissections of a goat, cat and human occurred. Both the goat and cat specimens that were used were bisected heads. This made the dissection increasingly more difficult. However, the human dissection was done via a superior approach. Dissection of the inferior oblique muscles and inferior rectus muscles among the three species were not done due to complexity. Each measurement was taking in millimeters (mm) and with the same ruler for consistency. Length was taken from the visible origin and followed until the visible insertion. Diameter was taken at the thickest portion of the muscle.

Figure 2: The diameter of superior rectus muscle of a human.

The first dissection that was done was the human. The dissection protocol that was used was from Grant's Dissector, page 279-281 (Sauerland, 1994).

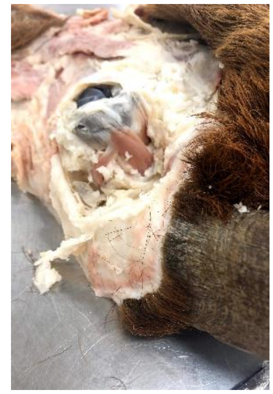

Figure 3: Goat dissection with the superior rectus and superior oblique muscles exposed.

The goat dissection was the second dissection performed. There was no previous protocol on how to dissect the extrinsic eye muscles on a bisected goat head. To dissect the goat orbit, a protocol similar of the human dissection protocol was followed. First, the skin and fur were removed from the goat. The facial muscles were also removed to expose the bone underneath. The goat skull is very thick and was broken piece by piece using a chisel and mallet. A lateral/superior approach was used to expose the extrinsic eye muscles. As more parts of the skull were removed, it became apparent that the origins of the muscles were not accessible from this approach. There was a plan to attempt a different approach later during another dissection period. Unfortunately, the dissection was not finished due to miscommunication about the specimen. It seemed to be discarded before the dissection could be finished. There was another dissection day scheduled to redo the dissection, but all university research and activities were halted due to COVID-19.

Figure 4: The diameter of the medial rectus muscle in the cat.

Figure 5: The length of the medial rectus muscle in the cat.

The last dissection was the cat. There was also no previous protocol on how to dissect the extrinsic eye muscles on a bisected cat head. This dissection started similarly to the goat dissection. The fur, skin and facial muscles were removed to

expose the underlying bone. Since the cat skull is very thin, dissection scissors were used to cut through the bone. Bone was removed from the superior, lateral and medial portions of the orbit to access the extrinsic eye muscles. Once the fat was removed, measurements of the muscles were taken and noted. The measurements stemmed from the origin to the insertion point. After all muscles were exposed and measured, the diameter of the orbit was measured using a caliper.

Figure 8: The length of the superior rectus muscle in the cat.

Figure 9: The diameter of the lateral rectus muscle in the cat.

Figure 6: The length of the lateral rectus muscle in the cat.

Figure 7: The diameter of the lateral rectus muscle in the cat.

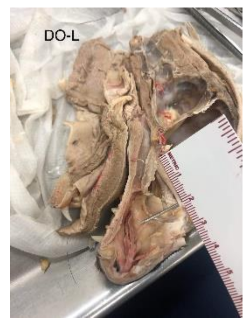

Figure 10: The length of the superior oblique muscle in the cat.

Figure 11: The diameter of the superior oblique muscle in the cat.

Results:

In the human, the lengths of superior rectus, superior oblique, lateral rectus, and medial rectus were 4.5 mm, 4 mm, 3.1 mm, and 2.2 mm, respectively. The diameters of the muscles were 0.8 mm, 0.7 mm, 1 mm, and 0.9 mm respectively. The during the dissection, the globe was cut, and the aqueous humor had leaked out. This led to the inability to measure the diameter of the globe. There was a plan to redo the dissection on the other orbit to gain this information, but all dissections were halted due to the university closing. The lengths and diameters of the goat were not measured due to the incompletion of the dissection. As seen in Table 1, the lengths of the superior rectus, superior oblique, lateral rectus, and medial rectus in the cat were 1.7 mm, 2.2 mm, 1.9 mm, and 1.8 mm

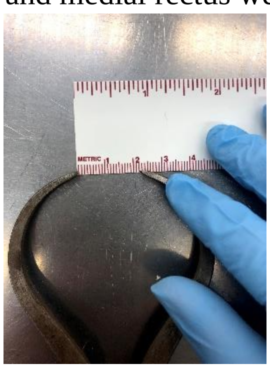

Figure 12 (left): Caliper used to measure the diameter of the globe. Figure 13 (right): Measurement of the caliper.

respectively. As seen in Table 2, the diameters of the muscles were 0.7 mm, 0.5 mm, 0.9 mm, and 0.8 mm respectively. The diameter of the globe was 2.2 mm. This data is presented in Table 1 below. Unfortunately, the results were incomplete due to the COVID-19 social distancing policy on Iowa State University's campus.

Species	Superior Rectus Diameter	Superior Oblique Diameter	Lateral Rectus Diameter	Medial Rectus Diameter	Diameter of Globe
Human	0.8 mm	0.7 mm	1 mm	0.9 mm	-
Goat	-	-	-	-	-
Cat	0.7 mm	0.5 mm	0.9 mm	0.8 mm	2.2 mm

Table 1: Information regarding diameter of the extrinsic eye muscles in each species, as well as diameter of the globe.

*mm = millimeters

Species	Superior Rectus Length	Superior Oblique Length	Lateral Rectus Length	Medial Rectus Length
Human	4.5 mm	4 mm	3.1 mm	2.2 mm
Goat	-	-	-	-
Cat	1.7 mm	2.2 mm	1.9 mm	1.8 mm

Table 2: Information regarding length of the extrinsic eye muscles in each species.

*mm = millimeters

Discussion:

Due to the data collection incompletion, the full scope of the differences between the extrinsic eye muscles was not determined. Even though the results were incomplete, this was a very beneficial case study. Not only were there dissection techniques learned, but there was also an enhanced understanding of how to dissect different tissue types. The goat, for instance, had very tough tissue. The dissection was difficult and rough. Fragility was not a concern. On the other hand, the cat tissue was very fragile. The dissection was done carefully so the structures were not damaged. As for the human, dissection was relatively simple due to the previous dissection of the donor. Dissection of these different tissues enhanced the dissection techniques and allowed for sharpening of skills.

If there is ever an opportunity to redo this case study, it would be beneficial to gain more background knowledge about lateral eyed species, especially how to locate the extrinsic eye muscles from a superior approach. The origins of the extrinsic eye muscles sit directly behind the globe, making it difficult to see the entire muscle. The bisection of the goat head made it difficult to chisel the bone away. However, it may be beneficial for future case studies because it would allow an intracranial approach to these muscles. If university activities were not halted, an intracranial approach would be performed to observe the origins of the muscles. The lengths and diameters of the muscles would then be able to be measured. Even if this approach were taken, it would still be beneficial if the lateral, medial and superior aspects of the orbit were dissected out. This would allow for a full range of observation of the extrinsic eye muscles.

It would also be interesting to spend time to identify differences among prey. Although small, mice are mostly front-eyed mammals, but are prey. It would be interesting to determine if all prey have monocular vision or if all predators have binocular vision. Another thing that could be studied is the differences in domesticated animals (i.e. dog) versus non-domesticated animals (i.e. wolf). There is potential for ongoing research, as well as a continuation of this case study.

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