The following discussion focuses on procedures performed by emergency clinicians during the evaluation and treatment of injuries and diseases of the eye. The emphasis is on the practical application of the techniques; cautions to be heeded by the emergency clinician are included.

VISUAL ACUITY ASSESSMENT

Visual acuity may initially be deferred in simple, obvious, or straightforward cases, such as a stye, periorbital laceration, or minor eye irritation; however, visual acuity assessment should be the first procedure performed in the majority of patients who present to the emergency department (ED) with an eye complaint. Whereas it may be initially deferred in the triage or trauma room setting, or under other relevant scenarios, it is incumbent upon the emergency clinician to ensure that visual acuity or function is ultimately adequately assessed.

Indications

Visual acuity should be done as soon as practicable and before the patient is examined with bright lights. In the event of blepharospasm from an injury (e.g., abrasion, chemical exposure), a topical anesthetic may facilitate the examination. Patients often present in the context of an eye complaint saying that they “can't see.” In these instances, emergent visual acuity assessment should first be performed beginning with the assessment of light perception, then hand motion, and finally counting fingers at 3 feet. If the patient succeeds in performing these assessments, a near vision card may then be used or distant visual acuity assessed. Under emergent circumstances, detailed formal vision testing is not essential; however, some form of visual acuity assessment is needed. In this situation, the ability to count fingers or read newsprint gives some indication of gross visual function. Formal visual acuity testing should never delay important therapeutic interventions such as eye irrigation.

Figure 63–1  The “routine” progression of visual acuity assessment is reversed in the emergent presentation. Assessing an intact visual pathway begins with quickly discerning whether the patient has light perception (LP), can see hand motion (HM), and can count fingers at 3 ft (CF). Subsequent progression to assess vision at 10, then 20, feet from a standard eye chart ensues.
Distant Visual Acuity Procedure

For formal vision testing, ask the patient to face a well-lit standard Snellen or similar eye chart from a premeasured distance of 20 feet. Use a card or the palm of the hand to occlude one eye at a time. If possible, all patients should be examined while wearing their current lens correction in order to obtain the best corrected distant visual acuity. If this is not available, measure visual acuity first without correction, then with a pinhole device, and note any improvement in visual acuity. This device functions as a corrective lens by reducing corneal refractive error. In general, visual acuity is improved with the pinhole device. Decreased visual acuity that is not improved with this device suggests that corneal refractive error is not the cause. Construct a pinhole device by punching several holes in the center of a card (3- × 5-inch index card) with an 18-gauge needle. Devices with one or more pinholes drilled into an eye cover are available commercially (Fig. 63–2A and B). Figure 63–2C presents a chart for visual acuity testing while the patient is on a stretcher or in a chair. The chart can be used directly from this text if it is held 14 inches from the eye. Begin by testing the affected eye or the one presumed to have the worst visual acuity. First, instruct the patient to read the smallest letters on the chart that can easily be seen. Then, ask the patient to read letters that can just barely be made out (i.e., they do not have to be clear). If the patient is unable to read the largest letter on the chart, move the patient to one half the distance from the chart (10 ft) or move the figure 7 inches closer to the edge and repeat the procedure. Record the results reflecting the change in distance (e.g., 10/200). The numerator in the vision ratio is the distance of the patient from the chart and the denominator is the distance at which a patient with normal vision can read the line of letters. For the patient who still cannot read the letters on the chart, test vision progressively as follows: ability to count fingers, detect hand motion, perceive light (with or without projection and ability to perceive the direction of light), and finally inability to perceive light.[2]
Figure 63–2 A commercial pinhole device reveals refractive error caused by corneal aberration (excess tearing or nearsightedness). A, First measure visual acuity without the device. B, Then measure with the pinhole cover lowered. Document the acuity with and without the pinhole device. C, If the patient cannot stand or a formal eye chart is not available, ask the patient to read this “distance equivalent” chart by holding this Figure 14 inches away from the patient.

Near Visual Acuity Procedure

Perform near visual acuity in the ED at the bedside or at triage. Hold a pocket near vision card (see Fig. 63–2 C) or any printed material at a distance of approximately 14 inches in good light in front of the patient and occlude each eye alternately as described earlier. When using available printed material in lieu of a near vision card, measure the size of the letters that are discerned by the patient. At a later time, compare these with the letter size on the near vision card to deduce the actual visual acuity. When near vision is decreased, it is usually either from loss of visual function or as a result of poor accommodation from advancing age (presbyopia). Less commonly, it is caused by traumatic mydriasis. Thus, examine patients with presbyopia with their reading correction in place to obtain the best corrected near visual acuity.

For patients who cannot communicate or in whom factitious blindness or malingering is suspected, check for optokinetic nystagmus (OKN) to determine whether there is an intact visual pathway. To test for OKN, pass a regularly sequenced pattern in front of the eyes. If an optokinetic drum is available, rotate the drum in front of the patient (Fig. 63–3). This is not available in many EDs, however. In place of the drum, substitute a printed piece of paper such as newsprint (without photographs or large areas with no print) or a standard tape measure. Pass it in front of the patient's eye at reading distance while instructing the patient to look at it
as it rapidly moves by. Evaluate for tracking as demonstrated by nystagmus-like eye movements seen when the test object is moved from side to side in front of the patient. This movement indicates an intact visual pathway. Finally, another effective method is to hold a mirror in front of the patient and slowly rotate the mirror to either side of the patient. The patient with an intact visual pathway will maintain eye contact with herself or himself as demonstrated by eye movement as the mirror is moved. A large mirror that reflects the patient’s entire face is most effective for this purpose.

Figure 63–3  Optokinetic nystagmus (OKN) testing will determine whether there is an intact visual pathway. Induce OKN by passing a regularly sequenced pattern in front of the eye such as this commercially available drum. Hold the drum in front of the patient. Direct the patient to look at the drum as you rotate it slowly. Alternatively, draw a tape measure across the line of sight while asking the patient to look directly at it as it passes.

All patients with decreased visual acuity from their baseline require routine referral for further ophthalmologic follow-up; however, those patients with moderately or severely decreased visual acuity not explained by refractive error require ophthalmologic consultation in the ED.
DILATING THE EYE

Dilating the eye is useful for both diagnostic and therapeutic purposes. Be advised, however, that an attack of narrow-angle (angle-closure) glaucoma may be precipitated by dilating the pupil. The most common form of glaucoma, however, is open-angle glaucoma and this type is not precipitated by dilating the pupil. Some patients may have a “mixed-mechanism” glaucoma with both open-angle and narrow-angle components. Systemic reactions, such as bradycardia from β-blocker eye drops, can be produced by mucosal absorption of dilating medications.

There are two types of dilators: sympathomimetic agents, which stimulate the dilator muscle of the iris, and cycloplegic agents, which block the parasympathetic stimulus that constricts the iris sphincter. Cycloplegic agents also block the contraction of the ciliary muscles, which control the focusing of the lens of the eye. This second effect of cycloplegic agents is of great importance in the therapeutic use of dilators for iritis.

Cycloplegic agents were used cosmetically as early as Galen’s time. Beginning in the early 1800s, extracts from the plants Hyoscyamus and belladonna were used in ophthalmology. Atropine was first isolated in 1833. Epinephrine was used on eyes in 1900 as the first sympathomimetic agent. [3]

Indications and Contraindications

There are diagnostic and therapeutic indications for dilating the pupil. Dilation is indicated for diagnosis when the fundus cannot be examined adequately through an undilated pupil. The elderly patient with miotic pupils and cataracts is an example of a patient in whom dilation may facilitate funduscopic examination. Dilation is therapeutically useful for many ophthalmic conditions, including inflammation in the eye. In the emergency setting, corneal injury with a secondary traumatic iritis is a common example. Dilation helps the inflamed eye in two ways. First, it may hinder adhesions (synechiae) from forming between the iris and other ocular structures. Such adhesions eventually limit the movement of the pupil and may precipitate glaucoma. Second, cycloplegic dilating agents relax the ciliary muscle spasm that often accompanies an inflamed eye and thus may reduce the pain associated with inflammation. Although traditionally used for these purposes, both benefits are largely theoretical with little formal evidence to support or refute their use in the ED.

Dilation is discouraged in the patient with head injury at risk for herniation, when it is necessary to monitor pupil findings. Dilation is contraindicated in the presence of narrow anterior chamber angles. Patients who are predisposed to having narrow angles may be unaware of this condition. Evaluate the depth of the anterior chamber before this procedure and do not dilate the eye if there is any question of a narrow angle. To estimate the depth of the anterior chamber, shine a penlight in tangentially from the lateral side of the eye. When the depth of the anterior chamber is normal, a uniform illumination of the iris is seen. However, when there is a forward convexity of the iris in the case of a narrow anterior chamber, only a sector of iris is illuminated and there will be a shadow on the medial (nasal) side of the iris (Fig. 63–4). With a slit lamp, the depth of the anterior chamber angle can be assessed directly. The definitive test for assessing the anterior chamber angle is gonioscopy, in which the anterior chamber angle structures are viewed directly by means of a special mirrored contact lens and the slit lamp. Gonioscopy is not a technique normally performed by emergency clinicians.
A. Normal anterior chamber

B. Shallow anterior chamber

C. Correct: Light source perpendicular to visual axis—positive finding

D. Incorrect: Light source too far anteriorly—false negative finding
Systemic effects can develop after the application of eyedrops. Review the following sections on agents and complications before using these drugs in patients with compromised cardiovascular function.

**Agents**

Only two dilating agents are really needed in the ED. Phenylephrine (Neo-Synephrine) 2.5% is used for diagnostic dilation of the pupil for visualization of the fundus. The drug is short-acting, and because accommodation is not affected, the patient's vision is not altered. Phenylephrine 10% should not be used routinely because it can be absorbed systemically and, in rare cases, has caused hypertensive crisis, myocardial infarction, and death.

For therapeutic cycloplegia in iritis, homatropine 5% works well. Although Table 63–1 indicates a maximum duration of 3 days, 24 hours is more common. Therefore, homatropine 5% is a useful therapeutic agent for traumatic iritis. Atropine should not be used for traumatic iritis because the undesirable effects of pupillary dilation and blurred vision persist for a week or longer after healing of associated corneal abrasions. Atropine drops may be prescribed as part of the therapy for nontraumatic iritis after appropriate ophthalmologic consultation. Individuals with lightly pigmented irides tend to have a greater sensitivity to the cycloplegic agents than do individuals with greater pigmentation; the cycloplegic effect might, therefore, be more prolonged in people with light eyes. It might be difficult to dilate some patients with deeply pigmented irides, and numerous applications of drops might be required.

**TABLE 63–1 -- Mydriatic Agents**

<table>
<thead>
<tr>
<th>Agent</th>
<th>Maximum Mydriasis</th>
<th>Duration of Mydriasis</th>
<th>Common Trade Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sympathomimetics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenylephrine †, 2.5% [†]</td>
<td>20 min</td>
<td>3 hr</td>
<td>Neo-Synephrine</td>
</tr>
<tr>
<td>Cocaine, 5% or 4%</td>
<td>20 min</td>
<td>2 hr</td>
<td>—</td>
</tr>
<tr>
<td><strong>Parasympatholytics (Cycloplegics)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drug</td>
<td>Duration</td>
<td>Effect</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------</td>
<td>-------------------------</td>
<td></td>
</tr>
<tr>
<td>Atropine, 1%</td>
<td>40 min</td>
<td>12 days</td>
<td></td>
</tr>
<tr>
<td>Scopolamine, 0.25%</td>
<td>30 min</td>
<td>7 days</td>
<td></td>
</tr>
<tr>
<td>Homatropine, 5% [‡]</td>
<td>30 min</td>
<td>1–3 days</td>
<td></td>
</tr>
<tr>
<td>Cyclopentolate, 1%</td>
<td>30 min</td>
<td>6–24 hr</td>
<td></td>
</tr>
<tr>
<td>Tropicamide, 1%</td>
<td>30 min</td>
<td>4 hr</td>
<td></td>
</tr>
</tbody>
</table>

* Preferred for funduscopic examination.
† A 10% solution may produce cardiovascular reaction and hence should not be used.
‡ Preferred for iritis or corneal abrasion therapy.
§ The duration of effect shows considerable individual variation. These are general estimates.

Maligners may use mydriatic agents to dilate a pupil unilaterally for the purpose of feigning neurologic disease. Normally, a pupillary dilation caused by intracranial third cranial nerve compression will constrict with 2% pilocarpine eye drops. The mydriatic-treated eye can be identified by full motor function of the third cranial nerve and the absence of miosis after pilocarpine instillation. A fixed and dilated pupil in an awake and alert patient cannot be secondary to brain herniation. Although other neurologic problems may be present, in the normal-appearing patient with a fixed and dilated pupil, a pharmacologic cause is highly likely. It should be noted that legitimate patients may not recall the name of an eye medicine that they used but will usually recall whether the bottle had a red cap, as is found on all cycloplegic solutions. An unexpected mydriasis in a trusted patient may be the result of such an agent. Medications that constrict the pupil, such as pilocarpine, have a green cap. Pressure-lowering drops for glaucoma may be yellow- or blue-topped (β-blockers), purple-topped (adrenergic agents) or orange-topped (topical carbonic anhydrase inhibitors).

A fixed and dilated pupil from a pharmacologic cause may be encountered after both nasotracheal and orotracheal intubation (Fig. 63–5). In such ill or injured patients, cerebral herniation must be considered. When phenylephrine is used to constrict the nasal mucosa prior to nasal intubation (endotrachial tube, nasogastric tube), the inadvertent contamination of the eye will cause a fixed and dilated pupil. The same scenario may occur after endotracheal epinephrine has been instilled into the lungs during resuscitation, and cardiopulmonary resuscitation has expelled epinephrine into the eye. Under such scenarios, the affected pupil will not constrict after intraocular pilocarpine administration. Finally, a fixed and dilated pupil might occur from inadvertent contamination of the eye with scopolamine after application of a scopolamine patch.
A, After phenylephrine (Neo-Synephrine) drops were instilled in the nose to facilitate tube passage, this comatose patient was nasotracheally intubated for his drug overdose. B, On a subsequent examination, a unilateral fixed and dilated pupil was noted. The pupil dilation was from Neo-Synephrine nose drops that were snorted from the nose into the eye during intubation, simulating cerebral herniation. Other unusual causes of a fixed and dilated pupil are endotracheal epinephrine expelled from the lungs and splashed in the eye during cardiopulmonary resuscitation and inadvertent contamination of the eye after application of a scopolamine patch behind the ear.

Procedure

The instillation of mydriatic agents is similar to the administration of other eye solutions. For medicolegal purposes, note the visual acuity before the instillation of the medicine. This documents that any decreased vision is not the result of the mydriatic agent. Whenever dilation is performed, note on the patient’s chart the dose and time that agents have been given to avoid confusion during subsequent neurologic evaluation.

Place the patient in a supine or a comfortable semi-recumbent position. Instruct the patient to gaze at an object in the upper visual field, such as a fixture on the ceiling. Gently depress the lower lid using a finger on the epidermis (Fig. 63–6). Instill a single drop of the solution into the lower lid fornix, and ask the patient to blink to spread the medication. Do not use more than a single drop because it produces reflex tearing and reduces the concentration in contact with the conjunctiva. Forewarn the patient that the medication is uncomfortable when it goes into the eyes. After the medication is in, the patient may blot the eye when it is closed but should not rub it with a tissue. If the desired effect is not noted in 15 to 20 minutes, repeat the dose, but this is seldom required.
Figure 63–6  A, Administration of eye drops. The patient should lie in a supine position or with the head tilted back. The patient's gaze should be directed upward. Pull the lower lid downward and instill a single drop of medicine in the lower conjunctival fornix. Instruct the patient to close the eyelids for 1 minute to increase the contact of the medicine with the globe and to decrease the medication outflow down the tear duct and over the lid margin. B,
If administering large amounts of eye drops that have systemic effects, such as β-blocker drops, the operator’s index finger is placed under the inferior eyelid along the nasal borders of the eye, firmly compressing the nasolacrimal duct against the globe for a few minutes, thereby preventing migration of the drops into the nose and reducing systemic absorption. (A, From Thomsen T, Setnik G [eds]: Procedures Consult—Emergency Medicine Module.

Complications

As mentioned in the section on “Indications and Contraindications,” any dilator can precipitate an attack of angle-closure glaucoma in susceptible patients. [10] In a case of angle-closure glaucoma, it may take several hours before symptoms become evident. The patient often complains of smoky vision with “halos” around lights as well as an aching pain that is sometimes severe. There may be nausea and vomiting. If the affected eye becomes injected in association with a hazy cornea, elevated pressure on tonometry, and an oval, fixed pupil, consult an ophthalmologist immediately. The treatment usually includes osmotic agents, carbonic anhydrase inhibitors, β-blocker drugs, pilocarpine, and later, definitive laser or surgical procedures (Table 63–2).

<table>
<thead>
<tr>
<th>TABLE 63–2 -- Treatment Options for Acute Angle-Closure Glaucoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pilocarpine 4%: 2 drops every 15 min for 1–2 hr *</td>
</tr>
<tr>
<td>2. Glycerol: 1 mL/kg by mouth (as 50% solution in citrus juice)</td>
</tr>
<tr>
<td>3. Mannitol: 1.5–3 g/kg intravenously over 20 min (as 20% solution) *</td>
</tr>
<tr>
<td>4. Acetazolamide: 500 mg intravenously *</td>
</tr>
<tr>
<td>5. β-Blocker drugs (e.g., timolol 0.5%) 1 drop every 30 min for 2 doses * [†]</td>
</tr>
<tr>
<td>6. α2-Agonist (apraclonidine [Iopidine] 0.5%) 1 drop [†]</td>
</tr>
</tbody>
</table>

* First-line therapy.
† May cause cardiovascular effects.

Be aware that using an eye medication might introduce infection. Most solutions contain bactericidal ingredients, but contamination of the tips of the droppers can still occur. [11] Use only newly opened bottles of eye medication, particularly if there is a deep corneal injury or if the patient has recently had eye surgery. Promptly discard out-of-date drops and drops in which crust or other material is found around the nozzle.

Forewarn the patient that any cycloplegic (in contrast to a sympathomimetic) will blur a patient’s near vision. Vision will be less blurred in adults older than 45 years of age, who generally have a reduced ability to focus for near vision. Although most adults will be able to drive safely, even with both eyes affected, it is advisable to have someone else drive whenever feasible. Light sensitivity caused by pupillary dilation may also be bothersome; sunglasses are sufficient for this problem.

Systemic reactions can rarely be produced by sympathomimetic and cycloplegic eyedrops. [4] [5] [6] [7] [8] [9] [10] In one report of 33 cases of adverse reactions associated with 10% phenylephrine, there were 15 myocardial infarctions (11 deaths), 7 cases of precipitation of angle-closure glaucoma, and a variety of systemic cardiovascular or neurologic reactions. [9]

After instillation of eye drops into the conjunctival sac, systemic absorption can occur through the conjunctival capillaries as well as by way of the nasal mucosa, the oral pharynx, and the gastrointestinal tract after passage through the lacrimal drainage system. Mucosal hyperemia enhances absorption. Symptoms can often be avoided by maintaining digital pressure on the nasal canthus, thus occluding the puncta, for several minutes after administration. [4]
THE FLUORESCEIN EXAMINATION

Perform fluorescein staining of the eye as part of the evaluation of all cases of eye trauma and infection. It is a quick and easy technique that is crucial for the proper diagnosis and management of common eye emergencies. View the fluorescein-stained cornea and conjunctiva under a “blue” light and ideally in conjunction with slit lamp magnification (see “Slit Lamp Examination,” later in this chapter).

Sodium fluorescein is a water-soluble chemical that fluoresces. It absorbs light in the blue wavelengths and emits the energy in the longer green wavelengths. It fluoresces in an alkaline environment (such as in the Bowman membrane, which is located below the corneal epithelium), but not in an acidic environment (such as in the tear film over an intact corneal epithelium). [12] Thus, it is useful in revealing even minute abrasions on the cornea (Fig. 63–7).
This large corneal abrasion (arrow) is readily seen without the slit lamp when fluorescein is instilled into the eye. Smaller abrasions, or corneal injuries produced by keratitis or welder's arc flash injuries, require slit lamp evaluation to identify minor corneal defects. Even minor traumatic abrasions will escape detection with only a blue light examination by the naked eye. B, This patient had severe eye pain, diffuse scleral injection, and tearing. A slit lamp was needed to discover multiple corneal defects due to keratitis from welding without eye protection.

Fluorescein staining is indicated for evaluation of suspected abrasions, foreign bodies (FBs), and infections of the eye. This includes "simple" cases of conjunctivitis, which may actually be herpetic keratitis. Pepper spray exposure to the face has been associated with corneal abrasions, and these patients should be stained with fluorescein and evaluated with a slit lamp or Wood's lamp. Corneal defects may be seen after unprotected viewing of a welder's arc flame.

Fluorescein permanently stains soft contact lenses. Therefore, when fluorescein is used, remove soft contact lenses before instilling the fluorescein and caution the patient not to put the lenses back into the eye for several hours. Topically administered fluorescein is considered nontoxic, although reactions to a fluorescein-containing solution (not impregnated strips) have been described.
These reports consisting of vagal reactions\cite{18} and generalized convulsions\cite{19} are rare, not rigorously supported, and believed to be caused by agents other than fluorescein in the solution. If using one of these fluorescein-containing solutions rather than the fluorescein-impregnated strips, be aware of these potential, yet scientifically suspect, idiosyncratic reactions.

Be aware also that fluorescein dye may enter the anterior chamber of the eye in the presence of deep corneal defects. This form of intraocular fluorescein accumulation is nontoxic. When the anterior chamber is viewed under the blue filter of the slit lamp, a fluorescein “flare” is visible and should not be confused with the flare reaction noted with iritis.

**Procedure**

Theoretically, one should not use topical anesthetics before fluorescein staining, because some patients may develop a superficial punctate keratitis from the anesthetic\cite{12}, which can confuse the diagnosis. However, with patients who are tearing profusely and who are squeezing their eyes shut from an abrasion or an FB, the examination often is impossible if a topical anesthetic is not first used. Theoretical downsides notwithstanding, it is common practice to apply a local anesthetic before instilling fluorescein.

Grasp the fluorescein strip by the non-orange end and wet the orange end with 1 drop of saline. There are several conveniently available forms including a small bottle of artificial tears, or a 5-mL “bullet” or “fish” of normal saline commonly used for nebulizer treatments. Alternatively, wet the strip with tap water or the recently used local anesthetic drops. Once the strip is moistened, place it gently into the inside of the patient’s lower lid (Fig. 63–8). Withdraw the strip, and ask the patient to blink, which spreads the fluorescein over the surface of the eye. The key to a good examination is to have a thin layer of fluorescein over the corneal and conjunctival surfaces. If the strip is too heavily moistened before placing it in the lower fornix, the eye may become flooded with the solution, which makes the evaluation difficult. If too much dye accumulates, the patient can remove the excess by blotting the closed eye with a tissue. Conversely, placing a dry strip in the unanesthetized eye may be irritating. Next, use a Wood’s lamp (4× magnification), the blue filter of a slit lamp, or simply a penlight with a blue filter to examine the eye in a darkened room. Check for areas of bright green fluorescence on the corneal and conjunctival surfaces. The naked eye may not be able to see small defects. Ideally, use a slit lamp, with 10× or 25× magnification, to examine the stained cornea before ruling out a pathologic process. A new handheld magnification device, the Eidolon BLUMINATOR ophthalmic illuminator, provides an intense blue light-emitting diode (LED) light with 7× magnification (Fig. 63–9). After completion of the fluorescein examination, irrigate excess dye from the eye to minimize damage to the patient’s clothing from dye-stained tears.

![Image](image.png)

**Figure 63–8**  The fluorescein strip has been moistened with 1 drop of saline or topical anesthetic. Depress the lower lid and gently place a wetted strip onto the inside of the patient’s lower lid so that only the smallest amount is instilled. Excess fluorescein may obscure subtle findings and thus should be avoided. Fluorescein will permanently stain contact lenses not removed (as seen in this model).
Figure 63–9  The Eidolon BLUMINATOR ophthalmic illuminator provides an intense blue LED light with 7× magnification. (Courtesy Michael W. Ohlson, OD, FAAO, and Victor J. Doherty, Eidolon Optical, LLC.)

The Seidel test uses fluorescein to detect perforation of the eye. To perform this test, instill a large amount of fluorescein onto the eye by profusely wetting the strip. Examine the eye for a small stream of fluid leaking from the globe (Fig. 63–10). This stream will fluoresce blue or green in contrast to the orange appearance of the rest of the globe flooded with fluorescein.

Interpretation

Fluorescein is mainly used for evaluation of corneal injuries. Although conjunctival abrasions pick up the stain, most of the staining on the conjunctiva represents patches of mucus rather than a real pathologic condition. Corneal staining is more specific for injury and the pattern of injury often reflects the original insult.

Corneal staining patterns are illustrated in Figure 63–11. Abrasions usually occur in the central cornea because of the limited protection of the patient's closing eyelids. The margins of the abrasions are usually sharp and linear if seen in the first 24 hours. Circular defects are seen about embedded FBs and may persist for up to 48 hours after removal of a superficial foreign object. Deeply embedded objects may be associated with defects persisting for longer than 48 hours. Objects under the upper lid (including some chalazia) often produce vertical linear lesions on the upper surface of the cornea. When vertical lesions are noted, search diligently for a retained FB under the upper lid. Hard contact lens overuse diminishes the nutrient supply to the cornea. The central cornea receives the most injury and thus fluoresces brightly when stained. Ultraviolet light exposure from sunlamp abuse, snow blindness, or welding flash produces a superficial punctate keratitis, which in its mildest form may not be visible without a slit lamp. The central cornea is the least protected by the lids, and a central horizontal band–like keratitis can result. Herpetic lesions may develop anywhere on the cornea. Classically, these lesions are dendritic, although ulcers may also be punctate or stellate. [21][22]
Figure 63–11 Patterns of acute corneal injury. 1, Traumatic abrasion: usually with linear features and sharp borders when seen early (<24 hr). Occurs more in the central cornea. 2, Abrasion from foreign body (FB): vertical abrasions on the upper cornea seen when an FB is embedded in the upper lid. Also shown is a rust ring with a metallic FB. 3, Exposure pattern: seen with prolonged exposure to ultraviolet (e.g., welding flash, sunlamp exposure); produces bandlike keratitis over lower half of the cornea. Squinting in the setting of the bright light protected the upper corneal surface. 4, Herpes simplex keratitis: classic dendritic pattern. 5, Adenovirus keratitis: diffuse minute corneal staining seen in epidemic keratoconjunctivitis about 7 days after symptoms. 6, Contact lens overuse: central punctate staining.

Any area of corneal staining with an infiltrate or opacification beneath or around the lesion should alert the practitioner to the possibility of a viral, bacterial, or fungal keratitis. Obtain urgent ophthalmologic consultation so that cultures of the possible etiologic agents can be procured and appropriate treatment initiated.

Many Pseudomonas organisms fluoresce when exposed to ultraviolet light; therefore, presence of fluorescence before the instillation of fluorescein in the red eye should suggest the possibility of a pseudomonal infection.

**Summary**

Fluorescein staining is a quick, easy diagnostic procedure that should be part of every eye evaluation. The extra minute that the
examination takes provides a wealth of diagnostic information for patients with eye trauma or infection. With the exception of the reactions noted with fluorescein solution, the potential discoloration of soft contact lenses, and the potential for infection when premixed solutions rather than fluorescein-impregnated paper strips are used, no complications are associated with the procedure.
EYE IRRIGATION

The crucial first step in the treatment of chemical injuries to the eye is eye irrigation. Irrigate as clinically appropriate to the exposure and severity of the injury. Serious chemical injury to the eye requires irrigation at the site of injury, before the patient is brought to the ED. Corneal injury can occur within seconds of contact with an alkaline substance. Eye irrigation must often be continued in the ED.

This section discusses methods of irrigation. Although it is best to irrigate liberally, copious irrigation is not needed when the patient has gotten a small amount of a noncaustic, nonalkaline compound in the eye.

Indications and Contraindications

Irrigation is indicated for all acute chemical injuries to the eyes. Irrigation may also be therapeutic for patients having an FB sensation with no visible FB. Small, unseen foreign material in the conjunctival tissues may be flushed out with irrigation. There is no contraindication to eye irrigation, but if there is the possibility of a perforating injury to the eye, perform the irrigation especially gently and carefully.

Equipment

The following equipment is necessary for eye irrigation:

- Topical anesthetic, such as proparacaine 0.5%
- Sterile irrigating solution (warmed intravenous saline or lactated Ringer's [LR] solution in a bag with tubing)*
- A basin to catch the fluid
- Cotton-tipped applicators
- Gauze pads to help hold the patient's lids open
- Lid retractors
- Irrigating device (e.g., Morgan Therapeutic Lens, modified central venous catheter, or Eye Irrigator) for prolonged irrigation
- Optimal: 10 ml of 1% lidocaine added to a liter of irrigating fluid

* A balanced salt solution designed for eye irrigation is preferred by some (when available) and may produce less corneal edema with chemical injuries. Readily available normal saline and lactated Ringer's solution are equally well tolerated.

Procedure

Basic Technique

First, instill a topical anesthetic in the eye. Evert the eyelid and sweep out any particulate matter in the conjunctival fornices with a moistened, cotton-tipped applicator[15] (see Ocular FB Removal, * later in this chapter, and Fig. 63–12 ). Hold the eyelids open during irrigation. The easiest method is to use gauze pads to grasp the wet, slippery lids and hold them open. If the patient has severe blepharospasm, however, consider using lid retractors (Desmarres or paper clip retractors; Figs. 63–13 and 63–14 ). When lid retractors are used, be certain that the eye is well anesthetized, that the retractors do not injure the globe or the lids, and that chemicals are not harbored under the retractors. Be aware that simple retractors fashioned from metal paper clips (especially those that are nickel-plated and shiny) may have surface chipping, which can create an ocular FB. [26] Use caution to avoid ocular injury when using such a makeshift retractor.
Figure 63–12  Eye irrigation. Note the severe blepharospasm from a chemical irritation. If this prohibits eye opening, circumferentially inject lidocaine anesthetic into the obicularis oris muscle to paralyze eye closure (see Fig. 63–15). A, First apply anesthetic drops. B, Sweep the eye with a wet cotton swab to remove particulate matter from under the lids. C, Begin irrigation by streaming saline or Ringer's solution directly from an intravenous bag. (A and B, From Thomsen T, Setnik G [eds]: Procedures Consult—Emergency Medicine Module.
Figure 63–13 Devices for separating eyelids. Desmarres retractor (A) and a retractor improvised from a paper clip (B) allow active manipulation of lids. Free-standing specula may require a seventh nerve block to reduce blepharospasm. C, A lid retractor in place. D, Lid eversion is easily accomplished with a cotton applicator. Have the patient look down, grasp the eyelash, pull out the lid and turn it over the swab that has been placed over the upper lid. (A and B, From Fogle JA, Spyker DA: Management of chemical and drug injury to the eye. In Haddad LM, Winchester JF [eds]: Clinical Management of Poisoning and Drug Overdose, 2nd ed. Philadelphia, WB Saunders, 1990. Reproduced by permission.)

Deutsch and Feller [15] recommended an ipsilateral facial nerve block for severe blepharospasm (Fig. 63–15). To avoid swelling of the periorbital tissue, block the facial nerve just anterior to the condyloid process of the ipsilateral mandible. Place a subcutaneous line of anesthesia (2% lidocaine) to temporarily paralyze the orbicularis muscle.
Irrigate with normal saline or LR solution directed over the globe and into the upper and lower fornices. The choice of fluid initially is less important than initiating irrigation as rapidly as possible. If tap water is available at the scene of the injury, begin irrigation immediately with copious amounts of fluid before transporting the patient to the hospital. Teach out-of-hospital care providers to irrigate all acid injuries of the eye for at least 5 minutes at the scene and to irrigate all alkali injuries for at least 15 minutes. [27] [28] LR solution or normal saline is preferred over tap water or D5W for eye irrigation, because these are isotonic and do not contain dextrose. Dextrose can be quite sticky if spilled and might serve as a nutrient for an opportunistic bacterial infection. Although one clinical trial found a balanced salt solution less painful in patients with a chemical eye injury, [29] another volunteer study on uninjured eyes found that LR solution is better tolerated than normal saline and balanced saline solution when used with a Morgan lens. [30] Warmed fluids are also better tolerated than fluids at room temperature. [31] Warmed LR solution should be considered when both it and normal saline are available for eye irrigation.

Be careful to direct the irrigating stream onto the conjunctiva and then across the cornea without letting the stream splash directly onto the cornea, because the mechanical injury of the solution striking the eye can in itself be harmful. Direct irrigation of the cornea can result in the development of a superficial punctate epithelial keratopathy.

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**Figure 63–15 Injection points for facial and orbital anesthesia and akinesia.**

Prior to irrigation, instill anesthetic eye drops, such as 0.5% tetracaine. Adding 10 ml of 1% lidocaine to a liter of saline irrigating fluid can decrease patient discomfort during prolonged irrigation.

Duration of Irrigation

Although Deutsch and Feller\[15\] recommended that a full liter of irrigating solution be used in every case of caustic injury, the duration of the irrigation is best determined by the extent of exposure and the causative agent. Acids are quickly neutralized by the proteins of the eye surface tissues and, once irrigated out, cause no further damage. The only exceptions are hydrofluoric and heavy metal acids, which can penetrate through the cornea. Alkalis can penetrate rapidly and, if not removed (because of the slow dissociation of the cation from combination with proteins), will continue to produce damage for days.\[15\] Therefore, prolonged irrigation is indicated; at least 2 L of solution should be used. Although rapid flushing with the first 500 mL is prudent, slow continuous irrigation as discussed later at a rate sufficient to generate a continuous trickle is often more effective and better tolerated than continued high-volume flushing. If the nature of the offending agent is in doubt, use prolonged irrigation.

Consult ophthalmology for all alkaline, hydrofluoric acid, and heavy metal acid injuries. Irrigation on an inpatient basis may be required for a period of 24 hours or more. This is especially likely when the cornea is hazy or obviously thickened. Note that the magnesium contained in sparklers combines with water from tears to produce magnesium hydroxide.\[32\] Treat such fireworks injuries as alkaline injuries rather than thermal injuries. Treat eye damage from hair straighteners,\[33\] phosphate-free detergents,\[34\] and automobile airbags\[35\] as alkaline injuries also.

Measure the pH of the conjunctival fornices with a pH paper strip to check the effectiveness of irrigation. In addition to litmus paper, the pH indicator on urine multi-indicator sticks can be used. The pH indicator on urine dipsticks is conveniently closest to the handle; all the distal indicator squares can be cut off with scissors. The normal tear film pH is 7.4. Use the noninjured eye as a control if the results are equivocal. If the pH measured in the conjunctival fornices after the initial irrigation is still abnormal, continue irrigation. If the pH is normal after irrigation, wait 20 minutes and check it again to make sure that it remains normal, especially in the presence of an alkaline contamination. Delayed pH changes are usually the result of incomplete irrigation and inadequate swabbing of the fornices. In anticipation of this deficiency, measure the pH deep in the fornices. Consider double-lid eversion with a lid elevator to expose the upper fornix for swabbing, irrigation, and pH testing (see Fig. 63–12).

Prolonged Irrigation

Alkaline burns may require prolonged irrigation and it is essential to consult ophthalmology in these cases. The Morgan therapeutic lens is a contact lens-type irrigation device, that can provide slow, continuous irrigation once the more vigorous initial irrigation has been done. First, anesthetize the eye with topical anesthetic drops. Then, place the device carefully on the surface of the eye with the lids closed around the intravenous tubing adaptor (Fig. 63–16). Attach the intravenous tubing to the adaptor and provide continuous flow through the device onto the cornea and into the fornices. As the local anesthetic agents wash out during the irrigation process, the device can become uncomfortable, so reapply the anesthetic drops frequently during irrigation for patient comfort. Such short-term use of local anesthetics will not inhibit healing of the cornea.
Figure 63–16  A, Morgan therapeutic lens: Instill anesthetic drops. Attach the lens to intravenous solution (Ringer's lactate or saline) and start the flow wide open so the Morgan lens floats on the fluid (it does not rest on the cornea). B, Insertion: Have the patient look down, insert the lens under the upper lid. Have the patient look up, retract the lower lid, drop the lens in place. C, Release the lower lid over the lens and adjust the flow. D, Tape tubing to the patient's forehead to prevent accidental lens removal. Absorb outflow. DO NOT RUN DRY. To remove, continue the flow, have the patient look up, retract the lower lid—hold position. Slide the lens out; terminate the flow. E, Bilateral irrigations. Place the patient's head over a sink. Note: adding 10 ml of 1% lidocaine to a liter of saline irrigating fluid can lessen patient discomfort from prolonged irrigation. (D, Courtesy of Mortan, Inc., Missoula, MT; E, from Thomsen T, Setnik G [eds]: Procedures Consult—Emergency Medicine Module.

Complications

The only significant complication from irrigation is abrasion of the cornea or the conjunctiva. This can be a mechanical injury from trying to keep the lids open in an uncooperative patient, a small corneal epithelial defect from a Morgan irrigating lens, or a fine punctate keratitis from the irrigation itself. [36] For this reason, do not direct the stream directly onto the cornea. If a superficial corneal defect occurs, treat it in the usual manner. Deep or penetrating corneal injuries are likely to be the result of the caustic chemical and require emergency ophthalmologic consultation. Continue to provide slow continuous irrigation pending the arrival of the ophthalmologist. Some experimental evidence suggests that massive parenteral or oral ascorbic acid supplementation may prevent the development of deep corneal injury, [37] but this treatment has not gained universal acceptance.

Summary

Eye irrigation is easy, and complications associated with the technique are usually minimal. At times, the clinician may be unsure whether a chemical injury is toxic enough to warrant irrigation. If any doubt exists, err on the side of irrigating the eye, rather than omitting this vital procedure and permitting the progression of eye injury.
OCULAR FB REMOVAL

Patients with an external FB in the eye are frequently seen in EDs. They are often in pain and desperate for help. Maintain a high degree of suspicion for FB injuries and perforation of the eye because such injuries might be occult and not readily detected. Not all FB injuries are associated with pain. Glass embedded in the cornea may be particularly difficult to detect. This section is a review of the procedures for locating and removing extraocular FBs and appropriate postprocedural care. Finally, a brief discussion covers evaluating the eye for a potential perforation of the globe and to detect the presence of an intraocular FB.

Indications and Contraindications

Extraocular FBs must always be removed. The timing of removal and the technique required vary according to the patient's clinical status and the type of injury. For the most part, the emergency clinician can proceed directly to removal of the object using the techniques described in this section. When the patient is extremely uncooperative (e.g., an intoxicated patient, a mentally deficient patient, or a young child) or when the injury is complicated (e.g., deeply embedded object, multiple foreign objects from a blast injury, or possible globe penetration), consult ophthalmology immediately. A patient who presents with a suspected FB or abrasion after exposure to a projectile (e.g., grinding wheel, hammering, metal objects colliding) should be rigorously evaluated for the presence of a deep intraocular FB. See further discussion later in this chapter. A penetrating injury to the cornea is of particular concern because the iris tissue may prolapse and look like a corneal FB (Fig. 63–17). Hence, in addition to the history of projectile exposure, an irregular pupil, especially a pear-shaped pupil, should alert the clinician that a penetrating injury might have occurred.
Figure 63–17  Serious eye injuries. A, Corneal laceration with prolapse of the iris. The extruded iris is dark, mimicking a corneal FB. Often, the only clue is an abnormal pupil, and the extruded iris may not be appreciated as intraocular tissue. The pupil is irregular (often pear- or teardrop-shaped), pointing toward the laceration. B, A pear-shaped pupil without protrusion of the lens is a more subtle, yet characteristic, indication of a perforated globe. C, Another indication of a penetrating globe injury is periorbital fat protruding from an upper eyelid laceration. This patient was stabbed by a knife. D, This patient has an obviously cloudy lens soon after trauma. A projectile entered the temporal portion of the globe and produced a seemingly minor scleral hemorrhage. Patients with penetrating injuries to the globe should be treated with systemic antibiotics (such as cefazolin/gentamycin combination), tetanus toxoid if indicated, and antiemetics to control vomiting (which raises intraocular pressure). (A, Courtesy of Lawrence B. Stack, MD.)

Globe Protection

In the evaluation of a patient in whom a penetrating injury to the globe is suspected, perform a careful expeditious examination of the eye, preferably with a slit lamp. Avoid any pressure on the eye or rapid eye movements. If perforation is obvious (e.g., teardrop pupil, flaccid globe, flat anterior chamber, prolapsed iris) or confirmed by slit lamp (Seidel’s test positive; see Fig. 63–10), do not perform any procedures (save perhaps irrigation) and consult ophthalmology early for definitive diagnosis and care. Until the ophthalmologist has arrived, protect the eye from further harm by keeping the patient quiet, elevating the head of the bed, and placing a protective shield over the eye. Commercial shields are available for this purpose. When a metal shield is not available, construct a makeshift protective shield with available materials (e.g., paper, plastic, or Styrofoam cups; Fig. 63–18). The protective shield functions to avoid pressure on the globe and overlying tissues to prevent extrusion of vitreous and other ocular contents. Extend the shield edges up to or beyond the bony orbital rim for this purpose. Apply adhesive tape over the shield from forehead to cheek to secure the shield in position.
Figure 63–18 When a penetrating globe injury is suspected and a metal shield is not available in the emergency department or prehospital setting, a makeshift shield can be fashioned with available materials. A paper cup was used to fashion this shield.

If a patient has a globe perforation, treat with systemic antibiotics (a combination of cefazolin and gentamycin is a good initial choice), tetanus toxoid, and antiemetics in doses aggressive enough to halt vomiting.

**Equipment**

The following equipment is necessary for extraocular FB removal:

- Topical anesthetic, such as proparacaine 0.5%
- Sterile cotton-tipped applicators
- Fluorescein strips
- Magnification: loupes plus a Wood's lamp, Eidolon BLUMINATOR ophthalmic illuminator or a slit lamp
- Eye spud or 25-gauge needle attached to a 1- or 3-mL syringe or to the tip of a cotton-tipped applicator
- Dilator drops, such as homatropine 5%
- Antibiotic ointment, such as erythromycin
Consideration of Intraocular FB

When examining a patient with an ocular “FB” sensation, always remain cognizant of the potential for an intraorbital or intraocular FB. Penetrating injuries represent a greater threat of visual loss than an extraocular FB and can be disastrous if overlooked. Note that an intraocular FB can be deceptively subtle on initial presentation.

The clinical presentation is most helpful in determining which patients are at risk for a penetrating injury to the globe. An individual who complains of an FB sensation in the absence of trauma or one whose history is simply that something “fell” or “blew” into the eye is at low risk for a globe perforation. Conversely, there is a greater probability of globe penetration in the individual who has sustained a high-velocity wound to the eye (e.g., drilling, hammering, grinding metal, blasting rock). The presence of any of the following physical findings should alert the clinician to a probable intraocular FB: irregular pupil, shallow anterior chamber on slit lamp examination, prolapsed iris, positive Seidel's test (see "The Fluorescein Examination," earlier in this chapter), focal conjunctival swelling, hemorrhage, hyphema, lens opacification, and reduced intraocular pressure (IOP). Do not perform tonometry if penetrating injury to the globe is suspected. Be aware that a penetrating injury may not be associated with eye pain. If there is strong historical evidence and physical findings to support a diagnosis of globe penetration, obtain emergent ophthalmologic consultation.

An intraocular FB is often not visible on direct ophthalmoscopy. Although orbital radiography for radiopaque objects and ultrasonography of the globe have been used for indirect FB localization, computed tomography of the orbit is now considered the most useful technique. When plain orbital radiography is performed looking for an intraocular FB, be aware that an eyelid FB may mimic an intraocular FB. Patients with a suspected metallic FB should not undergo magnetic resonance imaging if the FB may be intraocular. Therapy for intraocular and intraorbital FBs must be individualized. Often, an ophthalmologist can localize an intraocular FB (if the vitreous is clear) using indirect ophthalmoscopy. The role of the emergency clinician is to suspect the diagnosis, to protect the eye from further harm, and to obtain ophthalmologic consultation. The remainder of this section addresses the problem of extraocular FBs.

**Procedure**

**FB Location**

The first step is to locate the FB. Apply a drop of topical anesthetic to the inside of the lower lid (see Fig. 63–6A). Vertical corneal abrasions from FBs under the lids are helpful for localizing these hidden foreign objects (see Fig. 63–11,2). Use a penlight and loupes or a slit lamp to examine the bulbar conjunctiva by having the patient look in all directions. Examine the inside of the lower lid by pulling it down with the thumb while asking the patient to look up. Evert the upper lid by asking the patient to look down as the end of an applicator stick is pressed against the superior edge of the tarsal plate of the upper lid. Meanwhile, grasp the lashes and pull down, out, and then up to flip the eyelid over (Fig. 63–19).
This patient complained of an FB in the eye, despite irrigation. **A**, Lid eversion (technique described in Fig. 63–13) revealed a small speck (arrow) under the upper lid. This could cause a cornea abrasion characterized by vertical striations. **B**, It was easily removed (arrow) by touching it with a moistened cotton-tipped applicator. **C**, This patient presented with a swollen and tender upper eyelid thought to be secondary to a stye. With lid eversion, a small pustule (arrow) was found under the upper eyelid. **D**, With a 27-gauge needle, the pustule was incised and a drop of pus was expressed; she made a rapid and uneventful recovery.
Minute FBs under the lid may be missed with simple visual inspection. Ideally, examine the everted lid under magnification with loupes or a slit lamp. With simple lid eversion, it is still not possible to see the far recesses of the upper conjunctival fornix. Although double eversion of the upper lid (see Fig. 63–12) is helpful, the best way to rule out an FB in the upper fornix is to sweep the anesthetized fornix with a moistened applicator as the upper lid is held everted. Examine the applicator tip for removed foreign material. Small conjunctival FBs not hidden by the lids are often best removed with a moistened nasopharyngeal swab (e.g., nasopharyngeal Calgiswab).

Reexamine the cornea. Most corneal FBs have an area of fluorescein staining around them. Use a slit lamp or other magnification device such as the BLUMINATOR to make the examination easier. If the clinician is limited to loupes and a penlight, shine the light diagonally on the cornea to locate the FB. With a history of a high-speed projectile hitting the eye, rule out an intraocular FB. In the case of a blast injury, multiple FBs may penetrate the eye. If an FB cannot be found on the surface despite a suggestive history, examine the eye for physical evidence of penetration, as discussed earlier. Dilate the pupil, and examine the fundus. Although not foolproof, bedside ultrasonography may identify the presence of a metallic FB (sensitivity of 87.5%, specificity 95.8%, with positive predictive value and negative predictive value of 96.5% and 85.2%, respectively). If in doubt regarding an intraocular FB, consider computed tomography and ophthalmologic consultation.

FB Removal

Once an extraocular FB is located, the technique of removal depends on whether it is embedded. If the FB is lying on the surface, eject a stream of water from a syringe through a plastic catheter, which will usually wash the object onto the bulbar conjunctiva. Once the FB is on the inner lid or bulbar conjunctiva, gently touch a wetted cotton-tipped applicator to the conjunctiva and the object will adhere to the applicator tip. Be aware that overzealous use of an applicator for corneal FB removal can lead to extensive corneal epithelial injury. A spud device is required for removal of objects that cannot be irrigated off the cornea.

To remove embedded corneal FBs (Fig. 63–20), use a commercial spud device, a bur drill, a short 25- or 27-gauge needle on a small-diameter syringe (e.g., insulin or tuberculin syringe), or a cotton-tipped applicator (Fig. 63–21A and B). Use the applicator or syringe as a handle for the attached needle. Contrary to what one might expect, it is difficult to penetrate the sclera or the cornea with a needle, especially when it is applied tangentially to the cornea. As with removal of conjunctival FBs, anesthetize the eye. Position the patient so that the head is well secured (preferably in a slit lamp frame). At this point, provide a simple explanation of the procedure, which usually ensures excellent compliance on the part of the patient. Rest your hand on the patient's cheek so that unexpected movements on the part of the patient will not result in large movements of the removal device. Instruct the patient to gaze at an object in the distance (e.g., the practitioner's ear when a slit lamp is used) to further stabilize the eye. Bring the removal device close to the eye under direct vision; then, while it is in focus, manipulate it under the magnification device (e.g., Wood's Lamp, Eidolon BLUMINATOR ophthalmic illuminator (see Fig. 63–9), or slit lamp) to remove the FB. Hold the device tangentially to the globe, and pick up or scoop out the foreign object. If a bur drill is used, press the side of the drill against the FB until removal is accomplished (see Fig. 63–21C).
Figure 63-20  This embedded corneal FB is readily seen under slit lamp examination. A removal device (needle, spud, or bur drill) should be used for careful removal. A rust ring will remain if the FB has been there for only a few hours.
It is preferable to remove the corneal FB under the slit lamp. Apply a topical anesthetic and use a small syringe with a short 25- to 27-gauge needle (such as a tuberculin syringe). Be certain that the needle is firmly attached to the syringe.

A. Under direct vision (not looking through the slit lamp), bring the syringe close to the eye while resting the hand on the patient's cheek. Be sure that the patient's forehead maintains continual contact with the crossbar on the slit lamp. B. While looking through the slit lamp, bring the needle to the cornea and remove the FB. C. Hold the side of the instrument (drill bit or beveled edge of the needle) tangential to the cornea. (A and B, From Knoop K, Trott A: Ophthalmologic procedures in the emergency department—Part III: Slit lamp use and foreign bodies. Acad Emerg Med 2:224, 1995. Reproduced by permission.)

During removal, rest your hand against the patient's face. It may be also helpful to brace the elbow with a pad or half-full tissue box to provide further support to the arm as the FB is removed. If right-handed, place your lower hand against the left maxillary bone when removing a foreign object from the patient's left eye and against the bridge of the patient's nose or infranasal area when removing an object from the right eye. If left-handed, reverse these positions. Using loupes or a slit lamp for magnification is highly recommended to minimize further injury during removal. In particular, corneal contact with the spud device is more readily discerned when magnification is used. Only topical anesthesia is required to remove FBs from the cornea. Although the patient may feel pressure during FB removal, pain should not be felt after the eye is anesthetized.

**Rust Rings**

A common problem with metallic FBs is that they develop rust rings (Fig. 63–22). These can develop within hours because of oxidation of the iron in the FB. There are two preferred techniques for removal of a rust ring. The most direct is to remove it at the same time as the FB, either with repeated picking away with a spud device or with a rotating bur. The second approach is to let the iron of the rust ring oxidize and kill the surrounding epithelial cells during a 24- to 48-hour period. After that, the rust ring will be soft and often comes out in one solid plug. Generally, a small rust ring produces little visual difficulty unless it is directly in the line of sight. The rust ring, if large, may delay corneal healing. Close follow-up is important to ensure healing of the cornea and total removal of the rust ring and FB.
Multiple FBs

If a patient has multiple FBs in the eye, such as from an explosion, refer him or her to an ophthalmologist. One technique that may be chosen by the ophthalmologist is to denude the entire epithelium with alcohol and remove the superficial FBs. The deeper ones gradually work their way to the surface, sometimes years later.

Aftercare

After removing the FB, an antibiotic ointment is frequently instilled. Although commonly used, the value of the ointment for superficial corneal defects after FB removal is unproved, and no specific standard of care is supported by scientific evidence. Conjunctival and corneal abrasions do not need patching. Data suggest that eye patching offers no benefit in healing corneal abrasions secondary to FBs. If the patient sustains a superficial injury from the FB, instruct her or him to return only if the eye does not feel completely normal or if there is any blurred vision. The majority of superficial injuries heal without difficulty. The patient should be warned that the FB sensation might return temporarily when the anesthetic agent has worn off. One animal study with direct ocular exposure to Clostridium tetani organisms suggested that nonpenetrating ocular injuries are unlikely to lead to tetanus. Tetanus prophylaxis after a corneal FB removal is not standard, but it may be considered. However, tetanus prophylaxis appears essential for injuries that penetrate through the cornea or sclera.
Use of Ophthalmic Anesthetic Agents

Application of topical anesthetic agents can be both diagnostic and therapeutic. Relief of discomfort with topical anesthetic use often suggests, but does not ensure, a conjunctival or corneal injury. An ocular irritant may also be masked by the use of these agents. Classic teaching is that patients should not self-administer the anesthetic preparations. It is thought that they delay wound healing by disrupting surface microvilli causing a decrease in the tear film layer and tear break-up time. Although self-administered topical anesthetic agents are now routinely used after photorefractive keratectomy (PRK) surgery for the first 3 or 4 postoperative days, this has not become a part of the ED practice. The absence of protective reflexes while the patient is under the effect of the medicine may encourage the patient to use the eye while an FB or a corneal infection inflicts further corneal injury. While not advised for outpatient use, topical anesthetic drops can be used safely for a few days without documented adverse effects.

Bartfield and coworkers found that the pain of instillation of 0.5% proparacaine was significantly less than that of 0.5% tetracaine. As evident from Table 63–3, the anesthetic solutions commonly used have a duration of action of less than 20 minutes. The patient with a large corneal lesion may need a more extended period of pain relief. The discomfort associated with a large healing corneal lesion is usually made tolerable by bedrest, opioid analgesics, and appropriate sedatives. Even in the absence of infection or a retained FB, the long-term repeated use of ophthalmic anesthetic ointments might be detrimental to corneal healing.

Table 63–3  -- Ophthalmic Anesthetic Agents

<table>
<thead>
<tr>
<th>Generic Name</th>
<th>Trade Name</th>
<th>Concentration (%)</th>
<th>Onset of Anesthesia</th>
<th>Duration of Anesthesia (min)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetracaine</td>
<td>Pontocaine</td>
<td>0.5–1.0</td>
<td>&lt;1 min</td>
<td>15–20</td>
<td>Marked stinging; also available in ointment</td>
</tr>
<tr>
<td>Proparacaine</td>
<td>Ophthaine, Ophthetic</td>
<td>0.5</td>
<td>&lt;20 sec</td>
<td>10–15</td>
<td>Least irritating; no cross-sensitization with other agents</td>
</tr>
<tr>
<td>Benoxinate</td>
<td>Dorsacaine</td>
<td>0.4</td>
<td>1–2 min</td>
<td>10–15</td>
<td>Only anesthetic compatible with fluorescein in solution</td>
</tr>
</tbody>
</table>

A final word of caution should be added regarding the use of ophthalmic solutions. Guaiac solutions are commonly supplied in dropper bottles similar in size and appearance to those containing ophthalmic solutions. Well-intentioned ED personnel may store the guaiac reagent bottles with the ophthalmic bottles. One should encourage both color-coding of the bottles and examination of them and their labels before each use to avoid corneal injury from inadvertently instilling guaiac reagent in the eye.

Complications

Complications associated with ocular FB removal are rare. The most frequent problem is incomplete removal of the FB. In such cases, the epithelium has difficulty healing over the affected area, and thus the eye stays inflamed. Eventually, the diseased epithelium either sloughs off and heals or heals over the FB remnants, which are gradually absorbed. In either case, the adverse effects on the eye are minimal; a minute scar on the cornea, even directly in the center, will rarely affect the vision. Nonetheless, incomplete removal of a corneal foreign object warrants ophthalmologic follow-up.

Conjunctivitis may develop after removal of an extraocular FB. In most cases, the bacteria producing the infection are introduced by the patient through rubbing of the irritated eye.

Although perforation of the globe by the clinician’s spud device is theoretically possible, this complication is exceedingly rare. Treatment of this type of corneal puncture wound consists of antibiotics, eye shield placement, and ophthalmologic consultation. In the absence of resultant endophthalmitis, permanent sequelae are unlikely to develop.

Epithelial injury can occur when cotton-tipped applicators are vigorously used to remove corneal FBs. Indeed, the use of cotton-tipped applicators for embedded corneal FB removal is condemned.

Summary

Ocular FBs are one of the most common eye emergencies. Searching for and removing the FB is usually straightforward. The only real trap is missing an intraocular FB. This must be ruled out if there is a history of a high-speed projectile hitting the eye or if physical findings suggest globe penetration.
Use of Ophthalmic Nonsteroidal Anti-Inflammatory Drugs

Ophthalmic nonsteroidal anti-inflammatory drugs (NSAIDs) have been evaluated for their effectiveness in the treatment of traumatic corneal abrasions. Examples include ketorolac tromethamine, diclofenac, and flurbiprofen. These agents are safe to use and effective for the relief of pain associated with corneal abrasions. [49] [50] [51] [52]

EYE PATCHING

Patching the lids shut has traditionally been the last step in treatment of a number of common eye emergencies; however, multiple studies have shown that eye patching offers no benefit in pain relief or healing rates with conjunctival or corneal abrasions. [43] [53] [54] [55] A meta-analysis of studies on eye patching and corneal abrasions or ulcers showed that patching might actually slow healing rates and patients might actually have worsening of pain. This was found to be true in children as well. [56] [57] [58] Patching is also contraindicated in contact lens wearers and in situations in which the abrasion or ulcer may be infected. [54] In summary, eye patching is no longer indicated and might actually worsen the ophthalmologic process that it once was thought to help. The use of a therapeutic bandage contact lens applied directly to the cornea has been recommended as a possible treatment for corneal epithelial defects. Evidence from several small studies suggests that a bandage contact lens is safe, effective, and well tolerated and allows a significant number of patients to immediately resume their regular activities while maintaining baseline visual acuity. Further study for the application of this modality in the ED setting is needed. [59] [60] [61] [62]
CONTACT LENS PROCEDURES

An estimated 24 million Americans wear a form of contact lenses. Removal of these lenses in the ED may be required to permit further evaluation of the eye or to prevent injury from prolonged wear. Emergency clinicians also evaluate patients for “lost” contact lenses, which may be trapped under the upper lid. At times, the patient may request that the clinician remove a lens that he or she has failed to extract from the cornea. Corneal ulcers may occur in patients who wear contact lenses and may require prompt treatment. This section on contact lens procedures addresses these concerns and discusses injuries associated with removal attempts, the mechanism of injury from prolonged wear, and instructions to be given to patients at discharge.

The first contact lenses were scleral lenses made of glass. These lenses, covering the cornea as well as much of the surrounding sclera, are reported to have been in use from 1888 to 1948. Glass corneal lenses (sitting entirely on the cornea) made by the Carl Zeiss Optical Works of Jena were first described in 1912. A practical synthetic scleral lens using methyl methacrylate rather than glass was discussed by Obrig and Mullen in 1938. In 1947, Tuohy redeveloped the corneal lens using methyl methacrylate. This was the forerunner of the current hard contact lens. The development in Czechoslovakia of lenses made of soft gas-permeable polymers was reported in 1960. These hydrogel (hydrophilic gelatinous–like) lenses have evolved into today's soft contact lenses. Soft contact lenses now come in a variety of types including extended and daily wear. The majority of soft contact lenses in use are now disposable.

Mechanism of Corneal Injury from Contact Lens Wear

**Hard Contact Lenses**

The oxygenation of the cornea is dependent on movement of oxygen-rich tears under the hard contact lens during blinking. During the “adaptation” phase of early wear, the wearer of hard contact lenses produces hypotonic tears as a result of mechanical irritation from the lens. This results in corneal edema, which reduces subsequent tear flow under the lens during blinking. Overwearing a lens at this time leads to corneal ischemia, with superficial epithelial defects predominantly in the central corneal area (see Fig. 63–11), where the least tear flow occurs. With adaptation, the tears become isotonic and the blinking rate normalizes, permitting increased wear time. During early adaptation, blinking is more rapid than normal and then slows to a subnormal rate during late adaptation. Mucus delivery to the cornea in the tear film may also play an important role in maintaining corneal lubrication. Tight-fitting contact lenses may never permit good tear flow despite an adaptation phase; individuals with tightly fitted lenses may never be able to wear their original contact lenses for longer than 6 to 8 hours. Lenses that are excessively loose can also cause irritation by moving during blinking. Rough or cracked edges can cause corneal abrasions.

In the ED, the patient who presents with irritation caused by prolonged wear may be either a new or an adapted wearer. The adapted wearer may have been exposed to chemical irritants (e.g., smoke), which reduce the tonicity of tears and lead to corneal edema and decreased tear flow. Alternatively, the adapted wearer with irritation may have ingested sedatives (e.g., alcohol) or may have fallen asleep wearing the contact lenses, thus decreasing blinking and tear flow. Another possibility is that the patient may actually be wearing tight-fitting contact lenses that have never allowed true adaptation despite many months of wear.

The patient with the overwear syndrome usually awakens a few hours after removing the lenses. The patient experiences intense pain and tearing similar to that caused by an FB. The delay in the onset of symptoms until after removal of the lenses is caused by a temporary corneal anesthesia produced by the anoxic metabolic byproducts that build up during extended lens wear. A second factor is the slow passage of microcysts of edema, which are pushed up to the corneal surface by mitosis of the underlying cells. When the cysts break open on the surface, the corneal nerve endings are exposed.

Most patients with the overwear syndrome can be managed with reassurance, frequent administration of artificial tears, oral analgesics, and advice to “wait it out” in a darkened room. Some patients require patching for comfort. A patient who has experienced no problems with contact lenses before an overwear episode can return to using the lenses after 2 or 3 days of wearing glasses but should be advised to build up wearing time gradually. A patient who was having chronic problems with lens comfort before the episode should check with an ophthalmologist before using the contact lenses again.

**Soft Contact Lenses**

Although there is also oxygenation of the cornea by way of the tear film with soft contact lenses, only approximately one tenth of
the flow behind the lens that occurs with a hard lens is present during soft contact wear. The high degree of lens gas permeability permits the majority of oxygenation to occur directly through the lens. The hydrogel lens is more comfortable than the hard contact lens because lid motion over the lens is smooth. The minimization of lid and corneal irritation allows a more rapid adaptation phase because the initial reflex-induced tearing and blinking changes are reduced. Nonetheless, the lenses may still lead to corneal edema and secondary hypoxic epithelial changes if worn for an excessive period when blinking is inhibited. Some individuals can tolerate the lenses for extended periods and may on occasion sleep with the contact lenses in place, although this practice is not encouraged. Newer extended-wear hydrogel lenses (e.g., Permalens) permit wear for several days without injury. These lenses are not discernible from standard soft lenses on examination.

Although the acute overwear syndrome that occurs with hard contact lenses can also occur with soft lenses, it is infrequent. More commonly, ocular damage from soft contact lenses falls into one of three categories:

1. **Corneal neovascularization.** Often, the patient is asymptomatic, but on slit lamp examination, fine vessels are seen invading the peripheral cornea. Refer the patient to an ophthalmologist to refit with looser or thinner lenses or with contact lenses that are more gas permeable.

2. **Giant papillary conjunctivitis.** The patient notes decreased lens tolerance and increased mucus production. On examination of the tarsal conjunctiva (best seen on eversion of the upper lid), large papillae are seen. These grossly appear as a cobblestoned surface. Instruct the patient to discontinue wearing the lenses until the process reverses and to see an ophthalmologist to have the lenses refitted.

3. **A sensitivity reaction to the contact lens solutions (usually thimerosol or chlorhexidine).** There is diffuse conjunctival injection and sometimes a superficial keratitis. Advise the patient to switch to preservative-free saline with the use of heat sterilization. Often, the contact lenses will need to be replaced before lens wear can be resumed.

All of these problems with soft lenses have bilateral, subacute onsets and do not require emergency treatment. The only form of ocular damage associated with soft contact lenses that is a true emergency is a bacterial (often *Pseudomonas* or *Acanthamoeba*) with soft contact lenses) or fungal corneal ulcer. Because the nature of soft contact lenses is to absorb water, they can also absorb pathogens, which then can invade the cornea. This is especially true if the soft lens is worn continuously for extended periods of time. The patient presents with a painful, red eye with associated discharge and a white infiltrate on the cornea. Immediately consult an ophthalmologist for appropriate culturing and antimicrobial treatment. These infections can permanently affect the patient's visual acuity.

**Indications for Removal**

Remove a contact lens in the following situations:

1. **Contact lens wearer with an altered state of consciousness.** The emergency clinician should always be aware that the patient with a depressed or acutely agitated sensorium might be unable to express the need to have her or his contact lenses removed. Furthermore, it is likely that patients with a depressed sensorium will have decreased lid motion. During the secondary survey of these patients, identify the presence of the lenses and arrange for their removal and storage to prevent harm from excessive wear or possible accidental dislodgment at a later time. Without magnification, soft contact lenses may be difficult to see. Examine the eye with an obliquely directed penlight to reveal the edge of the soft lens 1 to 2 mm from the limbus on the bulbar conjunctiva.

2. **Eye trauma with lens in place.** After measurement of visual acuity with the patient's lenses in place, remove them and perform a more detailed examination of the cornea. Fluorescein may discolor hydrogel lenses; when possible, remove extended-wear lenses before using this chemical. After the dye is instilled, flush the eyes with normal saline. Advise the patient to wait at least 1 hour before reinserting the lenses. The availability of single-use droppers of 0.35% fluorexon (Fluresoft) has permitted the safe staining of eyes when soft lenses are to be worn immediately after the examination. A limited eye irrigation after the use of fluorexon drops is still recommended before the reinsertion of soft contact lenses.

3. **Inability of the patient to remove the contact lens.** A patient may present with a hard contact lens that cannot be removed because of corneal edema from prolonged wear. Alternatively, the patient may present with a “lost” contact lens believed to be behind the upper lid. There is no urgency for contact removal in the out-of-hospital setting; hence, removal can wait until the patient has been evaluated by a clinician.

**Contraindication to Removal**

The only major problem with contact lens removal occurs when the cornea may be perforated. In this case, the suction cup technique of removal, described later, is preferred.

**Procedure**
A number of maneuvers have been devised for removal of the corneal lens. One technique is to first lean the patient's face over a table or a collecting cloth. Pull the lids temporally from the lateral palpebral margin to lock the lids against the contact lens edges. Ask the patient to look toward the nose and then downward toward the chin. This movement works the lower eyelid under the lower lens edge and flips the lens off the eye. The technique requires a cooperative patient because the clinician must pull the patient's lids tightly against the edge of the contact lens. The movement of the patient's eye then flips the contact free.

In the unresponsive patient in the supine position, modify the technique. Take a more active role in lid movement using the following procedure: Place one thumb on the upper eyelid and the other on the lower eyelid near the margin of each lid. With the lens centered over the cornea, open the eyelids until the lid margins are beyond the edges of the lens (Fig. 63–23A). Then press both eyelids gently but firmly on the globe of the eye and move the lids so that they are barely touching the edges of the lens (see Fig. 63–23B). Press slightly harder on the lower lid to move it under the bottom edge of the lens. As the lower edge of the lens begins to tip away from the eye, move the lids together, allowing the lens to slide out to where it can be grasped (see Fig. 63–23C). Remember to use clean hands (and preferably wear examination gloves that have been rinsed in tap water or saline) when removing the lens.

![Figure 63–23](image_url)

Alternatively, move the lens gently off the cornea using a cotton-tipped applicator to guide the lens onto the sclera. Force the applicator tip under an edge of the lens and flip the contact loose. Use topical anesthesia when using an applicator and the patient is awake. Take care with this technique to avoid contact of the applicator with the cornea when the lens is moved off the eye. Perhaps the easiest technique is to use a moistened suction-tipped device and simply lift the lens off the cornea (Fig. 63–24).
Several lenses (those hard contact lenses that cover both the cornea and an amount of the sclera) can be removed by an exaggeration of the manual technique described earlier (Fig. 63–25). Elevation of the lens with a cotton-tipped applicator or a suction-tipped device is also an effective technique. Soft contact lenses should not be removed with a suction-tipped device because tearing or splitting of the lens might occur.

Soft Contact Lens Removal

With clean hands (preferably using gloves rinsed in saline or tap water), pull down the lower eyelid using the middle finger. Place the tip of the index finger on the lower edge of the lens. Slide the lens down onto the sclera and compress it slightly between the thumb and the index finger. This pinching motion folds the lens so it can be removed from the eye (Fig. 63–26). Alternatively, use a cotton-tipped applicator (e.g., Q-Tip) instead of a gloved hand. Occasionally, a tight-fitting lens will be difficult to remove. One potential method is the use of topical anesthetic drops, lubricating eye drops (e.g., Refresh Celluvisc lubricant eye drops) and a cotton-tipped applicator to lift the edge of the lens from the limbus. This breaks the seal of the lens on the cornea and allows removal.
Figure 63–26  Removal of a soft contact lens. A, Separate the eyelids and then move the contact onto the sclera with the index finger. B, Pinch the lens between the thumb and index finger. (A and B, From Grant HD, Murray RH, Bergeron JF [eds]: Brady Emergency Care, 5th ed. Englewood Cliffs, NJ, Prentice Hall, 1990, p 338. Reproduced by permission.)

**Lens Storage**

After a contact lens is removed, store it in sterile normal saline solution. Use the patient's own storage container and lens solution if available. A variety of alternative sterile containers are available for use in the ED. Be certain to keep right and left lenses separate and in appropriately labeled containers. The containers should be kept with the patient until a friend or family member can procure them, or they should be locked with the patient's valuables.

**Evaluation of the “Lost” Contact**

A patient may present with a request to be examined for a "lost" contact lens. The patient may be unsure whether the lens is hidden under a lid, remains on the cornea, or is truly outside the eye. The evaluation of the patient with a "lost" contact should begin, as should all eye examinations, with the measurement of visual acuity. Measure visual acuity preferably using a 20-foot eye chart. Diminished visual acuity in the eye with the lost contact is convincing evidence that the lens is missing, although transparent, soft contact lenses in proper position are usually seen when viewed closely with loupes or a slit lamp. The lens forms a fine line where it ends on the sclera several millimeters peripherally to the limbus. Hard contact lenses are even more evident as they
change in position on the cornea.

If the contact is not evident on initial inspection, ever the lids as discussed in the section on "Ocular FB Removal" (double eversion of the upper lid). If the lens is still not visible, place a drop of topical anesthetic in the eye. Gently sweep the upper fornix with a moistened cotton-tipped applicator while the patient looks toward the chin. If the lens is still not evident even though the patient remains insistent that it is in the eye, perform a fluorescein examination after explaining that the dye will color the lens (permanently). Evert the upper lid again and examine with an ultraviolet light source.

If the lens remains elusive, reassure the patient that a thorough examination was performed and that no object was located under the eyelids or on the cornea. Next, examine the cornea for defects that warrant antibiotic ointment and a pressure patch placed over the eye (as discussed in "Eye Patching"). Follow-up with the patient's eye specialist for a replacement lens and provide further reassurance. Ask the patient to retrace movements at the time the contact began to give trouble or was missed. Check the clothing being worn at that time and look for the lens there. A final possibility is that the patient may have accidentally placed the two lenses together in the same side of the carrying case, causing them to stick together. Hence, take a methodical approach, as outlined earlier, to ensure that no lens remains hidden in the eye.

**Complications of Lens Removal**

A corneal abrasion can occur during lens removal. It is difficult at times to determine whether the injury was produced by the patient or was a result of the removal by the clinician. Fortunately, the corneal injury is usually of a superficial nature and responds well to eye patching or other symptomatic care.

**Summary**

Contact lens removal is usually simple. Challenging situations include identifying patients at risk for corneal injury due to overuse, helping patients who have lost a contact lens in the eye, and providing aftercare instructions for patients with contact lens–related problems.
INFECTIOUS KERATITIS

Infectious keratitis with corneal ulceration can have a variety of causes, including the overwear of contact lenses. Diagnosis of a corneal ulcer requires the use of a slit lamp and an accurate determination of the patient's history. Infectious keratitis is a frequent problem in ophthalmic practice. Herpes simplex is a common corneal pathogen. *Acanthamoeba* is another pathogen particularly associated with contact lens use and exposure to organism-tainted environments. When a patient presents to the ED with a corneal ulcer, promptly refer the patient to an ophthalmologist. When immediate referral is not possible, obtain telephone guidance from the ophthalmologist in order to initiate therapy and arrange for ophthalmology follow-up within 24 hours.

Patients with herpes simplex keratitis often give a history of prior episodes of the disease. Patients who undergo almost any form of corneal stress may sustain an activation of preexisting corneal disease. Herpes simplex keratitis is classically recognized by its dendritic pattern on fluorescein staining.

*Acanthamoeba* keratitis is a disease with potentially devastating consequences. Its frequency seems to be increasing, particularly in contact lens wearers, and its pathophysiology is not completely understood. Patients often present with a red eye in which initial bacterial culture results are negative.

Bacterial keratitis occurs in a variety of settings. Organisms range from the relatively common *Staphylococcus* (including methicillin-resistant *Staphylococcus aureus*) or *Streptococcus* to *Mycobacterium*, which can be difficult to identify. A variety of antibiotics are used against bacterial agents. Ciprofloxacin is a quinolone that has demonstrated efficacy against most of the common causative agents. Bacterial organisms in the cornea can develop resistance to any antibiotic, and resistance to fluoroquinolones has also been observed. Ideally, treatment follows culturing of the ulcer.

In instances in which a cellular infiltrate is seen on slit lamp examination and in which there will be a delay of hours before an ophthalmologic consultant can culture the patient, it is prudent to initiate therapy with topical ciprofloxacin. In such circumstances, under the telephone guidance of the consultant, obtain corneal cultures before starting the antibiotic. One approach is to lightly touch a culture-moistened cotton-tipped swab against the ulcer and then streak standard culture media. If the ulcer is chronic or the patient is immunocompromised, a fungal organism may be the causative agent. Finally, a saline-moistened cotton-tipped swab may be used to obtain a Gram stain of the ulcer. Initiation of therapy before obtaining specimens for culture makes the subsequent identification of an organism difficult. For this reason, consider the circumstances of the individual case before initiating treatment.
TONOMETRY

Tonometry is the estimation of IOP. It is obtained by measuring the resistance of the eyeball to indentation by an applied force. Prolonged elevated IOP is associated with visual field loss and blindness. Sudden elevation of IOP can result from trauma or primary angle-closure glaucoma. Patients with primary angle-closure glaucoma often come to the ED with systemic complaints including nausea, vomiting, and headache. Occasionally, these patients are surprisingly free of pain in or about the eye. The emergency clinician must determine the IOP and its relationship to the systemic symptoms.

Ophthalmologists depended on tactile estimation of eye pressure until the 1860s when von Graefe developed the first mechanical tonometer. Applanation tonometry was introduced in 1885 by Maklakoff but was not popularized until Goldmann improved the instrument in the 1930s. Schiøtz developed an impression tonometer in 1905 and modified it in the 1920s; this form is still in use today. Aside from modifications in configuration, current tonometers closely resemble the devices popularized by Schiøtz and Goldmann. The most dramatic variations are the Mackay-Marg tonometer, which permits a continuous tonographic recording, and the noncontact tonometer, a pneumatic applanation tonometer. Pocket-sized tonometers using the MacKay-Marg tonometer principle are available. One such device is the Tono-Pen XL (Reichert, Inc, Depew, NY). These devices are portable, lightweight, and relatively accurate, with built-in provisions for calibration. They have the advantage of a one-time-use replaceable cover that eliminates concern about the possible transmission of an infectious agent. Whereas numerous devices are available, the Schiøtz tonometer is the standard way for emergency clinicians to measure IOP.

Tonometric Techniques

Three tonometric techniques are reliable and clinically useful for estimating IOP:

1. The impression method uses a plunger (3 mm in diameter) to deform the cornea and the “indentation” is then measured. This technique was popularized by Schiøtz and commonly bears his name.

2. The MacKay-Marg method is a refined version of the impression technique in which smaller amounts of cornea are indented.

3. In the applanation method, a planar surface is pressed against the cornea.

The Schiotz tonometer (Fig. 63–27) actually measures the total IOP (initial pressure plus the pressure added by the weight of the tonometer and the plunger). Friedenwald empirically found that a “rigidity coefficient” could be introduced to allow an estimation of the true IOP. One must be aware, however, that calculated conversion tables for Schiotz tonometers use an average estimate of the rigidity coefficient and, hence, are not accurate when eye rigidity is altered (e.g., after scleral buckle procedures for retinal detachment or with extreme myopia).
Measurement of IOP in the ED by tonometry is a technique available to most emergency clinicians. Tonometry is not a standard procedure for many eye-related complaints, but special situations in which tonometry may be particularly helpful are

- Confirmation of a clinical diagnosis of acute angle-closure glaucoma. The middle-aged or elderly patient who presents with acute aching pain in one eye, blurred vision (including “halos” around lights), and a red eye with a smoky cornea and a fixed midposition pupil obviously needs a pressure reading. Sometimes, the findings are less dramatic, and sometimes, the patient complains mostly of nausea and vomiting that suggest a “flu” rather than an eye disorder.
- Determination of a baseline ocular pressure after blunt ocular injury. Patients with hyphema often have acute rises in IOP because of blood obstructing the trabecular meshwork.[85] Later, angle recession can cause a permanent form of open-angle glaucoma. Arts and colleagues[86] suggested that an IOP greater than 22 mm Hg or a difference of 3 mm Hg or greater between eyes is a good marker for “ocular injury” in the setting of an orbital fracture.

Tonometry may also be considered under the following scenarios:

- Determination of a baseline ocular pressure in a patient with iritis. Patients with iritis can develop both open- and closed-angle glaucoma as well as corticosteroid-induced glaucoma. Because most cases of iritis are referred, tonometry may also be deferred unless there are signs of increased IOP.
- Documentation of ocular pressure in the patient at risk for open-angle glaucoma. All patients older than 40 years with a familial history of open-angle glaucoma, optic disk changes, visual field defects, and pressures of 21 mm Hg or higher should be referred to an ophthalmologist for further workup. Referral should also be made for those patients with suspiciously cupped disks who have normal pressures; some of these patients may have “low-pressure” glaucoma associated with visual field defects. This is usually part of an ophthalmologist's examination.

Contraindications to Tonometry

Tonometry is relatively contraindicated in eyes that are infected unless one is using a device such as the Tono-Pen XL, which uses a sterilized cover.[2] Sterilize a tonometer before and after applying it to a potentially infected eye. Measure infected eyes with either a noncontact tonometer or a device with a covered tip (e.g., Tono-Pen). Swab the contact portions of any device with alcohol and allow it to dry before using on another eye. Not all viruses are destroyed by alcohol cleansing. Hydrogen peroxide is effective for deactivating the human immunodeficiency virus responsible for the acquired immunodeficiency syndrome (AIDS).
Ultraviolet sterilization, cold-sterilizer bathing of the footplate and plunger, and ethylene oxide sterilization have all been advocated as alternatives to sterilizing the Schiotz tonometer tip. The Schiotz tonometer may also be used with sterile disposable coverings (marketed as Tonofilm). Nonetheless, defer the measurement of IOP in an obviously infected eye until a subsequent visit to the ED or private clinician unless the red eye demands an immediate determination of IOP.

Examples of indications for immediate tonometry in the setting of a red eye are suspected angle-closure glaucoma (acute onset of redness and pain in the eye with smoky vision, a cloudy cornea, and a fixed pupil in mid-dilation, often with headache and nausea) and iritis (ciliary injection with photophobia), in which secondary angle-closure or corticosteroid-induced pressure changes may occur (Fig. 63–28).

Reported cases of conjunctivitis spread by tonometry predominantly tend to be viral infections. Particular efforts should be made to avoid use of the instrument on patients with active facial or ocular herpetic lesions or who may have AIDS.

Figure 63–28  This woman complained of severe headache, nausea and blurry vision. The eye was obviously red, the pupil was dilated and minimally reactive, and the cornea was slightly cloudy. This is acute angle-closure glaucoma.

The presence of corneal defects also represents a relative contraindication to tonometry. The use of a tonometer on an abraded cornea may lead to further injury and is commonly deferred until a subsequent visit. Patients who cannot maintain a relaxed position (e.g., because of significant apprehension, blepharospasm, uncontrolled coughing, nystagmus, or uncontrolled hiccups) are unlikely to permit an adequate examination and can receive corneal injury when sudden movements occur during an
examination. Furthermore, tonometric examination, with the exception of the palpation technique (through the lids) and the noncontact method, should not be performed on a cornea without complete anesthesia.

Tonometry should not be performed with a suspected penetrating ocular injury.[2] Globe perforation may be exacerbated by pressure on the globe with resultant extrusion of intraocular contents. Slit lamp examination can be used for detection of a possible perforation.

Procedure

Palpation Technique

All forms of tonometry are essentially ways of determining the ease of deforming the eye; an eye that is easily deformed has a low pressure. The most direct way to do this is simply to press on the sclera through the lids and grossly compare one eye with the other. One can easily distinguish the rock-hard eye of acute glaucoma from the normal opposite eye by this method. Direct the patient to look down without closing the lids. Rest both hands upon the patient’s forehead and apply just enough digital pressure on the involved eye to indent it slightly with one index finger. With the other index finger, alternately feel and compare the compliance of the other eye (Fig. 63–29). An experienced examiner is able to estimate the IOP within 3 to 5 mm Hg of the actual IOP with the palpation technique, but most emergency clinicians do not have enough experience to trust this method.[31]
Another method is to anesthetize the eyes topically and press a wetted applicator on the sclera of each eye. Again, eye deformation is inversely related to ocular pressure. Rigidity of the globe also is a factor in this crude method of tonometry.

Impression (Schiøtz) Technique

Use of the Schiøtz tonometer requires relaxation on the part of the patient and steadiness on the part of the clinician. Place the patient in either a supine or a semi-recumbent position and instruct him or her to gaze at a spot directly above the eyes. A spot on the ceiling should suffice; alternatively, the patient can stretch the arm up over the head and gaze at the thumb. Place a drop of topical anesthetic in each eye. After the irritation of the drop passes, allow the patient to blink while blotting the tears away with a tissue. Rubbing the eyes lowers IOP. Reassure the patient that further discomfort will not occur during the procedure.

Ask the patient to keep both eyes wide open and fixed on an object. Separate the eyelids on the side you are standing on. Test the tonometer on a flat surface to confirm smooth movement of the device (Fig. 63–30). Take care to direct pressure onto the orbital rims rather than into the orbit, because pressure directed into the orbit falsely raises the reading. Hold the tonometer momentarily over the open eye, and inform the patient that the instrument will block vision in the one eye. Instruct the patient to continue to gaze at the fixation point as though the instrument were not there. After the patient relaxes the involuntary muscle contraction that occurs when the instrument is first placed in the line of sight, gently lower the instrument onto the middle portion of the cornea (Fig. 63–31). This is a painless experience for the patient with an anesthetized cornea. Vertically align the instrument with the footplate resting on the cornea; the reading should be in midscale. Should the reading be on the low end of the scale (<5 units), place additional weight onto the plunger after the instrument has been removed. Repeat the process as before with the additional weight.

Figure 63–30  Before using the Schiøtz tonometer, test it on a flat surface to ensure smooth motion of the device and that the zero line is achieved.
Figure 63–31 One technique of lid separation and Schiøtz tonometer placement. Lid separation pressure is applied to the bony orbital rims. An assistant may separate the lids while the operator concentrates on proper placement of the tonometer. The tonometer is held vertically during use, and the clinician's hand is established against the patient's facial bones. After anesthetic drops are instilled, the patient will not experience any pain from this procedure. It is important to have a relaxed patient, because squinting and blepharospasm may interfere with the reading. Note: gloves should be worn.

Measure the opposite eye in the same fashion. Use the chart provided to determine the converted reading based on the reading and the amount of weight on the scale. Refer to ophthalmology if the converted scale reading is higher than 21 mm Hg (Table 63–4). Patients with elevations of IOP ≥ 30 mm Hg require more urgent consultation and initiation of therapy. Associated symptoms or signs of angle-closure glaucoma (primary or secondary) represent an ophthalmologic emergency.[87]

**TABLE 63–4 -- Schiøtz Tonometry**

<table>
<thead>
<tr>
<th>Tonometer Scale Reading (Units)</th>
<th>5.5 (mm Hg)</th>
<th>7.5 (mm Hg)</th>
<th>10 (mm Hg)</th>
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<tr>
<td>2.50</td>
<td>27</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>3.00</td>
<td>24</td>
<td>36</td>
<td>51</td>
</tr>
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</tr>
<tr>
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<td>21</td>
<td>30</td>
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</tr>
<tr>
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<td>5.00</td>
<td>5.50</td>
</tr>
<tr>
<td>---------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
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</tr>
<tr>
<td>Pressure (mm Hg)</td>
<td>40</td>
<td>37</td>
<td>34</td>
</tr>
</tbody>
</table>

* The table provides estimates of the intraocular pressure to the nearest mm Hg for the different weight of the Schiötz tonometer. Accuracy is most dependable with scale readings greater than 5. If the scale reading is less than 5, use the next highest weight that will give a reading of 5 or more.

**Errors with Impression Tonometry**

Inaccurate readings occur with the Schiötz tonometer for a variety of reasons. Falsely low readings may occur if the plunger is sticky. Check the plunger motion and the zero point of the tonometer on a firm test button before use. If the plunger is sticky, clean it with isopropyl alcohol and dry it with a tissue. Inadvertently directing pressure onto the orbit when the lids are held open may elevate the IOP and provide a falsely elevated reading. The following eye movements have been found to elevate the IOP: closing the lids (increase by 5 mm Hg), blinking (increase by 5–10 mm Hg), accommodation (increase by 2 mm Hg), and looking toward the nose (increase by 5–10 mm Hg). [88] Repeated or prolonged measurements have been found to lower the IOP approximately 2 mm Hg and may also lower the pressure in the opposite eye. [89] As mentioned in the introduction to this section, the calibration of the Schiötz tonometer is based on a mean rigidity coefficient. Factors that produce a reduction in ocular rigidity falsely lower the measured pressure. These factors include high myopia, anticholinesterase drugs, overhydration (e.g., four large cups of coffee or six cans of beer), and scleral buckle operations. [88] [90]

Ocular pressure measurements can vary with ocular perfusion. When measured after a premature ventricular contraction, the IOP may be reduced as much as 8 mm Hg. [91] Similarly, decreased venous return as produced by breath holding, the Valsalva maneuver, or a tight collar can increase the IOP. [88]

**Impression (Tono-Pen XL) Technique**

When using this device (Fig. 63–32), the preparations for testing are similar to those for the Schiötz device. Encourage the patient to relax, and apply a topical anesthetic to numb the cornea (Fig. 63–33). Ask the patient to stare with both eyes at a distant object during testing. As noted previously, help to separate the eyelids but do not apply direct pressure on the globe. One major advantage to using the Tono-Pen XL is that the patient may be evaluated in any position as long as the device is applied perpendicular to the corneal surface. Another advantage is that the device can be used in cases of irregular or high corneal astigmatism.
Figure 63–32  A, Bedside tonometry is easily accomplished with the Tono-Pen XL. The battery-powered device averages four consecutive readings and reports statistical reliability. B, Note the disposable sterile cover used to cover the Tono-Pen to ensure sterility. (A, Courtesy of Reichert, Inc., from Thomsen T, Setnik G [eds]: Procedures Consult—Emergency Medicine Module.)
Figure 63–33 Tonometry using the Tono-Pen XL. The device averages four consecutive readings and reports ocular pressure and statistical reliability on a digital readout. A, Position the patient in a semi-upright position, hold the lids open, and instill anesthetic drops. B, Apply sterile condom (Ocu-Film cover) to tip of device. C, See text and Table 63–5 for instruction on calibration and use. D, Read out of ocular pressure. (A–D, From Thomsen T, Setnik G [eds]: Procedures Consult—Emergency Medicine Module.

Ideally, the complete instructions provided with the device should be consulted before each use; however, the following synopsis is provided to help in circumstances in which instructions are unavailable (Table 63–5).

**TABLE 63–5 -- Tono-Pen Instructions**

Steps in Setting up Tono-Pen:

1. Remove the Ocu-Film tip cover from the probe.
2. To help prevent buildup of debris around the probe post, spray the probe tip with compressed gas before the first use of the day.
3. Cover the Tono-Pen XL probe tip with a new Ocu-Film tip cover.
4. Check calibration only before the first use of each day.
   a. Depress the activation switch momentarily, then release.
   b. If the previous calibration check was good, the LCD will briefly display “—” followed by “====,” accompanied by a beep.
   c. If the previous calibration was bad, a long beep sounds, after which “CAL” appears and a short beep sounds. The display then changes to “—” and another short beep sounds.
5. Hold the Tono-Pen vertically with the probe tip pointing straight down.
6. Press and release the activation switch twice in rapid succession. Two beeps will sound and “CAL” appears.
7. Wait (up to 20 sec) until a beep sounds and “-up-” appears.
8. Quickly turn the probe straight up.
9. Wait a few seconds. A second beep will sound, indicating the end of the calibration check.

10. Instill a drop of topical anesthetic (proparacaine) into both eyes.

11. Instruct the patient to look straight ahead at the fixation target with his or her eyes fully open.

12. Brace the heel of your hand on the patient’s cheek for stability.

13. Activate the Tono-Pen by pressing the activation switch.

14. The LCD will display “=====” and a beep will sound.

15. Once activated, touch the Tono-Pen probe against the patient’s cornea lightly and briefly. Repeat several times.

16. A click will sound and a digital intraocular pressure measurement is displayed.

17. Proceed to the other eye. Repeat steps 12 through 15.


LCD, liquid crystal display.

First, spray the probe tip with compressed gas to clean the mechanism and ensure its free movement. Place an Ocu-Film (latex) cover snugly (but without tension) over the probe tip.

Perform calibration before use at least once each day (see Table 63–5). Depress and release the activation switch momentarily. The liquid crystal display (LCD) should show “—.” If the device beeps and “= = = =” appears on the LCD, push the activation switch again so that the “—” reappears. If the prior calibration shows “bAd” (on LCD), a long beep sounds, followed by “CAL” (on LCD). A short beep follows and then the desired “—” is displayed. Once the “—” is displayed, hold the probe vertically with the tip pointing straight down. Press and release the activation switch twice in rapid succession. Two beeps will then sound, and “CAL” will appear (on LCD). Hold the probe in this position (up to 20 sec) until a beep sounds and “-UP-” appears (on LCD). Immediately turn the probe 180° so that the tip points straight up. In a few seconds, another beep occurs, and the LCD changes. If the LCD reads “Good,” the calibration was successful. If the LCD reads “bAd,” the calibration was unsuccessful.

With an unsuccessful calibration, repeat the calibration steps described earlier until two consecutive “Good” readings are obtained. If further attempts are unsuccessful, loosen the Ocu-Film tip cover and repeat the calibration process. If attempts are still unsuccessful, press the RESET button and repeat the process. If still unsuccessful, use compressed air to clean the probe tip and repeat the process. If still unsuccessful, the battery should be replaced and the process repeated. Continued failure warrants a call to the Reichert Technical Support (http://www.reicherttonopen.com/ss.html) at 1-888-849-8955.

Proceed to measurement once the device is calibrated and the patient is prepared as outlined earlier. Depress and release the activation switch to obtain “= = = =” (on LCD). A beep will occur when ready. If the switch is not depressed long enough, the LCD will be blank. If a blank screen is seen, press and release the activation switch again to obtain “= = = =” (on LCD). Hold the probe like a pen and touch it to the cornea briefly and lightly (see Fig. 63–32B). Touch the cornea four times. A click will sound and a reading will appear on the LCD each time a valid reading is obtained. After four valid readings, a final beep will sound and the averaged measurement will appear on the LCD. The number represents the IOP in millimeters of mercury. The associated bar reflects the statistical reliability (a reading > 20% reflects an unreliable measurement, and should be repeated).

If four dashes (“----”) appear on the LCD after the final beep, too few valid readings were obtained. In such a case, reactivate the probe (without recalibration) and repeat the measurement procedure. If the probe is not reactivated within 20 seconds, the LCD will clear, but the device can be activated as noted previously without recalibration.

The values are interpreted as outlined earlier for the Schiøtz device. Readings may be affected by the same features noted as causes of errors with impression tonometry via the Schiøtz device. Store the device with an unused Ocu-Film cover protecting the probe tip.

Complications

When tonometric instruments are used properly and reasonable precautions are taken, complications are unusual. The eye with
preexisting corneal injury should be spared the additional trauma of tonometer placement. Corneal abrasions can be produced by ocular movement during testing. In particular, patients with uncontrollable nystagmus, hiccups, or coughing or those who are extremely apprehensive should not be subjected to tonometry. Infection can be transmitted by the use of the instrument. Careful cleansing of the device and avoidance of tonometry in patients with obvious conjunctivitis, corneal ulcers, or active herpetic lesions should minimize the risk of spreading the infection to the unaffected eye or to subsequent patients. Although protective coverings can be placed over the tonometer contact, tonometry can usually be postponed in the aforementioned individuals until the risk of infection is minimal. Extrusion of ocular contents with penetrating injuries is a potential, but rare, complication.

SLIT LAMP EXAMINATION

The slit lamp is an extremely useful instrument for examination of the anterior segment of the eye. The instrument can reveal pathologic conditions that would otherwise be invisible, such as minor corneal defects, anterior chamber hemorrhage, and inflammation.

Indications and Contraindications

The slit lamp can be used in the majority of eye examinations. It is especially useful in the ED for the diagnosis of corneal abrasions, FBs, and iritis. The slit lamp facilitates FB removal and is also used in conjunction with most applanation tonometers. Although portable slit lamp instruments exist, emergency clinicians generally have access only to a stationary, upright device. Therefore, in the absence of a portable device, a slit lamp examination is contraindicated in patients who cannot tolerate an upright sitting position (e.g., those with orthostatic syncope).

Equipment

The slit lamp has three essential components: a binocular microscope mounted horizontally, a light source that can create a beam of variable width, and a mechanical assembly to immobilize the patient's head and manipulate the microscope and the light source. The location and arrangement of the knobs that control these components vary in devices made by different manufacturers. Usually, by simply turning each knob and watching the results, one can quickly master a new machine. Figure 63–34 illustrates the location of the functional controls on one particular instrument.
First, locate the on/off switch for the instrument. Often, this switch incorporates or is adjacent to a rheostat that provides two or three different power settings. The lowest setting is adequate for routine examination and will preserve bulb life. One can use a high-intensity setting when examining the anterior chamber with a narrow slit beam. Often, these controls are located on a transformer placed beneath the table to which the slit lamp has been attached. The second knob that one should find is the locking nut for the mechanical assembly. Loosen the nut so the assembly can be moved.

Make adjustments so the patient is comfortable while sitting with the head in the device. Ask the patient to press her or his forehead firmly against the headrest with the chin in the chinrest. By varying the table height and height of the chinrest, one should be able to maximize the comfort of the patient's neck and back. Adjust the chinrest to align the patient's eye level with the mark on the headrest support rods.

The binocular microscope has a control for varying the magnification. Usually low powers, such as 10× or 16×, are the most useful. Use a higher power to examine the anterior chamber for cells and flare and when the cornea is examined in minute detail. Adjust
the binocular interpupillary distance to match that of the examiner. Focus the eyepieces by moving the instrument forward and backward until the narrowed vertical beam is sharpest on the patient's cornea when viewed with the unaided eye. Then, while viewing through each eyepiece individually, adjust the focus of each to produce a sharp image of the anterior cornea.

Notice that the light source is mounted on a swinging arm. Find the knobs that adjust the width and the height of the light beam. Click various filters in as needed, usually white and blue filters for standard examination. Alter the angle of the slit lamp beam from vertical to horizontal. The vertical alignment is preferred for routine examinations in the ED.

Both the microscope and the light source are mounted on swivel arms, linked at their base to a movable table. Change the position of this table by pushing on any part of it. Find the joystick on the table that can be used for finer movements. Vary the height of the microscope and the light source by twisting either the joystick or a separate knob at the base, depending on the design of the instrument.

**Procedure**

There are three setups that every slit lamp operator must know. The first is for an overall screening of the anterior segment of the eye. For examination of the patient's right eye, swing the light source to your left at a 45° angle while the microscope is directly in front of the patient's eye. Set the slit beam to the maximum height and the minimum width using the white light. To scan across the patient's cornea, first focus the beam on the cornea by moving the entire base of the slit lamp forward and backward. Then, move the whole base left and right to scan across the cornea. The 45° angle between the microscope and the light source is the default position. The most common mistake is to try to scan by swinging the arm of the light source in an arc; this does not work because the light beam will remain centered on the same point of the patient's eye. Scan across at the level of the conjunctiva and the cornea and then push slightly forward on the base or joystick and scan at the level of the iris. The depth of the anterior chamber is easily appreciated with this low-magnification setup (Fig. 63–35). When the depth of the anterior chamber is reduced, suspect a corneal perforation or a predisposition to angle-closure glaucoma.

![Slit lamp photograph of a normal right eye under low power. The curved slit of light on the left is reflected off the cornea and the slit on the right is reflected off the iris. The depth of the anterior chamber can easily be appreciated under this low-magnification setup. Note that the light](image)
source is on the patient's right side to examine the right eye, with the path of the light going in a temporal-to-nasal direction. (Courtesy of D. Price.)

Use this basic setup to examine the conjunctiva for traumatic lesions, inflammation, and FBs. Examine the eyelids for hordeolum, blepharitis, or trichiasis. Completely evert the lids (as described earlier in the section on “Ocular FB Removal”) in conjunction with the slit lamp examination to permit evaluation of the undersurface of the upper lid for FB retention.

Corneal FB removal can be enhanced by use of the slit lamp. In particular, the instrument allows stabilization of the patient's head. Magnification also minimizes corneal injury during FB or rust ring removal. The upper eyelid may be immobilized by a cotton-tipped applicator, as discussed previously. The clinician's hand can be steadied against the patient's nose, cheek, or forehead or against the support rods of the headrest. The patient should be instructed to stare straight ahead at a fixed light or at the clinician's ear during removal of the FB.

The second setup is essentially the same as the first but uses the blue filter. The purpose is to identify any areas of fluorescein staining. After fluorescein is applied, “click” the blue filter into position and widen the beam to 3 or 4 mm. A patient can tolerate a wider beam without photophobia if it is blue. Search for corneal defects (as discussed earlier in “The Fluorescein Examination”) with this setup. The blue filter may also be used with applanation tonometry, as discussed earlier in “Tonometry.”

The purpose of the third setup is to search for cells in the anterior chamber—either the white cells of iritis or the red cells of a microscopic hyphema. Shorten the height of the beam to 3 or 4 mm and make it as narrow as possible. Switch the microscope to high power. Focus the beam on the center of the cornea and then push forward slightly so that it is focused on the anterior surface of the lens. Pull back the joystick again to a focus point midway between the cornea and the lens where it will be focused on the anterior chamber (Fig. 63–36). Keep the beam centered over the pupil so that there is a black background. Normally, the aqueous humor of the anterior chamber is totally clear. Small particles visible floating up or down through the beam are usually circulating cells. If the beam lights up the aqueous like a searchlight in the fog, then the examiner has found the protein flare that accompanies iritis. Note that fluorescein can penetrate an abraded cornea, producing a fluorescein flare on slit lamp evaluation. To avoid confusion, some clinicians prefer to examine for anterior chamber flare before the stain is used. A variety of conditions evaluated by the slit lamp are pictured in Figure 63–37.

![Figure 63–36](image_url) Appearance of the left eye during anterior chamber examination under low power: a, corneal epithelium; b, corneal stroma; c, corneal endothelium; d, anterior chamber (potential location of cells or flare); e, iris; f, lens reflection. The slit of light shines in the temporal-to-nasal direction at 45° to the anterior surface of the cornea. The depth of the cornea and anterior chamber examinations are best done under high power in a dark room.
Figure 63–37  External signs of eye pathology.  
A, Subconjunctival hemorrhage.  
B, Ocular allergy, enlarged lid follicles.  
C, Acute iritis.  
D, Acute epidemic keratoconjunctivitis shows corneal infiltrates and chemosis.  
E, Herpes simplex (dendritic keratitis).  
F, Narrow angle-closure glaucoma shows dilated pupil, loss of corneal luster, and red eye.  
G, Bilateral subconjunctival hematoma.  
H, Large hyphema.  
I, Small hyphema layering out in the inferior portion of the anterior chamber may be missed in the supine position and without a slit lamp examination.  
J, Nontraumatic iritis. Note that the conjunctival injection goes right up to the cornea (arrows demonstrate “perilimbal flush”), whereas with conjunctivitis, the peripheral conjunctiva is predominantly involved. These patients will have photophobia and eye pain.  
UNILATERAL LOSS OF VISION

There are a variety of reasons that an individual may sustain a complete loss of vision in one eye, but most commonly, such loss is caused by occlusion of the central retinal vein, occlusion of the central retinal artery, or optic nerve damage. Less commonly, pressure in the orbit from a retro-orbital hemorrhage may compromise the ophthalmic artery.

Although discussion of all the potential causes of unilateral loss of vision is beyond the scope of this text, amaurosis fugax deserves special mention. Amaurosis fugax is a transient loss of vision most commonly due to cholesterol or platelet emboli from atherosclerotic carotid occlusive disease. When plaques are visualized in the retinal vasculature, auscultate the neck for carotid bruits and refer the patient for ultrasound examination of the carotid artery. [93] [94]

Central Retinal Artery Occlusion

The patient with central retinal artery occlusion generally presents with a recent sudden (complete or nearly complete) unilateral vision loss. On examination, there is an afferent pupillary defect (i.e., sluggish or nonreactive pupil in the affected eye with direct illumination with a normal consensual response) and reduced visual acuity. Immediately after the event, the fundus may appear nearly normal; however, it soon becomes pale and a classic “cherry-red spot” in the macula may be evident as a result of patent choroidal vessels showing through the transparent fovea.

Therapy

Visual recovery has been noted to occur up to 3 days after central retinal arterial obstruction. Start treatment if the patient is seen within 24 hours after onset of symptoms. [95] Consult ophthalmology while initiating therapy.

Most of the emergency techniques suggested to treat vascular insults to the eye in the ED are theoretically sound but are not supported nor refuted by rigorous scientific data. No specific standard of care has been promulgated for these interventions by emergency clinicians. Techniques discussed later are likely safe and possibly useful, and may be attempted in an emergency situation. It is unknown whether or not these interventions will be vision saving.

Slow rebreathing into a paper bag is believed to increase the arterial carbon dioxide level, thus aiding vasodilation and permitting the occlusion to move more peripherally, possibly reducing the ischemic area. At the same time, initiate digital globe massage. With the patient lying supine, apply firm steady pressure with the thumbs to the affected globe through the patient's closed lids. Apply pressure for 5 seconds and then abruptly release it (Fig. 63–38). Immediately repeat this maneuver several more times for up to 20 minutes. The object of this technique is to help break up the occlusion and to encourage its movement more peripherally.
A more aggressive therapy, generally performed only by ophthalmologists, is anterior chamber paracentesis. In the absence of available consultation, consider this technique when central retinal occlusion is recent and unresponsive to the previously described therapeutic approaches. For this procedure, keep the patient supine with the head and eyelids secured. Anesthetize the cornea with topical anesthetic drops (e.g., 0.5% proparacaine drops). Inject the conjunctiva adjacent to the limbus using a 27- or 30-gauge needle until the entire perilimbal area is infiltrated, giving the appearance of chemosis in all quadrants. During the remainder of the procedure, ask an assistant to firmly grasp the conjunctiva with toothless forceps at the 3 and 9 o’clock positions to stabilize the eye. Insert a 30-gauge needle on a tuberculin syringe obliquely just adjacent to the limbus, at either the 4:30 or the 7:30 o’clock position and direct it toward the 6 o’clock position to avoid the lens (Fig. 63–39). Apply gentle pressure on the globe and, after 1 to 2 drops of aqueous are expressed, withdraw the needle. [96] [97]
Figure 63–39 Anterior chamber paracentesis. After topical and subconjunctival anesthesia (see text), a 30-gauge needle is directed obliquely from the 4:30 or 7:30 o’clock position toward the 6 o’clock position to avoid the lens. An assistant stabilizes the globe with forceps, grasping the conjunctiva (see text). Top, Anteroposterior projection. Bottom, Tangential projection. (Top and bottom, From Knoop K, Trott A: Ophthalmologic procedures in the emergency department: I. Immediate sight-saving procedures. Acad Emerg Med 1:408, 1994.)

One study describes a systematic approach in which ocular massage, sublingual isosorbide dinitrate 10 mg, acetazolamide 500 mg intravenously, mannitol 20% (1 mg/kg,) or oral glycerol 50% (1 mg/kg), anterior chamber paracentesis, methylprednisolone 500 mg intravenously, streptokinase 750 kIU, and retrobulbar tolazoline 50 mg were given until visual symptoms improved or until all steps were complete.[98] Of the 11 patients in this arm of the study, 8 had improved visual acuity. In those who improved, all had symptoms in 12 hours or less. The presumed cause was either platelet-derived or cholesterol embolus from atheroma or glaucoma.[97] Although this study is small, it supports emergent ophthalmology consultation and aggressive treatment of patients who present within 12 to 24 hours of symptom onset.

Complications

Overzealous globe massage has the potential to produce intraocular trauma including retinal detachment and intraocular hemorrhage. Anterior chamber paracentesis may produce hemorrhage, infection, or mechanical injury to the cornea, iris, or lens.[99] Although these complications are rare, ophthalmologic consultation for assistance with the underlying central retinal artery occlusion and surveillance for these potential complications should be initiated on an emergent basis.


**Orbital Compartment Syndrome**

Acute facial trauma or recent retrobulbar anesthesia may produce retrobulbar hemorrhage with sufficient pressure to compromise the ophthalmic artery, resulting in an orbital compartment syndrome. A form of post-traumatic glaucoma may also occur when the retrobulbar hematoma forces the globe against the eyelids. In this case, IOP rises precipitously because the globe is in a relatively closed space owing to the firm attachment of the eyelids to the orbital rim by the medial and lateral canthal ligaments. The optic nerve and its vascular supply and the central retinal artery are compressed, resulting in ischemia and subsequent visual loss. In this situation, an emergency lateral canthotomy may be considered for relief of the pressure on the eye. It would not be considered a standard of care for most emergency clinicians to possess the skills for this procedure, but under the proper scenario, it may be a prudent intervention.

Ophthalmoscopic evaluation reveals a blanched ophthalmic artery in the presence of obvious retrobulbar pressure and ecchymosis around the eye. The patient exhibits decreased visual acuity, and an afferent pupil defect is often seen. The IOP is markedly elevated but may be relieved by an emergency lateral canthotomy and cantholysis. Such a procedure needs to be performed quickly because the ischemic retina will not retain function if it is deprived of blood for a long period of time.

**Technique: Lateral Canthotomy and Cantholysis**

The goals of the procedure are to release pressure on the globe and to decrease IOP enough to reinstitute retinal artery blood flow. Because retinal recovery is unlikely to occur if rapid relief of ischemia is not accomplished, taking time to clean the eye beyond simple saline cleansing of the lids and lateral canthus is ill advised. Stabilize the patient's head and lids and anesthetize the lateral canthus by injecting 1% to 2% lidocaine with epinephrine. Before incising, crush the lateral canthus with a small hemostat for 1 to 2 minutes to minimize bleeding. Incise the canthus by using iris or Steven's scissors. Take precautions to avoid injury to the protruding globe (Fig. 63–40). Begin the incision at the lateral canthus and extend it toward the orbital rim. Find the superior and inferior crus of the lateral canthal tendon and release them from the orbital rim (Fig. 63–41). Some operators prefer to release the inferior crus and reassess the IOP before considering release of the superior crus. An instructional video of the procedure can be found at www.brown.edu/Administration/Emergency_Medicine/eye.htm.
Indications for lateral canthotomy and cantholysis include decreased visual acuity, ocular pressure greater than 40 mm Hg, proptosis, afferent papillary defect (Marcus Gunn pupil), cherry-red macula, ophthalmoplegia, optic nerve pallor, and severe eye pain. A ruptured globe is a contraindication. A, Severe proptosis secondary to acute traumatic retrotubular hemorrhage. B, Anatomy of orbital structures demonstrates the inferior and superior crura of the lateral canthal tendon beneath the lateral canthus. The crura join and as a common tendon are attached to the inner aspect of the lateral orbital wall, forming Whitnall’s tubercle. The lateral canthus, formed by the upper and lower eyelid, has been removed. C, Lateral canthotomy. Only the inferior crus need be incised initially. (A and B, From Vassallo S, Hartstein M, Howard D, Stetz J: Traumatic retrotubular hemorrhage: Emergent decompression by lateral canthotomy and cantholysis. J Emerg Med 22:251, 2002.)
Figure 63–41 Procedure for lateral cathotomy. Step 1: Local anesthesia of the lateral canthus. Step 2: Crush the lateral canthus with a clamp to reduce bleeding when it is incised. Step 3: Lateral canthus incised to allow the inferior crus to be exposed. Step 4: To decompress the eyeball, cut the canthal ligament with scissors pointed inferoposteriorly toward the lateral rim. Pull the lower lid down and away from the lateral orbital rim, separating the skin and conjunctiva. If bleeding hinders identification of the inferior crus, it may be palpated. Only the inferior crus need be lysed initially. If intraocular pressure is not reduced, the superior crus is lysed. (From Custalow CB: The Color Atlas of Emergency Department Procedures. Philadelphia, Elsevier Saunders, 2005.)

Complications

Although hemorrhage, infection, and mechanical injury might result from the procedure, these complications generally respond to therapy better than does retinal injury from prolonged ischemia. Emergent ophthalmologic consultation should be obtained, although when the procedure is indicated, it may be considered by the emergency clinician. Lateral canthotomy incisions generally heal without suturing or significant scarring.
REDUCTION OF GLOBE LUXATION

Although luxation of the globe is uncommon, the emergency clinician should be aware of the condition and its mechanisms, know how to reduce the globe, and know when to prioritize ophthalmologic consultation. With luxation of the globe, there is extreme proptosis, which permits the lids to slip behind the globe equator (Fig. 63–42). Subsequent spasm of the orbicularis oculi muscles sustains the luxation and limits extraocular movements. Traction on the optic nerve and retinal vessels may produce direct or indirect injury to the optic nerve and retina.
Figure 63–42 Appearance of luxated globe. This globe protruded when the eye was opened for pupil examination. It was easily reduced with slight manual pressure on the closed upper lid. Afterward, the patient had no eye or vision complaints.

Luxation may be spontaneous, voluntary, or traumatic. A variety of conditions (e.g., orbital neoplasms, Graves disease, histiocytosis X, cerebral gumma, and craniofacial dysostoses) may predispose the patient to luxation. Triggering events include maneuvers increasing intraorbital pressure (e.g., the Valsalva maneuver), trauma to the orbit or forehead, or eyelid manipulation.

Indications and Contraindications

Early globe reduction is indicated to relieve symptoms and to minimize visual impairment. Attempts at reduction in the ED are relatively contraindicated when there is obvious rupture of the globe.

Technique

Before globe reduction, perform a rapid eye examination to document visual acuity, range of eye motion, pupillary reactivity, and any evidence of globe rupture (see earlier discussion).\[101\] Place the patient in a recumbent position, and administer a topical ocular anesthetic agent (e.g., 0.5% proparacaine). When the lashes are visible, ask an assistant to apply steady outward and upward traction while the globe is gently pushed behind the lids. Use gloved fingers to apply steady scleral pressure and manipulate the globe back into the orbit. When the lashes cannot be grasped, introduce a lid retractor behind the lid to provide countertraction. Others recommend placing a suture through the anesthetized skin of each lid to provide countertraction.

After the procedure, repeat the eye examination documenting visual acuity and extraocular movement. It is not uncommon for return of full visual function to be delayed for several days, or occasionally longer.

Complications

It is common with this procedure for lashes to be retained in the conjunctival fornices. Evaluate for and remove any free lashes to
prevent corneal injury. Edema, retrobulbar hemorrhage, or orbital deformity may prevent outpatient reduction. When reduction is not possible in the ED, saline drops should be applied to the globe and a noncontact eye shield applied.

**Aftercare**

Patients with spontaneous luxation and no visual impairment in whom the globe is easily reduced warrant follow-up within 24 to 48 hours. Instructions to avoid potential triggering maneuvers should be given. Recurrent luxation may warrant lateral tarsorrhaphy. Further evaluation of potential precipitating illness can be pursued on an outpatient basis.

Patients with traumatic luxation are at greater risk for underlying ophthalmic injury and warrant emergent consultation. A computed tomography scan of the orbit is helpful for evaluating both the soft tissue and the bony structures about the globe.
STYE

A stye, or hordeolum, is an acute purulent inflammation (bacterial infection) of the eyelid characterized by pain, swelling, and redness. They can be quite annoying and painful to the touch. A small nodule or abscess first develops in an eyelid hair follicle or a modified sebaceous gland at the eyelid margin. This may be external (pointing at the lid margin) or internal (pointing under the conjunctival lid; Fig. 63–43). An obvious pustule may be seen, and if so, incising it with a small needle and expressing pus produces a faster cure. The lid may be inverted to find a small pustule on the inner lid that can be nicked with a 25-gauge needle (see Fig. 63–19C). *S. aureus* is the organism most frequently isolated from the infection. [1] Treat with warm compresses on the eyelid as frequently as possible. One method is to fill a sink with very hot water and alternate wet washcloths for 15 to 20 minutes. Topical ophthalmic antibiotics (drops q2h or ointment five to six times a day) are usually prescribed. Erythromycin ointment is often suggested. Topical treatment is usually sufficient, but antistaphylococcal oral antibiotics (dicloxacillin, cephalosporins) might occasionally be needed, especially if there is significant surrounding lid cellulitis. More formal incision and drainage may be necessary if the infection is unresponsive to conservative therapy. [102] Spread of the infection can lead to preseptal cellulitis.
**Figure 63–43  Stye (hordeolum).** A, External hordeolum. An erythematous, tender swelling at the lid margin points externally. B, Internal stye. This may form a pustule on the inner surface of the lid that may be incised and pus expressed (see also Fig. 63–19 C).
Afferent Pupillary Defect or Marcus-Gunn Pupil

An afferent papillary defect (APD), or Marcus-Gunn pupil, is caused by a variety of diseases of the afferent, or “in-going,” pathways of the eye. It is produced by a unilateral lesion of the retina or optic nerve. Causes include optic neuritis (as seen with multiple sclerosis), ischemic optic neuropathy, optic tumor, and retrobulbar hematoma (an indication for lateral canthotomy). To evaluate for an afferent pupillary defect, the swinging flashlight test may be used. Normally, shining a light in either eye causes bilateral pupil constriction. To evaluate for an APD (no light reaching the brain via the optic nerve on the affected side), record the pupil size at baseline. Shine a light into the affected eye. Record the direct response (constriction of the illuminated pupil in response to light) and the indirect or consensual response (constriction of the opposite pupil in response to light). Next, shine the light into the other eye and record the direct and indirect responses. Repeat this procedure back and forth until the pattern of response to light is identified. In the APD, there is a decreased direct response to light along the afferent or “in-going” pathways, whereas the efferent or “out-going” pathways to the opposite eye are preserved. Thus, light shined into the affected eye will cause neither a direct nor a consensual response, but light shined into the unaffected eye will cause bilateral pupillary constriction.

Subconjunctival Hemorrhage

Subconjunctival hemorrhage may occur spontaneously (often noticed on awakening) or after straining, vomiting, or serve coughing. The patient notices a painless bright red hemorrhage of the eye (sclera). It may be bilateral (see Fig. 63–37). Vision is not affected. Although this is concerning to the patient, it is benign. No laboratory evaluation is required unless that patient is anticoagulated; then, clotting studies should be performed. The hemorrhage will disappear spontaneously over a few weeks, turning various colors as it recedes. No treatment will hasten resolution.
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REFERENCES


