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The Anophthalmic Socket: Trends of Surgical Technique and Implant Selection

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Enucleation and evisceration have long been employed by ophthalmologists to manage ophthalmic conditions such as severe penetrating trauma or blind painful eyes. Debate surrounding both preferred surgical technique and choice of orbital implant in the anophthalmic socket have persisted over many decades, and continues today. This issue of *Ophthalmology Rounds* reviews the principal points on the different sides of these contentious surgical issues. The fundamental aspects of pre- and post-surgical care of the patient are also presented, including attention to the potential psychological effects of undergoing removal of an eye.

Despite improvements in the management of clinical conditions such as severe penetrating trauma, blind painful eyes, intraocular malignancy, and phthisis, removal of the eye remains the last resort in many cases that have either failed to respond to earlier measures or have presented too late to attempt more conservative measures. The primary management options of choice for these end-stage and unfortunate ophthalmic conditions in which little or no visual potential remains are enucleation and evisceration.

Enucleation is indicated for primary intraocular malignancies, of which the most common are retinoblastoma and choroidal melanoma, that are not amenable to alternative therapies such as radiation or plaque brachytherapy. Severely traumatized eyes in which the risk of sympathetic ophthalmia (SO) is deemed to be greater than the risk of regaining useful vision, may also be considered for early enucleation. In blind eyes with opaque media, it is essential to suspect and rule out intraocular malignancy, as this can occasionally cause globe degeneration.

Painful blind eyes can be managed with more conservative measures, including medical management of increased intraocular pressure, cycloablative procedures, and retrobulbar alcohol injection. Non-painful eyes may be managed first with a cosmetic scleral shell. If conservative measures fail, significant relief can be obtained with either enucleation or evisceration, and either procedure may be indicated for this purpose.

Enucleation Versus Evisceration

Enucleation

Enucleation involves the removal of the bulbus oculi, including the cornea, sclera, and part of the optic nerve. Evidence of enucleation by physicians dates back to as early as 2200 BC.[1] In fact, relics of a Chinese god devoted exclusively to the interest of oculists date back to 2600 BC. The first recorded enucleation was described by Bartisch in 1583.[2] Performed without anesthesia, the procedure consisted of passing a needle and thread through the globe, and pulling on the globe while passing a curved knife into the orbit to sever its attachments to the globe. In 1826, Cleoburey described a more refined procedure of carefully cutting the conjunctiva and extraocular muscles before cleanly severing the optic nerve.[3] Stoeber (1842)[4] and Critchett (1855)[3] described a simple enucleation by shelling the globe from within the Tenon capsule. By the end of the 19th century, the technique had evolved to involve closing conjunctiva over the implant and placing a conformer within the lids to discourage socket contracture.[1] The introduction of orbital implants, first

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described by Mules in 1884,[4] was a significant surgical contribution, allowing improved socket stability, motility and cosmesis.

Evisceration

Evisceration describes the removal of the contents of the globe, while leaving the sclera and optic nerve intact. In some cases, the cornea is also preserved. It is historically a much younger procedure than enucleation. The first evisceration was described in 1817 by Beer, after a planned iridectomy was complicated by an expulsive hemorrhage, and the contents of the globe were emergently removed.[1] Noyes performed the first routine evisceration in 1872.[5]

Comparison of procedures

Insofar as these procedures are employed for similar indications, arguments of enucleation versus evisceration have endured for decades, with their perceived advantages and disadvantages fuelling the debate. In fact, in the late 19th century, the argument went so far as to prompt the United Kingdom Ophthalmological Society to charge a committee with assessing the relative value of the procedures.[6] Although the report concluded that simple extirpation of the globe from the Tenon capsule, with or without placement of a glass implant, was the recommended procedure, the report was not unanimously accepted. A smaller report was subsequently filed asserting necessity for enucleation only in very specific cases, including intraocular or intraorbital malignancy, markedly shrunken globes, or in cases where SO is present.

More than a century later, ophthalmic surgeons remain divided on this issue. In a 1996 survey of United States oculoplastic surgeons, Levine et al[7] found that 72.3% of respondents preferred enucleation to evisceration. In a study from the University of Copenhagen, Hansen et al[8] compared pathology specimens received in 3 different periods: 1975-76, 1985-86, and 1995-96. Conversely to the conclusion by Levine et al, they found a significant decrease in enucleations and an increase in eviscerations over this time period. A 2012 longitudinal comparison of indications, complications, and relative frequencies of eviscerations and enucleations at a single academic centre in Washington, DC, by Yousuf et al[9] also found a significant decrease in the average number of enucleations and an increase in eviscerations.

Studies comparing the clinical outcomes of eviscerations to enucleations are rare. Nakra et al[10] found that although esthetic outcomes were similar between evisceration and pegged enucleation, implant motility was significantly better in eviscerated eyes. This group also found significantly more postoperative complications in enucleated patients (21.9%) than in eviscerated patients (13.5%). The most frequent complication was implant exposure, which was also significantly higher in enucleated patients than eviscerated patients (12.5% versus 3.8%). Sympathetic ophthalmia was not reported in any of the 84 patients. Yousuf et al[9] found no difference in implant exposure between eviscerated and enucleated patients, but reported significantly shorter operating time for evisceration, as well as increasing preference for evisceration over enucleation over a 20-year period.

The perspective of ocularists, who have significant longitudinal interactions with these patients, should inform this debate considerably. From their point of view, evisceration provides far superior socket stability, exposure rates, and motility. A 2002 survey of US ocularists by Timothy et al[11] found that 82% of the 85 respondents believed that evisceration provides superior motility compared to enucleation. Overall, 92% of surveyed ocularists indicated evisceration was their primary choice of procedure for eye removal. For blind, painful eyes, without suspicion of intraocular malignancy, it would be a disservice not to consider evisceration in the surgical management of these patients.

Enucleation has classically been the preferred choice of orbital surgeons for various reasons. Proponents of enucleation assert a decreased risk of SO with complete removal of uvea, as well as the potential to restore greater orbital volume without the constraints of the patient's residual sclera. This may be of particular concern in phthisical globes where evisceration may provide unsatisfactory implant volume. Furthermore, enucleation eliminates the risk of leaving in place an unidentified intraocular malignancy, and full histopathological study is only available with enucleated globes. However, evisceration-related SO has declined dramatically since the 1970s and is now very rare. Furthermore, ease and speed of surgery, as well as improved motility and similar or less complication rates have popularized evisceration in recent years for treatment of blind, painful eyes or following severe ocular trauma with no visual potential. The relative advantages of enucleation and evisceration are listed in Table 1.

Two issues deserve special mention in this discussion: the risk of sympathetic ophthalmia, and the possibility of overlooking an occult intraocular malignancy.

Sympathetic ophthalmia (SO)

SO is a rare but potentially blinding condition characterized by bilateral granulomatous panuveitis and thought to result from an immune reaction against ocular antigens. The overall incidence of SO varies by series, but has been estimated at approximately 0.03 in 100,000 per year.[12] The interval between inciting trauma and the onset of SO ranges from days to decades. Proponents of enucleation cite the complete removal of the entire globe as the only means of abolishing the risk of SO. Indeed, in 1963, Ruedemann[13]

Table 1: Relative advantages of enucleation and evisceration

Enucleation	Evisceration
• Lower risk of sympathetic ophthalmia • Potential to restore greater orbital volume – Particularly important for phthisical globes • Eliminates the risk of leaving in place an unidentified intraocular malignancy – Full histopathological study is only available with enucleated globes	• Simpler, quicker procedure • Improved implant motility • Lower complication rate • Superior socket stability

summarized 47 reported cases of SO following evisceration, all of which occurred prior to 1917. In 1972, Green et al[14] reported a 4-case series of SO following evisceration. However, at least 5 more recent reports totalling more than 3000 patients have compared rates of SO between the 2 procedures.[7,8,10,15,16] No identified cases of SO were reported following evisceration. Thus, although enucleation may indeed offer absolute elimination of the risk of SO, this risk at baseline appears to be so remote as to give other factors significantly more credence in deciding which procedure to undertake.

Undiagnosed neoplasms

A second issue that deserves attention is that of undiagnosed neoplasms in blind eyes with opaque media. Novais et al[17] recently reported 4 unexpected neoplasms of 205 evisceration specimens (2.0%) collected between 1994 and 2011. Similar case series were reported by Eagle et al[18] (7 cases) and Rath et al[19] (6 cases). Eagle et al reported that some patients were misdiagnosed with conditions such as endophthalmitis, orbital cellulitis, or idiopathic orbital inflammation due to inflammation secondary to necrosis of the tumour and other tissues. It is impossible to extrapolate from these selected cases the true prevalence of unexpected neoplasms in the population; however, despite the apparent rarity of undetected neoplasms, these case reports underline the importance of ruling out this condition through meticulous preoperative history and examination and ophthalmic imaging.

Implant Material

As in the controversy over preferred ocular procedure, a variety of factors surrounding choice of orbital implant, in particular following enucleation, are also widely debated. Surgeons are divided in their preferences in a number of categories: bio-inert versus bio-integrated, spherical versus shaped, wrapped versus unwrapped, and pegged versus unpegged. In a 2004 survey of 1919 primary oculoplastic surgeons, Su and Yen[20] found that 42.7% preferred porous polyethylene, 27.3% selected HA, and 19.9% preferred nonporous alloplastic. Cost and hospital budget constraints may also play a significant role in determining implant choice.

An exhaustive discussion of all available and historical implants is beyond the scope of this article; the authors have highlighted those they consider significant in the evolution of orbital implantation.

Solid/inert implants

In 1884, Mules placed the first orbital implant, a hollow glass sphere, into an eviscerated socket.[4] In 1887, Frost placed the first glass implant into the Tenon capsule of an enucleated socket.[21] Since this time, many different materials have been used, and ongoing interest in the subject has primarily led to the evolution of orbital implants following enucleation. Early bio-inert materials such as glass, gold, silver, and silicone (Figure 1) replaced lost orbital volume effectively; however, their tendency for migration and exposure has led to the search for different materials.

In 1941, Ruedemann introduced partially exposed integrated polymethyl methacrylate (PMMA) implants, with extraocular muscles sutured directly to the implant.[22] Although acrylic implants incited very little host inflammation and improved implant motility, their long-term success was hampered by late implant migration and extrusion,[23] as well as suboptimal implant motility.

Porous bio-integrated implants

Focus shifted in the 1980s to porous implants,[24] which have crystalline structures with multiple interconnected pores. Fibrovascularization occurs within weeks, and tissue reaction is minimal. Porous implants offer many theoretical advantages, including less implant extrusion, potential for surface tissue to heal spontaneously via implant blood supply, less implant infection due to vascular growth within it, and poten-

Figure 1: Silicone sphere implant

Courtesy: Oculoplastik, Inc.

tial for soft tissue integration with extraocular muscles leading to improved motility.

Hydroxyapatite

The hydroxyapatite (HA) / corraline implant was first used by Perry in 1985.[25] As the first bio-integrated implant, the HA implant appeared to be an answer to the pitfalls of its bio-inert predecessors. With its interconnecting pores, the HA implant allowed fibrovascular ingrowth and integration. Motility was also improved with HA implants, both because extraocular muscles could be securely attached to the implant's enveloping mesh, but also by the novel possibility of implant pegging. Several drawbacks to HA soon became clear, however, including implant exposure, conjunctival thinning, socket discharge, pyogenic granuloma, implant infection, and persistent pain. Furthermore, the cost of HA implants (CAD $650) was significantly higher than bio-inert silicone or PMMA (CAD $15-$50), as well as the associated costs of magnetic resonance imaging (MRI) for assessment of implant vascularization and secondary pegging procedures.[25]

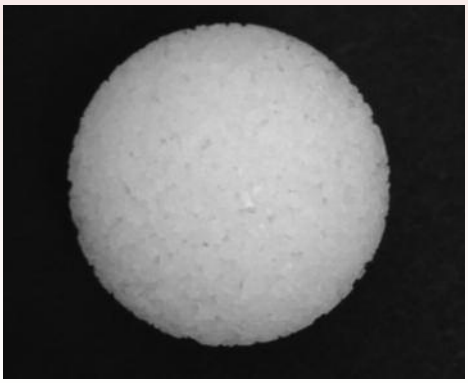
Polyethylene

Synthetic porous implants made of polyethylene were developed as an alternative to HA (Figure 2). These implants have a smoother surface than HA, and can be differentially fashioned to be smooth on the anterior surface with larger pores for bio-integration posteriorly, thus producing less conjunctival erosion than HA. Extraocular muscles can be directly sutured to synthetic porous implants, without the enveloping mesh that is necessary in HA implants. The cost of these implants is also approximately $200 less than HA.

Ceramic

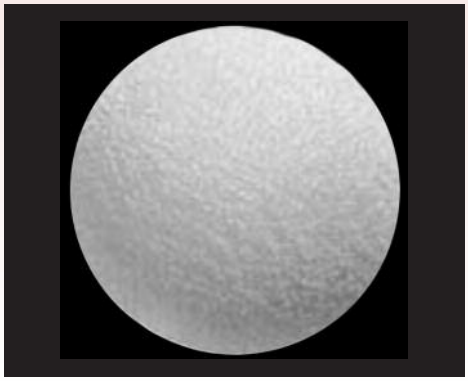
Ceramic (aluminum oxide) implants were approved for use in Canada in 2001 (Figure 3).

Figure 2: Polyethylene



Courtesy: Michael Webb

Figure 3: Bio-ceramic sphere implant



Courtesy: Oculoplastik, Inc.

Ceramic is a lightweight, inert, porous material with similar potential for fibrovascular ingrowth as HA. Osteoblasts and fibroblasts proliferate faster on ceramic than on HA, allowing more rapid tissue integration. Furthermore, ceramic has a much smoother surface than HA, as well as less post-operative tissue inflammation. Like synthetic porous implants, ceramic implants cost approximately $200 less than HA.

Wrapping

Porous implants may require a wrapping material prior to implantation into the orbit. Implants may be wrapped with donor sclera, bovine pericardium, autologous rectus abdominus sheath, or synthetic materials such as polyglactin mesh.[26] Wrapping allows careful attachment of extraocular muscles, especially in materials such as HA, which are too brittle to allow direct suturing of muscles. HA implants are also easier to place into the orbit when wrapped, and some authors have suggested that wrapping may decrease exposure rates. Wrapping increases the cost and time of the procedure, however, and may act as a barrier to the fibrovascular ingrowth that allows porous implants integration into the socket.

Pegging

Pegging is a secondary procedure that is possible in porous implants. The procedure involves drilling into the implant, followed by coupling the implant and prosthesis together. This creates a direct connection between them and theoretically improves motility. It is usually done at least 6 months after the primary implant is placed, and after a technetium bone scan or gadolinium enhanced MRI confirms adequate implant vascularization.[26] Although relatively few studies have measured the objective improvement in motility, a study by Gullinta[27] showed significant

improvement in horizontal excursion, and very high patient satisfaction scores. Nevertheless, several factors limit the use of pegging. It is associated with significant costs, including additional imaging and a secondary procedure. Pegging also introduces high rates of minor complications such as extrusion as well as the need to repeg. Furthermore, many patients are satisfied with the motility offered by their primary unpegged implant.

Although there are clearly theoretical advantages to porous over nonporous implants, it is unclear whether these translate to clinical advantages. Studies by Christmas et al[28] and Trichopoulos et al[29] found no statistically significant difference between groups receiving porous and nonporous implants. In contrast, Nunery et al[30] reported significantly more exposure in HA implants compared to silicone implants.

Clinical Examination and Complications

Close follow up after eye removal procedures is critical, both in the short and long term, and should involve both the ocularist and the treating ophthalmologist. The patient should be assessed by the treating surgeon within the first postoperative week, and is usually also seen by the ocularist within the first 2 weeks following surgery.

At these and ensuing visits, the socket is evaluated for more common complications, including irritation, bleeding, implant exposure, contraction of the fornices, and Tenon prolapse. The conformer is also assessed for fit: it should sit snugly within the socket without significant friction with the posterior conjunctiva or implant. An ill-fitting conformer can provoke bleeding and mucus production, as well as conjunctival dehiscence, leading to exposure and (rarely) extrusion of the implant. If the conformer is not properly fitting, a custom conformer can be fabricated by the ocularist to help control the edema and stabilize the socket for fitting the final prosthesis. Approximately 4–6 weeks following surgery, the socket is typically ready to be fit with a custom prosthesis.

Fortunately, frank implant extrusion is a relatively uncommon complication of the anophthalmic socket, and sympathetic ophthalmia is exceedingly rare.

Psychological effect

Significant consideration should be given to the psychological impact of loss of an eye from the patient's perspective. Goulart et al[31] concluded that the loss of an eye was significantly associated with emotional difficulties, and that prosthetic replacement is an important element of social inclusion. Nijhawan et al[32] noted a significant reduction in patient concern further to enucleation or evisceration since 1985. This improvement in psychological and esthetic acceptability is likely rooted not only in the advent of HA implants around this time, but also the trend toward oculoplastic specialists performing these procedures and the increasing support of ocularists in this unique multidisciplinary team.

Conclusion

After the therapeutic decision has been made for removal of a patient's eye, several additional factors must be considered. Controversy remains regarding the relative advantages of the 2 most common techniques, enucleation and evisceration. Ophthalmic surgeons remain divided on their surgery of choice, save in specific situations (eg, intraocular malignancy). Enucleation was previously preferred by the majority of surgeons, but recent literature suggests that evisceration is gaining popularity. Orbital implants in enucleated sockets have evolved over the past several decades and have incited much debate. Nonporous implants such as silicone and acrylic are relatively inexpensive and cause very little host inflammation. Conversely, porous implants offer a number of theoretical advantages by promoting fibrovascularization, including less exposure, the potential for spontaneous healing of surface tissue, reduced implant infection, and improved motility. Several studies have reported exposure rates to be similar between porous and non-porous implants. However, from the ocularist's point of view, porous implants provide a higher degree of socket stability and lessened rates of complications in the long term.

As these procedures and orbital implants have evolved, so too have the opinions and controversies surrounding them. Amid these disagreements, however, one thing is unequivocal. Improvements, especially over the last 30 years, now allow the ophthalmologist and the ocularist to offer a more functional and acceptable procedure for these most unfortunate patients.

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