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The evolution of cataract surgery

Introduction

Cataracts are common. They are the main cause of blindness, with an estimated 17 million people worldwide blind from cataract[1]. By way of comparison, six million are estimated to be blind from onchoceriasis, trachoma and other causes of corneal opacity[1]. Presently, the only known treatment for cataract is the surgical removal of the lens.

The number of cataract operations performed in the UK has risen dramatically in recent years. Anyone reaching full life expectancy is more likely to have a cataract operation, than any of the next nine surgical procedures combined[2,3].
A number of factors have contributed to this remarkable increase. The population is on average older and the environment has become more demanding of older people. To function independently, one needs to drive, to work various computer interfaces such as automatic teller machines, and to watch the news on television. However, the major reason for the increase in the frequency of cataract surgery is that a more effective procedure has evolved.[4] This means that surgery can be performed on patients with minimal disability, or excellent visual acuity and those patients with cataract in only one eye can benefit from cataract surgery[5-8].

Nowadays, not only is the procedure more effective, but it is also safer[9]. Indeed, cataract surgery, as it is performed today, is one of mankind's greatest achievements of the last millennium. However, the history of cataract surgery dates back at least two millennia earlier.

Historical aspects

The eye is one of surgery's oldest interests. There are numerous references to cataracts and their treatment in the literature of many ancient civilisations. Perhaps the first is in the Code of Hammurabi (1750 BC) **(Figure 1)**. This includes a schedule of payments for the surgeon, should sight be restored, along with the penalty of the removal of the surgeon's fingers should the patient die or lose their eye[10].

Prior to 1750 AD, cataract was treated by dislocation into the vitreous cavity using a lance, a process known as couching. Reference to this technique can be found in Hindu manuscripts dating from 600 BC. Lancing instruments such as that used for couching have been found in Greece dating from 1000 to 2000 BC. It is unclear whether these cultures developed couching independently or whether the technology was handed on. Certainly couching was common during the Roman Empire around the time of Christ and thereafter **(Figure 2)**. The procedure is described in Celsus' "De re Medicina", which is the oldest Greco-Latin medical document after the Hippocratic writings. It appeared around
29 AD.

Prior to the establishment of ophthalmology as a specialty, separate from mainstream surgery, general surgeons treated cataractous lenses by couching. However, cataract treatment also attracted others. In the 18th century, travelling quacks were common. They attracted patients through vigorous self-promotion and operated on cataracts, and other common maladies, in town centres and marketplaces. The outcome from the patient's point of view lagged well behind the claims of the cataract lancer.

Figure 1.
a. The Code of Hammurabi
b. The section of the code dealing with payments and penalties associated with couching

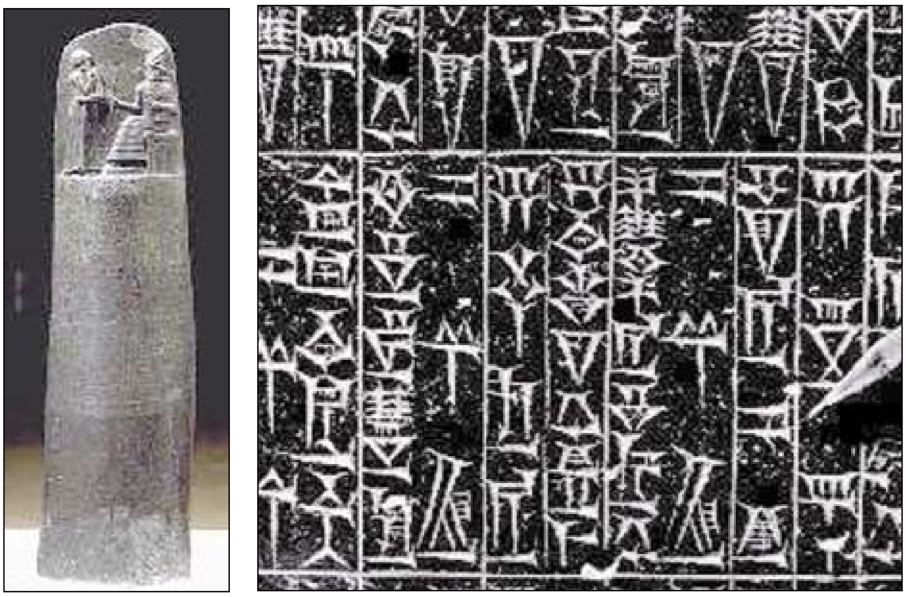

Figure 2
Couching of a cataract depicted on a Roman relief

Cataract extraction

Progress in cataract surgery required a modern understanding of light which came through the work of Newton, Dalton[11] and Young[12], as well as a modern understanding of the anatomy and pathology of the eye. French surgeon Pierre Brisseau, in 1705, was the first to describe cataracts as a clouding of the lens[13]. His countryman, Jacques Daviel pursued an alternative to couching after one of his patients suffered bilateral blindness following couching, presumably from sympathetic ophthalmia. He described the first planned surgical extraction of cataract in 1753[13,14]. Debate over the relative merits of couching and extraction raged into the next century.

Technical development of extraction occurred throughout the 19th century. Elbrecht von Greafe (1828-1870), in Germany, established the benefit of a small linear scleral incision for extracapsular surgery rather than a large limbal corneal incision[15]. The benefits could be seen in terms of surgical outcome for the patient – a lower rate of infection, less post-operative astigmatism and more rapid post-operative recovery. These goals still drive technical development today.

Two 19th century developments, which were important to cataract surgery, include Lister's asepsis in 1867, and the introduction of cocaine local anesthesia. Koller, an ophthalmologist and colleague of Sigmund Freud, who became aware of the anaesthetic properties of cocaine through recreational use, introduced it for eye surgery[16].

During the second half of the 19th century, surgeons became interested in removing the complete lens within its capsule, a procedure described as intracapsular extraction. This was not a new idea, with Sharp advocating this method in 1753 as an improvement on the extracapsular method of Daviel[17]. Later, Beer wrote about the advantages of intracapsular surgery in terms of outcome: quicker healing, better post-operative vision and the avoidance of capsular thickening and proliferation, which was common and termed "after cataract"[15].

Again, all surgeons did not immediately adopt this advance. An acrimonious argument about the relative merits of intracapsular and extracapsular extraction ensued for decades. It was not until the early 20th century that intracapsular surgery was firmly established as preferable to extracapsular surgery. Developments in anesthesia and then the introduction of sutures greatly assisted the progress of intracapsular surgery during this time.

Intracapsular surgery and aphakia

The finding that animals could see after having their ocular lens removed was made in 1707 by Antoine Maitre Jean[15]. The quality of the vision in "aphakia", however, is greatly affected because the lens is responsible for much of the converging power of the optical system of the eye. Patients with their lens removed and without optical correction cannot see the largest letter on the Snellen chart. Providing the patient with spectacles to overcome the loss of converging power of the aphakic eye can treat the optical deficiency. Such spectacles allow the patient to read the bottom line of the chart, but there is a serious disadvantage. The thick converging lenses provide the retina with a magnified image and a reduced visual field. For such patients, one form of visual disability, which was due to cataracts, was replaced by another, that associated with aphakia. The frustration for aphakic patients was considerable. It was the limitations of aphakic spectacle vision which drove the search for effective prosthetic correction[18].

Contact lenses were an option for the correction of aphakia. They are optically much more desirable since the image magnification is less and the field of view is greater. However, lens handling is a real difficulty for the elderly with poor vision and possibly limited hand strength or flexibility. Although contact lens correction of aphakia represents an improved outcome for the aphakic patient, success rates for contact lens wear in aphakia are limited[19].

The next advance for cataract surgery was the introduction of the operating microscope, first used for eye surgery by Dr Ken Swann in Portland, Oregon, in 1948. This began the era of ophthalmic microsurgery. This was closely followed by another important watershed, the invention of the intraocular lens (IOL). Although the suggestion of using an optical aid (a magnifying glass) implanted in the eye dates back to the 18th century and is attributed to by Giacomo Casanova (who is perhaps best remembered for some of his other accomplishments!)[20], Harold Ridley implanted the first IOL in 1948. He observed, along with other cataract surgeons, the disability experienced by those who had cataract surgery and who were required to wear convex spectacles to compensate for the lost converging power of the eye lens. The invention of the IOL was driven by the need to overcome the disability of the patient.

Ridley had observed that the eye could accommodate foreign material without destructive inflammatory reaction. Polymethylmethacrylate (PMMA) fragments (from shattered Spitfire canopies) which had found their way into the eyes of pilots were well tolerated. Ridley first proposed and manufactured IOLs, from the biocompatible PMMA. The early attempts at implantation often failed, but there were enough successes for optimistic surgeons to pursue intraocular implantation.

It was not until surgeons returned to extracapsular surgery and inserted the lens prosthesis into the posterior chamber of the anterior segment that success rates for the procedure became acceptable. Earlier attempts to rest the IOL in the anterior chamber, or to clip it to the fragile iris, were complicated by corneal injury, which was usually progressive, often severe and disabling.

Extracapsular surgery and pseudophakia

The advantages of intraocular lenses over aphakia with respect to visual function are well known. An eye with an intraocular lens (pseudophakic eye) is optically very similar to a normal eye. This means that a person who has had a cataract removed and has had an IOL can see well without a supplementary aid, although will usually require spectacles either for near vision (reading) or distance (driving). There is no significant magnification of the retinal image, hence a person can have a unilateral cataract removed without developing intolerable difference in image size between the two eyes, as a result of surgery.

As a consequence of the greatly improved optical performance of the eye after cataract removal and lens implantation, surgery can be considered for a patient who has less advanced cataract than was the case prior to the introduction of IOLs. The vision from pseudophakic eyes is usually better than that of patients who might have been considered quite normal in years gone by. In addition, unilateral cataracts can be operated on with much improved results. These two sequalae of intraocular lens surgery have contributed to the great increase in cataract surgery worldwide.

Thus, extracapsular extraction, involving removal of the nucleus and lens cortex from the capsular bag and the insertion and fixation of an IOL within the capsular remnant is now universally accepted as the procedure of choice for cataracts.

Phacoemulsification

Removing the cataract from the capsular bag can be achieved in two ways. The nucleus can be manually expressed from the eye, with a technique similar to that described by Daviel in 1753[14,13]. Alternatively, the hard nucleus can be liquefied (or at least fractured) by ultrasonic energy and aspirated from the eye (phacoemulsification). Charles Kelman first introduced phacoemulsification in 1967[21]. However, the procedure did not achieve widespread acceptance until the late 1980's and early 1990's. An ultrasonic probe emitting high frequency (44KHz) sonic energy is used to disrupt the hard lens nucleus. This is achieved through cavitation, a process analogous to the way in which bubbles are created around boat propellers. The technique has evolved to use low enough amounts of energy to split the nucleus into fragments without damaging the neighbouring structures of the eye. Manual expression of the nucleus demands a larger wound of approximately 9.0-mm chord length. Phacoemulsification can be done through a smaller wound of approximately 3.0-mm length.

Wound length is also governed by the size of the intraocular lens that is inserted. Conventional PMMA lenses require the phacoemulsification incision to be enlarged to 6.0 mm to allow their insertion. Intraocular lenses made from different materials such as hydroxyethyl methacrylate (HEMA) or silicone can be folded to allow their insertion. This further facilitates the use of small incisions.

Internal wound architecture has been important in the evolution of cataract surgery. Paying careful attention to wound construction can create wounds that need not be sutured. Separating the external and internal wounds by making these incisions of partial thickness and splitting along the eye wall to create a tunnel creates a structure where application of force to the eye will not result in wound gape and loss of intraocular contents.

Phacoemulsification predominates as the procedure of choice for cataract extraction in the Western world. The reasons are rooted in improved outcome for the patient. The main advantage is reduced corneal astigmatism after cataract surgery. Since the cornea is the major refracting surface of the eye, minor disturbances to its shape may result in marked astigmatism with serious consequences for vision. All corneal surgery has the tendency to produce astigmatism with less intervention producing less distortion than more disruptive procedures. Small cataract incisions produce less astigmatism than large incision cataract surgery, but the difference is short lived[22]. However, there is some dispute over the advantages of phacoemulsification.

Phacoemulsification is more expensive to perform requiring the use of sophisticated machinery. The most serious ocular complication of phacoemulsification lens extraction is dropping the nucleus into the vitreous cavity. This may result in visual loss due to inflammation and retinal detachment. Fortunately, this complication is unusual in experienced surgeons and sight loss can be prevented by vitrectomy and nucleus removal. Conversely, the risk of expulsive haemorrhage, a rare but devastating complication of cataract surgery, is thought to be less with phacoemulsification. This is because with phacoemulsification the eye may be maintained as a closed system during surgery. That is, through the use of viscoelastic materials and infusion of a physiological salt solution, the intraocular pressure is maintained at normal levels. Unlike with extracapsular lens expression where once the eye is opened the intraocular pressure falls to atmospheric pressure and haemorrhage from incompetent intraocular vessels is encouraged.

The future

Clearly, the future is brighter for cataract sufferers in the Western world. The only obstacle lying between cataract sufferers and surgical cure is resource allocation. Throughout the world, regulatory bodies and third party payers have been looking at the implications of escalating cataract surgery rates on resource distribution[23]. A procedure performed so often and consuming such a large portion of public health budgets needs to, and inevitably will, be monitored closely. Indeed, it is important to establish whether the outcome justifies the expenditure. It is important to develop methods for measuring outcome such as visual disability, if cost-benefit analyses are to be performed. Techniques for predicting outcomes are also important for improving the prioritisation of resource usage, especially to prevent unnecessary (non-beneficial) surgery. Continued research in this area should facilitate continued progress in the care of the cataract patient.

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