The eye in Vesalius' works.

J. Delaey

UGent,

Summary

In the times of Vesalius, the knowledge of ocular anatomy was limited. Probably the first description of the anatomy of the eye is due to Democrites, for whom the eye is surrounded by two coats, filled with a homogenous fluid. The optic nerve is hollow and the lens is considered to be a postmortem artefact. Till the 15 th century AD medicine will be influenced by Galenus' writings and the model of the eye which he proposes will still be considered valid even after the time of Vesalius. Following the Alexandrian tradition the lens is considered as the seat of visual perception. Whereas Vesalius rightly deserves the title of Father of Modern Anatomy, his description of the ocular anatomy is rudimentary and often incorrect. He still describes a Musculus retractorius bulbi, which is only found in lower mammals but not in primates. The lens, of which he correctly recognizes the role as an optical device is placed too centrally in the eye. The optic nerve is not correctly placed and following Galenus, he only describes seven cranial nerves. The Galenian concept of ocular anatomy will last till the discovery of the microscope by Anthony van Leeuwenhoek and modern ocular anatomy will in fact only start with the works of Zinn.

Introduction

Ophthalmology is one of the eldest medical specialities. Iry is the first ophthalmologist whose name was recorded. He lived during the 6th dynasty (about 2400 BC) and his tomb was found near the pyramid of Cheops. Iry's title was "royal oculist and shepherd of the rectum". A number of ocular diseases are described in the Edwin-Smith papyrus (1800 BC) now in the library of the New York Historical Society. The Ebers papyrus which was found in 1862 between the legs of a mummy and is now owned by the University of Leipzigonly contains no anatomical references except that the blood of the eyes is supplied by temporal vessels. It discusses a number of ocular diseases such as blepharitis, chalazion, ectropion, entropion, trichiasis, pinguecula, leucoma, staphyloma, iritis, cataract, dacryocystitis and ophthalmoplegia.

In the Codex Hammurabi (about 1800 BC) the fee for ocular surgery is indicated. To operate on a free man, the ophthalmologist was entitled to ask the considerable sum of 10 silver shekels (about the annual salary of a workman), for a poor 5 and for a slave 2 shekels. However if the patient lost his eye after an unsuccessful operation, the surgeon was penalized by having his hand cut off. Possibly this punishment was inflicted not on the surgeon himself but on one of his slaves . If the eye of a slave was lost, the surgeon had to replace the slave.

Ocular anatomy before Vesalius

Democrites (ca 460-370 BC) gave probably the first anatomical description of the eye. He describes two coats, the eye is filled with a homogenous fluid, there is no lens and the optic nerve is hollow. Alcmaeon of Croton (500 BC) is considered to have given the first description of the optic nerve, indicating that it is connected to the brain. For him the brain and not the heart is the seat of the soul and also the organ of movement and sensation.

Hippocrates of Cos (ca 460-375 BC) is considered as the father of medicine. He insisted on careful observation of the patient. He probably was the first to describe what would later be called Behcet disease and notes the cardinal symptoms of the disease: fever, aphths in mouth and genitalia, joint and ocular inflammation.

No dissections were performed in the early Greek period as they had a reverence for the dead body which needed a proper burial.

Aristotle (384-322 BC) probably dissected animal eyes. He describes the eye as a spherical organ with 3 coats filled with a homogenous fluid. The eye is in contact with the brains by means of three tubes, of which one is in contact with a similar tube originating from the other eye. This could be the first observation of the optical chiasm. The two other tubes represent possibly bloodvessels and the trigeminal nerve. The lens is considered as a postmortem artefact, due to the accumulation of phlegma.

In Alexandria dissections were performed on convicts and the anatomical knowledge of the Romans is based on the Alexandrian school. The Romans were quite superstitious and thus dissection of the human body was for them unthinkable.

Aurelius Cornelius Celsus (25 BC-50 AD) lived under the emperor Tiberius. His description of the ocular anatomy is probably based on papyrusses from the Alexandrian Library. Celsus describes three ocular coats and the lens (crystalloides), which is still considered as the seat of visual perception. For the first time the anterior chamber (locus vacuus) is mentionned as well as the vitreous body.

Rufos of Ephesus (98-117), a contemporary of the emperor Trajan mentions a fourth ocular coat, the conjunctiva which he calls “epidermis”. He distinguishes the anterior chamber filled with an aqueous fluid from the posterior segment of the eye, which contains a substance resembling white of an egg.

Claudius Galenus (130-200) is the best known physician in the roman period and his writings will be considered as the essential of medicine till the period of Vesalius. Galen originated from Pergamon, studied in Alexandria and became physyician of the emperors Marcus Aurelius and Commodus. His writings on ophthalmology are lost although his description of ocular anatomy survived. He considers seven coats: the conjunctiva which for him is an extension of the periost of the orbit, the ocular muscles and their tendons, the sclera, the choroid, the retina, the vitreous body and the crystalline lens. The corneoscleral limbus is the junction of choroid and retina. The optic nerve is hollow, allowing the passage of pathological humours which provoke ocular diseases. There are 7 ocular muscles, including the M.retractor bulbi, which is only found in lower mammals. It is worth noting that Vesalius will not rectify Galen's mistake.

The retina is an extension of the optic nerve which nourishes the vitreous and through the vitreous the crystalline lens. The lens (divinum oculi) is considered as the center of visual perception. Visual corpusculi or emanations are sent from the lens to the object which is looked at and return via the lens to be transported through the hollow optic nerve to the third ventricle of the brain where the soul is located.

After Galen starts a period of scientific inertia especially in Western Europe. The burning of the Alexandrian Library in 641 resulted in the loss of a mass of knowledge, fortunately partially transmitted by the Arabs to the West through the schools of Toledo and Salerno. Rhazes (Al Razi, 865-925) describes the reaction of the pupil to light. The mathematician Alhazen (Ibn Al Haitham, 965-1038), who worked in Cairo, dismissed the corpuscular emission theory of vision

Averroes (Ibn Rushd, 1126-1198), wrote extensively on optics and suggested that the retina and not the crystalline lens was responsible for vision..

A few schematic descriptions of the eye are known, especially from Alhazen and from Hunain Ibn Ishak. They are still based on the Galenic concepts: the optic nerve is hollow, the crystalline lens, which is considered as the most essential part of the eye is centrally located and connected to the optic nerve. Cataract is considered to be a corrupt humour in front of the lens, and could thus not be located immediately behind the iris.

The ophthalmological treaties written during that period in the West are far from original. Peter the Spaniard who will be the only ophthalmologist to become a pope (John XXI,

1210-1276) wrote the “Liber de oculo”. The most popular work on ophthalmology in those times is the “Practica oculorum” of Benvenutus Grassus (or Grapheus).
Even Roger Bacon (1214-1294), a franciscan and philosopher, still considers the crystalline lens as the site of visual perception. The optic nerve is hollow as the visual spirit or pneuma passes through it.
The most reknown surgeon of his time, Guy de Chauliac of Montpellier, wrote in his “Chirurgia Magna” : “I am not interested in knowing whether the cataract is present between the cornea and the iris , as Jesus proves, or between the aqueous and the lens as Galen pretends”. This sentence illustrates the total lack of scientific interest of even the most famous physicians in the Middle Ages.
Leonardo da Vinci (1452-1519) adheres to the old anatomical description of the eye, but for one point. The lens is no more responsible for visual perception. He describes the double refraction of the light by the cornea and by the crystalline lens which then reaches the optic nerve. The lens in his drawing, is relatively too large and centrally located , the optic nerve is hollow and connected to the third ventricle. Leonardo could have been the first to consider a technique of fixation of ocular tissue. He proposes to place the eye in white of egg and then boil it, so that it would be easier to dissect.

Vesalius and the eye

Vesalius rightly deserves the title of father of modern anatomy. Andreas van Wesel was born on December 31, 1514 in Brussels. The family with the name Wytinck originated from Wesel in the duchy of Cleves and had close links with the court. Vesalius great-grandfather Johannes obtained his medical degree in 1427 at the University of Padua and was appointed as professor of the recently created University of Louvain in 1429. In 1449 he became the city physician in Brussels. The emperor Frederic III delivered him a coat of arms with three weasels. This coat of arms is to be seen on the frontpage of the

Fabrica. Johannes' eldest son Everaert studied medicine in Louvain and became physician to the Emperor Maximilian of Austria. He did not marry but had a number of illegitimate children, one of whom was Andries, who became an apothecary and worked for Margaretha of Austria and later for Charles V.

Andreas Vesalius started his medical studies first in Louvain and later in Paris where he became a pupil of Jacques du Bois (Jacobus Sylvius) and of Johann Günther d'Andernach. In Paris, Vesalius performed his first public dissection, and in contrast with was usual in those days, where the teacher supervised, sitted on his catheder, the dissection done by an assistant, he and not an assistant, did the job.

He returned to Louvain where he studied further one semester and left in 1537 for Padua. On the 5th of December 1537 he obtained his doctoral degree "cum ultima diminutione": This "diminutione" means that because of the excellence of his defence he only had to pay a markedly reduced fee of 17 ½ ducats for the diploma. One day after graduating he was appointed as professor of anatomy and of surgery at the University of Padua. He immediately started to work as the same semester he obtained a corpse for dissection. Already in Paris but even more in Padua, Vesalius realized that Galen's anatomy was based on the dissection of animals and did not necessarily correspond to the human anatomy. In Paris he had the opportunity to collaborate with Günther van Anderach at a new edition of Galen's "Institutiones anatomicae". In Padua he will further adapt this work for his students and include own drawings but also illustrations of his friend Jan Stevens van Calcar, a former pupil of Titian. This work is entitled "Tabulae Anatomicae Sex". Calcar most probably also produced the frontpage of the "De Humani Corporis Fabrica Libri Septem" and drew the skeletons. A portrait of Vesalius painted by Calcar is to be seen in the collections of the Hermitage in St Petersburg. The Fabrica, dedicated to the Emperor Charles V, is published in Basel by Vesalius' friend Johannes Oporinus in 1543. There is also a shorter (and less expensive) version for students and artists: the “Epitome”, dedicated to Philips II of Spain, Charles’ son. The Fabrica becomes a bestselling book. However Vesalius’ corrections of some of the errors he had detected in Galen’s work were not unanimously accepted and some, among them his former teacher Sylvius will heavily critize Vesalius for daring to contradict the unfailing Galen. As a reaction to Sylvius’ criticism Vesalius will write the “Epistola rationem modumque propinandi radicis Chynae”. In fact this letter to Joachim Roelants, physician to Margaretha of Austria,who asked him about the use of the china root gives the opportunity to Vesalius to respond to Sylvius’ accusations. Meanwhile Vesalius had become physician to the Emperor and later to his son Philips II and had thus to live in Brussels.

He will have the opportunity to visit Padua again where his pupil Colombo had succeeded him. In 1550 Vesalius is sent by Philips II to Paris where King Henri II had been fatally injured by the earl of Montgomery during a tournament. There Vesalius meets Ambroise Paré. After the death followed by the autopsy of Henri II he will return to Brussels. He will accompany King Philips to Madrid but is not particularly well received there. His autopsies provoke marked criticisms. Possibly to escape from this animosity, but also possibly by order of the Inquisition or even by pure religious believes, Vesalius undertakes a pilgrimage to Jerusalem. He certainly obtained the permission to leave Madrid from Philips II as he was entrusted by him of a sum of 500 ducats to be given to the guardians of the Holy Places. He will receive a letter of thanks addressed to Philips, which is a clear indication of his intention to return to Madrid and not to accept the chair in Padua, left vacant by Fallopio death as had been proposed. During the return journey the boat on which he sailed was struck by a heavy storm near the Greek island of Zanten. Probably Vesalius did not drown. He nevertheless died on the 15th October 1564 on the island of Zanten, possibly from typhus.

Vesalius was a true innovator and the quality of his' anatomical descriptions especially of the skeleton and of the muscles introduced a new era. In sharp contrast with this is his limited contribution to ocular anatomy. In the sixteenth century there were no adequate fixation techniques and the instruments at his disposal did not allow minute dissections. He follows Galen in his description of the extra-ocular muscles and still mentions the musculus retractorius, which is only to be found in lower mammals. He also adheres to Galen's classification of 7 pairs of cranial nerves:

I Nervus Opticus

II Nervus Oculomotorius

III Sensible branch of the Trigeminal nerve and N. Trochlearis

IV Motor branch of the Trigeminal nerve

V Facial accustic complex with the N.Abducens

VI N.Glossoparyngeus

VII N.Vagus

The crystalline lens is still placed in the center of the eye. He however recognizes the optical role of the lens "quodammodo ad lentis similtudinem". He also shows that the anterior lenscurvature differs from the posterior curvature but considers both as separate parts. He points out that the colour of the iris is due to irispigmentation and not to the aqueous humour.The ciliary body is described as follows "Tunica ab uvea unitatem ducans, cilii seu palpebrarum pilis imagine correspondens ac interstitium pariter vitrei humoris ab aqueo" (A tunic starting from the uvea and with an aspect corresponding to eyelashes or eyelid hair as well as interspaces dividing equally the vitreous and the aqueous". That description could indicate that he noticed the ciliary processes and the zonular fibers, unfortunately his drawing is unclear in that respect. The retina is described as "Tunica quam reti assimilamus quamqui resoluta visorii nervi efficit substantia" (A tunic which we compare to a net which is detached from the

substance of the optic nerve). Vesalius' optic nerve is nor more hollow as was the opinion of previous anatomists including Jan Yperman and da Vinci, but is still located exactly opposite to the center of the cornea.
Vesalius' anatomic studies of the eye does not match his other achievements. He remains in the Galenic tradition and we will have to wait till the 18th Century for an adequate ocular anatomy.

Ocular anatomy after Vesalius

Vesalius will be plagiated without any scruple and his description of the ocular anatomy (with an identical drawing of the eye) will be used by Felix Platter in his "De Corporis Humani Structura" published in 1583 by Oporinus. Platter reiterate the opinion which was introduced 4 centuries before by Ibn Rushd that the retina and not the crystalline lens was the place where visual stimuli were processed.
Whereas Galen considered that the conjunctiva was an extension of the orbital septum Giacomo Berengario (1470-1530) showed it to be a separate structure. Gabriele Fallopio (1523-1563), who became professor of anatomy in Padua after Vesalius and Colombo, denies the existence of a musculus retractorius bulbi in humans. He also describes the M.Levator Palpebrae, gives a more correct description of the Mm.Obliqui and adds the Trochlear nerve to Galen's 7 cranial nerves. Georg Bartisch (1535-1606) oculist and lithotomist from Dresden is the author of the first book on ophthalmology written in German, "Ophthalmodouleia, das ist Augendienst" published in Dresden in 1583. It contains a number of colourful illustrations and descriptions of a series of eye diseases and of ocular surgical procedures. He remains however highly superstitious. Ocular surgery is best performed under the following constellations: balance, sagittarius or aquarius. In case of emergency one can also intervene under the constellations of virgo, scorpio or pisces. His book contains remarkable drawings of the eye and of the

brain, with consecutive sheets which can be flipped over so to discover the various structures layer by layer. The lens is situated more anteriorly than for Vesalius. According to Bartisch the crystalline lens contains fluid surrounded by arinea. He still describes the M.retractorius bulbi raound the optic nerve and seems not to know the chiasm, already mentionned by Aristotle.

Hieronimus Fabricius ab Aquaponte (1537-1619) disciple and succesor of Fallopio, will show the correct location of the crystalline lens. We will have to wait till 1619 for the first more or less acceptable diagram of the eye. Christophorus Scheiner (1575-1650) a jesuite priest shows that the radius of the cornea is smaller than the radius of the sclera, places the lens where it belongs and moves the optic nerve to the nasal side.

Frederik Ruysch (1638-1731) is the first to use injection techniques to study the ocular vessels and describes the central retinal artery and the vortex veins.

Antony van Leeuwenhoek (1638-1731), the inventor of the microscope discovers the corneal epithelium and could be the first to have seen rods and cones in the retina uitvinder van de microscoop, ontdekt het cornea epitheel en de lensvezels en zou als eerste ook staafjes en kegels gezien hebben in het netvlies.

Antoine Maître-Jean (1650-1730) and François Pourfour du Petit (1664-1741), two french scientists will demonstrate the lamellar structure of the lens and the latter will introduce frozen sections which allow a more correct representation of the ocular tissues. The posterior chamber is noticed for the first time.

The true father of ocular anatomy is however Johann Gottfried Zinn (1727-1759). Zinn studied anatomy and botanic in Göttingen and Berlin en becomes professor at the medical faculty of Göttingen in 1753 where he will also be the director of the botanic garden. His reputation as a botanist is suggested by the fact that Linnaeus named the genus Zinnea after him. In his “Descriptio Anatomica Oculi Humani” published in 1755 Zinn describes layer by layer the various ocular structures. The ocular muscles are correctly reproduced. Zinn introduces the term of ciliary processes, describes the zonular fibers and the bloodvessels around the optic nerve head. Three ocular structures are named after him: the zonula of Zinn, the annulus tendineus of Zinn and the circulus of Zinn. This clearly indicates the importance of this brilliant anatomist who died in 1759 at the young age of 31 years. Further scientists who continued the work of Zinn and his predecessors are Fontana, Cloquet, Schlemm, Bowman. The improvement of fixation and coloration techniques by Purkinje, the invention of the microtome, of phase contrast microscopy, of polarization microscopy and finally of electronmicroscopy will lead to our actual knowledge of the anatomy and the histology of the visual system.

References

1. G.Bartisch. Ophthalmodouleia. That is the service of the eyes.1583. Translated by D.L.Blanchard. ed.JP Wayenborgh,Ostend 1996.
2. S.Duke-Elder & K.C.Wybar. System of Ophthalmology. Vol 2. The anatomy of the visual system.. Chapter 1. The history of the anatomy of the eye. Pp 1-72. ed.Henry Kimpton, London, 1961.
3. H.Elkhadem, J.P.Heerbrant, L.Wellens-De Donder, N.Walch,C.Dumortier, N.Walch.Andreas Vesalius. Experiment en onderwijs in de anatomie tijdens de 16e eeuw., Koninklijke Bibliotheek Albert I, Brussel, 1993.
4. Hahn, P.Dumaitre, J.Samion-Contet. Vésale et son temps. Le de Humani Corporis Fabrica. Médecine de France, 133,17-28, 1962.
5. J.Hirschberg. The History of Ophthalmology. Vol I. Antiquity. Translated by F.C.Blodi. ed. JP Wayenborgh, Bonn 1982.
6. J.Hirschberg. The History of Ophthalmology. Vol.2. The Middle Ages, the 16 and 17th Centuries. Translated by F.C.Blodi. ed.JP Wayenborgh, Bonn, 1985.
7. J.Hirschberg. The History of Ophthalmology. Vol 3. The Renaissance of Ophthalmology in the 18th Century (Part one). Translated by F.C.Blodi. ed. JP Wayenborgh, Bonn, 1984
8. J.Hirschberg. The History of Ophthalmology. Vol.4. The Renaissance of Ophthalmology in the 18th Century (Party two). Translated by F.C.Blodi. ed.JP Wayenborgh, Bonn, 1984.
9. J.Hirschberg. The History of Ophthalmology. Vol.5. The Renaissance of Ophthalmology in the 18th Century (Part three). The first half of the 19th Century (part one).Translated by F.C.Blodi. ed. JP Wayenborgh.Bonn, 1985.
10. W.Jaeger. Die Illustrationen von Peter Paul Rubens zum Lehrbuch der Optik des Franciscus Aguilonius (1613). Ed. Brausdruck, Heidelberg, 1976.

11. D.A.Jdanov. Un portrait de Vésale à l'Ermitage de Leningrad. Symposium Ciba, 12, 180-183,1964.

12. J.B.deC.M.Saunders & C.D.O'Malley. The illustrations from the works of Vesalius of Brussels. Dover Publications, New York, 1950

13. R.Van Hee (ed). Ziek of gezond zijn ten tijde van Keizer karel. Vesalius en de gezondheidszorg in de 16de eeuw. Academia Press, Ghent, 2000.

14. Ph.Verheyen. Corporis humani anatomiae. Liber primus. Editio Secunda. Ed. 't Serstevens Brussels, 1710