Management of Glaucoma Following Boston Keratoprosthesis

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Abstract

Boston keratoprosthesis (KPro) surgery has revolutionised the treatment of corneal and ocular surface disease. At present, glaucoma is the most important vision-threatening complication following KPro surgery. Diagnosis of glaucoma in KPro patients is difficult since the current method of determining intraocular pressure (IOP) by digital palpation is subjective and dependent upon the skill of the examiner. Optic nerve evaluation and visual field testing are important tools to follow glaucoma progression. Management of glaucoma following Boston KPro consists of medical therapy and surgical options. Glaucoma drainage devices are useful in this population but can have a variety of complications. Cyclophotocoagulation, either the non-invasive transscleral method or endocyclophotocoagulation, is also useful as an adjunctive measure in glaucoma management. Appropriate diagnosis and management of glaucoma is essential after KPro surgery to reduce the chance of vision loss.

Keywords

Keratoprosthesis, glaucoma, intraocular pressure, Ahmed valve

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The explosion of Boston keratoprosthesis (KPro) surgery over the last 10 years has revolutionised the field of cornea and ocular surface disease. Options for patients with severe inflammation of the corneal and conjunctival surface were limited prior to the development of the KPro surgical technique by Dohlman et al.[1] The Type 1 KPro, which is most frequently used, has a collar button design consisting of two plates joined by a stem, which forms the optical portion (see *Figure 1*). A fresh donor graft is used as a carrier for the device and a soft contact lens is placed over the ocular surface. The Type 2 Boston KPro is similar in design except that the 2 mm optical portion protrudes through a tarsorrhaphy.[2]

The Boston KPro allows for dramatic and rapid visual improvement in patients whose ocular disease is confined to the anterior segment.[3] In the past, vision loss following Boston KPro could result from a number of complications including infection, corneal melting and retinal detachment. Modifications in device design and post-operative management have reduced the occurrence of these problems. At present, glaucoma is the most important threat to long-term preservation of vision following Boston KPro surgery.[4–6] Appropriate diagnosis and management of glaucoma following Boston KPro is vital to ensure the best outcomes.

Pre-operative Glaucoma

Many patients who are candidates for Boston KPro surgery have pre-existing glaucoma. Previous case series from multiple institutions have shown a prevalence of pre-operative glaucoma of between 36 and 76 %.[5–10] This is not surprising since patients who need a Boston KPro have often had multiple prior corneal surgeries or have diseases that cause intraocular inflammation, necessitating topical, subtenon or systemic glucocorticoids.[2] Steroid-response ocular hypertension is prevalent among these patients, which can contribute to the development of glaucoma.[11]

In addition, various ocular diseases have individual factors that can contribute to ocular hypertension and glaucomatous optic neuropathy. Akpek et al. reported a case series of 15 patients with aniridic keratopathy who underwent KPro placement in which 14 patients (93 %) were diagnosed with glaucoma pre-operatively.[12] Aniridic patients have abnormal angle structures that predispose the eye to glaucoma. Iris stubs can contribute to secondary angle closure, further increasing intraocular pressure (IOP). In a case series of 17 eyes with herpetic keratitis, Khan et al. found that 66 % of eyes had pre-operative co-morbid glaucoma.[13] Herpes simplex virus can cause trabeculitis, which also contributes to elevated IOP. Sayegh et al. reported 75 % of their patients with Stevens-Johnson syndrome (SJS) undergoing KPro placement had pre-operative glaucoma. The authors hypothesised that damage to the anterior segment structures by inflammation and scarring from SJS contributed to glaucoma development.[14]

The most severe cases of pre-operative glaucoma are caused by chemical burns. In a series of 28 eyes with chemical burns, 21 eyes (75 %) had evidence of pre-operative glaucoma or ocular hypertension.[15] Alkali burns penetrate deeper than acidic burns, and cause scarring in the drainage angle, and even injury to the retina. Progressive optic nerve damage typical of glaucoma has even been reported in patients with normal IOP, thought to be secondary to ganglion cell layer damage due to alkali.[15] Harissi-Dagher et al. observed that there is often risk of advancing glaucoma even after

tube shunt placement and normalisation of IOP given previous damage to the trabecular meshwork, retinal ganglion cells and nerve fibre layer.[16] Given the frequency of glaucoma in chemical burns both before and after KPro placement, Cade et al. recommended aggressive glaucoma management during the acute and chronic care of patients with chemical injuries, including placement of a glaucoma drainage device if medical therapy is unable to maintain IOP in the mid-teens. If not done before KPro placement, they recommend shunt implantation concomitantly with the KPro surgery.[15]

Post-operative Glaucoma

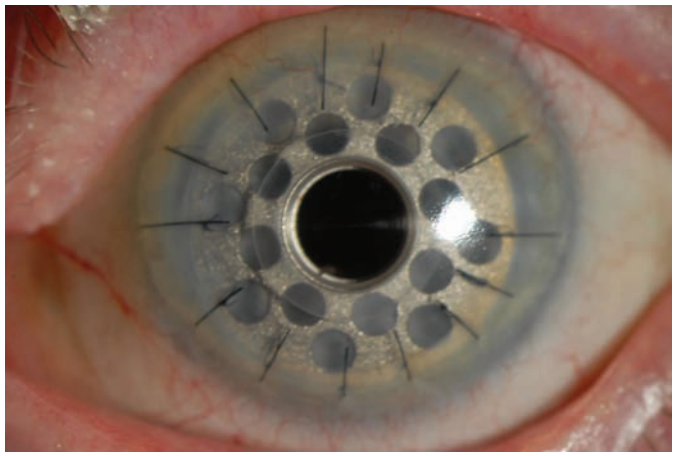
Glaucoma can also occur following Boston KPro surgery, with recent series reporting an elevation of intraocular pressure in 19–28 % of patients postoperatively.[7,10,14] Progression of pre-operative glaucoma, defined as increased cupping, loss of visual field, or uncontrolled IOP was found in 7–14 % of patients.[6,7,9] However, it is possible that some of these patients had undiagnosed glaucomatous damage prior to KPro surgery, as severe corneal scarring may limit evaluation of the optic nerve and visual field, and cause difficulty with IOP measurement pre-operatively.[6]

The pathophysiology of glaucoma development after KPro placement is multifactorial. Both open and closed angles from extensive peripheral anterior synechiae (PAS) have been observed by ultrasound biomicroscopy.[7] Progressive angle closure from inflammation is thought to be one of the major aetiologies of glaucoma.[11,14,17] Most KPro patients have undergone penetrating keratoplasties, and, thus already have some degree of synechial angle closure.[11] Also, as some KPro patients are left aphakic, there can be distortion of the normal angle morphological features as well as direct blockage of the trabecular meshwork with vitreous material.[18] In addition, the iridotrabecular angle may be crowded by the KPro back plate in some patients thereby predisposing patients to angle closure.[11,18] New KPro designs may reduce PAS formation. For example, changing the back plate from the original poly (methyl methacrylate) (PMMA) to titanium allowed a reduction in the thickness of the back plate to 0.20 mm, thus reducing angle crowding. Larger back plates can clamp the graft wound, thereby lowering the rate of PAS formation.[2,19]

In theory, partial or total iridectomy may prevent secondary angle closure glaucoma and synechiae formation.[7,20] Despite this manoeuvre, Netland et al. reported that 21 out of 36 eyes (58 %) treated with iris removal still developed evidence of angle closure glaucoma.[7] Although the true effectiveness of this step is unclear, some authors have recommended that all patients with intact irises undergo a iridectomy at the time of surgery to help prevent subsequent angle closure glaucoma.[6] Banitt, however, reported that removing the iris, which also helps eliminate the scaffold upon which retroprosthetic membranes can form, can also contribute to glaucoma by distortion of the trabecular meshwork. Akin to aniridic patients, the remaining iris stump may also contribute to angle closure.[11]

Hypertensive spikes in the immediate post-operative period may also contribute to glaucoma development. These hypertensive episodes are often reversible and controlled by drops and oral medications.[6] The hypertensive spike is likely caused by surgically induced inflammation and pigment dispersion, causing a mechanical inhibition of aqueous outflow. Talajic et al. recently suggested that the PMMA optic and back plate induces scleral rigidity, which may cause a change in the biomechanical forces, thus causing injury to the optic nerve despite normal IOP.[18]

Figure 1: KPro Type 1 in a Patient with a History of Corneal Scarring from Herpes Zoster Ophthalmicus



Diagnosis

Diagnosis of glaucoma is based largely on IOP measurements, optic nerve appearance, nerve fibre layer analysis and visual fields, some of which may be difficult to test in the KPro patient population.

Before Boston KPro placement, IOP can be measured in multiple standard ways including Tonopen, pneumotonometer, applanation or tactile estimation; the severity of pre-operative corneal disease may affect reliability with some of these methods.[7] Post-operatively, IOP measurement is more challenging.[8] A Tonopen can be used at the limbus for a rough estimation of the pressure, but not with enough accuracy to monitor glaucoma.[11] Central and peripheral applanation values are invalid given the KPro optic and back plate.[11] Tactile estimation, although operator-dependent, can be estimated as low, normal or elevated (above 21 mmHg).[7] Comparison with the IOP measurement from the other eye is useful. Digital tension is fairly accurate when using both index fingers over the patient's closed lids, while the patient is looking down, taking care to avoid palpating any area where glaucoma drainage devices are located.[11] However, Chew et al. noted that the presence of glaucoma drainage devices can change the dynamics of the sclera, thus complicating the assessment of IOP with digital palpation.[6]

A wireless IOP transducer with telemetry capabilities may provide a more precise method of assessing IOP in KPro eyes. The wireless IOP transducer (WIT, Implandata Gmbh, Germany) is a donut-shaped microchip positioned in the ciliary sulcus. The IOP measurements in rabbit studies correlate well with those obtained by Tonopen, indicating that this tool may become useful for KPro patients in the future.[21]

Unlike IOP measurement, optic nerve assessment and visual field testing is easily obtainable post-operatively given the often clear view through the 3 mm optic. Visual fields can be tested by automated or kinetic perimetry and followed over time. With Goldmann kinetic visual fields, the maximal visual field seen through the Boston KPro optic is 90–95 degrees.[22] In a small series of patients, visual field testing with Humphrey (Carl Zeiss Ophthalmic Systems, Dublinc CA) or Matrix (Carl Zeiss Ophthalmic Systems) instruments were more reliable than nerve fibre layer analysis (Heidelberg Retina Tomograph [HRT], Heidelberg Engineering, Heidelberg, Germany and GDx, Carl Zeiss Ophthalmic Systems) to follow glaucomatous optic neuropathy.

The authors did note that both visual field testing as well as structural testing were useful in patients with KPro.[23]

Anterior segment imaging can be helpful in assessing the drainage angle for evidence of secondary angle closure glaucoma. Netland et al. reported inability to assess the angle with early-generation ultrasound biomicroscopy (UBM) secondary to the thickness of the overlying tissue in 78 % of patients with KPro.[7] More recently, Garcia et al. successfully used anterior segment optical coherence tomography (OCT) to image the drainage angle and reported that it was superior to UBM to view angle structures in their KPro patients, although UBM was more useful for evaluating the tube shunts placed beneath the iris plane.[24]

Treatment

Management of glaucoma in patients with KPro is similar to management of glaucoma in other patients, with early initiation of medical therapy and consideration of surgical options if IOP is not well-controlled. Topical medications, however, can only be used in eyes with Type 1 KPro but may not be as effective due to a reduction in surface area because of the PMMA optic, resulting in a decreased surface area for absorption.[11] Oral medications such as systemic carbonic anhydrase inhibitors are the only choice for patients with a Type 2 KPro due to the virtually complete tarsorrhaphy required with this device.[14,25]

The decision about when to proceed with surgical treatment of glaucoma is dependent upon the practice patterns of the corneal and glaucoma specialists involved with a particular patient. Aldave et al. placed glaucoma drainage devices at the time of KPro surgery based on the pre-operative IOP.[26] Cade et al. recommended placing a tube shunt if the IOP felt closer to 20 mmHg with finger tension.[15]

Filtering trabeculectomies are not feasible in KPro patients due to severe conjunctival scarring in many patients undergoing Type 1 KPro and total conjunctival removal in all patients undergoing Type 2 KPro.[7]

Standard glaucoma drainage devices use an alloplastic tube in the anterior chamber to direct aqueous into the subconjunctival space with or without a valved connection to an open plate, which undergoes fibrous encapsulation. This area acts as a reservoir for the aqueous and allows for the fluid to be absorbed into the interstitial and intravascular space.[27] Glaucoma drainage devices are usually placed superonasally or superotemporally in KPro patients.[7] Although several types of tube shunts have been used, Yaghouti et al. supported the use of the Ahmed valve shunt, given the smaller incidence of hypotony in the post-operative period as compared with non-valved shunts.[20] Aquavella et al. reported two cases in paediatric patients with KPro who underwent Baerveldt non-valved shunts, of which both developed hypotony, while no cases of hypotony were reported in their patients with Ahmed valves.[28]

A common cause of tube failure is development of a thickened and impermeable fibrous capsule around the shunt plate. The subcapsular aqueous pressure equilibrates with the IOP from an increased resistance to aqueous flow, thereby causing elevated pressures.[27] This complication is often seen in cicatrising conjunctival disorders.[17,29] To avoid this complication, Rubin et al. developed a novel method using a modified Ahmed shunt which directed aqueous to an epithelium-lined cavity (maxillary sinus, ethmoid sinus and lacrimal sac).[27] They reported a series of 19 patients with KPro and intractable glaucoma in which they created physiological reservoirs in the periorbital area. Like other KPro patients, these patients were treated with topical antibiotics. They reported no episodes of endophthalmitis, which they attributed to the unidirectionality of the double-tubed shunt.[27] The case series was later expanded to include 15 more patients in which the lower lid fornix was included as a drainage site.[30] They reported one case of bacterial endophthalmitis in an eye that had aqueous shunted to the lower lid fornix 2.3 years after surgery in a patient noted to be non-compliant with his topical medication regimen. Other complications included three valve exposures and four eyes that developed hypotony from valve failure.[30]

Another complication of tube shunt surgery is exposure of the tube.[31] Although surgeons will often aim to place the plate superotemporally or superonasally, the amount of conjunctival scarring often dictates the quadrant in which the plate can be positioned. Despite placing the plate and tube in the least scarred quadrant, inadequate closure may lead to tube exposure. The two major risk factors for tube erosion are the length of time that the tube has been in place and the presence of a bandage contact lens.[32] Li et al. reported three out of nine of their patients with tube erosion had conjunctival breakdown at the edge of the bandage contact lens (BCL), where repeated focal trauma likely caused the complication.[32] They described a method for avoiding tube erosion via a pars plana approach in which the tube is passed into the posterior chamber under a thick scleral flap with pericardial patch graft reinforcement, thereby keeping the device away from the limbus and giving the tube extra reinforcement.[32] Vajaranant et al. also proposed more posterior pars plana tube placement (at 5 mm from the limbus) with reinforcement with a partial thickness cornea patch graft, thus allowing for improved BCL fitting and reduced tube distortion.[31]

Other complications to glaucoma drainage devices have been reported. Netland et al. reported nine out of 36 eyes with KPro and tube shunt had non-vision threatening complications, including blocked tubes, erosion of scleral graft, anterior choroidal effusion and choroidal haemorrhage.[7]

Cyclophotocoagulation, in which the ciliary body is partially destroyed to decrease the amount of aqueous fluid production, can also be used in the management of glaucoma. Transscleral cyclophotocoagulation (TSCPC) is non-invasive, but is difficult to titrate with a danger of overtreatment resulting in hypotension; repeated applications may be necessary and phthisis bulbi is a rare complication.[11,15] Retreatment may be required if there is anterior or posterior displacement of the ciliary body during the KPro surgery.[26] Rivier et al. reported a case series of 18 eyes that underwent diode laser transscleral CPC to control the IOP in patients with uncontrolled glaucoma.[29] Although a third of the eyes required repeated treatment for worsening visual fields, a significant reduction in IOP was found in all patients for up to 48 months. Normal IOP was restored in 67 % of patients with a single treatment. Transscleral illumination with a fibre optic light was not possible in these patients secondary to scar tissue and keratinised ocular surface. They reported complications of conjunctival dehiscence and fungal endophthalmitis, which may have been related to the initial KPro placement.[29]

Endocyclophotocoagulation (ECP) has also been used, with Talajic et al. reporting that ECP can be used as a first-line therapy for combating glaucoma, avoiding the many complications of tube shunts, as well as the trauma to overlying structures seen in TSCPC.[18]

Conclusion

Currently, glaucoma is the most important remaining vision-threatening complication of Boston KPro surgery. Glaucoma must be well-controlled prior to KPro placement. If there is any question about the degree of glaucoma control, a drainage device should be placed, ideally before KPro placement. Certain patients may not tolerate two separate surgeries and in these cases consideration can be given to concurrent KPro and valve placement, although our strong preference is for placement of the glaucoma device (and recovery from this surgery) prior to proceeding with KPro surgery. Careful IOP monitoring, optic nerve assessment and frequent visual field testing are needed to detect development or progression of glaucoma post-operatively in Boston KPro patients. Appropriately aggressive management with medication and surgical procedures are required. Boston KPro surgery can be life-changing for patients with severe cornea disease. Corneal and glaucoma specialists must work together as a team to manage KPro patients to prevent irreversible vision loss from glaucomatous optic neuropathy. ■

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