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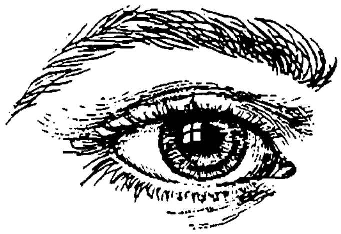

Determination of Human Cadaver Eye Injuries after Trauma Experimentation (Is it Possible?)

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Abstract

The orbital/ocular region is an area of the body in need of biomechanical study for the mitigation of injuries related to blunt trauma. The human cadaver is a potential model for such studies. In this paper, basic orbital/ocular anatomy is reviewed as are some of the common injury terms associated with the eye. Standard examination methods and diagnostic imaging techniques (X-ray, CT, NM and Ultrasound) are briefly explained and investigative results are noted for both five accident victims and postmortem subjects. Finally, post-mortem tissue changes are discussed in terms of their hindrance to the determination and validity of eye injuries in human cadavers subjected to trauma experimentation.

Introduction

The orbital (bony socket and structures related to the eye) and ocular (eyeball) regions are in need of biomechanical study for the mitigation of injuries related to trauma. Blunt trauma to the eye, commonly seen in sports and motor vehicle accidents, can lead to the debilitating loss of a major sensory organ as well as cosmetic disfigurement. Research on human tolerance to specific mechanisms of injury requires the use of a suitable model. The model must account for two major aspects of biofidefity: 1) accurate representation of structure (shape, size and mass); and 2) life-like tissue response including frangibility. Porcine eyeballs are nearly the same size as human eyeballs and are often used in the study of ocular anatomy and injury. However, the porcine facial skeleton provides a less than ideal representation of the human face. In the study of how facial trauma affects the orbital regions, a human cadaver would obviously provide the most anatomically accurate model. Given the use of such a model, great attention should be paid to dynamic tissue response. Can a cadaver eye accurately represent the dynamic response of a living eye?

For biomechanical testing with human cadaver tissue, a critical component is the determination of damage by post-test analyses. Due to the nature of post-mortem tissue, the human cadaver eye presents a particularly difficult area in which to assess trauma. Initial indications of ocular injury in the living almost always manifest as a functional deficit. Such deficits are basically impossible to detect in cadaveric specimens for a number of reasons noted later. Therefore, researchers must carefully note pre- and post-test anatomy in order to determine damage resulting from a particular biomechanical test. Often, a physiologic deficit can be reasonably inferred from the documented damage. To that end, a brief description of the anatomy of the orbital/ocular region is presented. Injury terms will be noted followed by an exposition of medical examination and diagnostic imaging techniques.

Anatomy of Orbital/Ocular Region

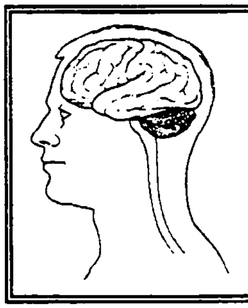

Figure 1 Proximity of Eye to Brain

The eyes are located within orbits (bony sockets) found at the junction between the facial and cranial portions of the skull. The cranial bones serve as a strong, protective case for the brain. Facial bones generally support special sensory organs and allow for the passage of air and nutrients into the body via the nasal and oral cavities. As can be seen in Figure 1, the eye is in close proximity to the brain. In fact, during the 4th and 5th weeks of prenatal development, parts of the eye actually form from an outgrowth of brain tissue. (This explains why the optic nerves are invested with meninges - dura, arachnoid and pia mater). According to the classic work, Grant's Dissector (edited by Sauerland, 1994), each orbit is usually described as being somewhat pyramidal in shape with the base serving as the orbital opening and the apex being directed somewhat medially towards the brain. The medial or nasal walls of each orbit are parallel and spaced approximately 25 mm apart. The medial walls run about 50 mm posteriorly. The lateral walls of the left and right orbits are angled laterally to such a degree that they are nearly perpendicular to each other. The orbit is formed by portions of several bones as shown in figure 2. The bone of the forehead, the Frontal bone (F), forms most of the orbital roof as well as portions of the lateral and medial walls. The cheek bone or Zygoma (Z) helps form the lateral wall and part of the floor along with a deeper bone termed the Sphenoid. The Maxilla (M) contributes to the floor and medial wall. The medial wall is also formed by parts of the Lacrimal and Ethmoid bones which are deep to the Nasal (N) bones. The bones of the orbit are fairly fragile. It should be noted that the Frontal, Ethmoid, Sphenoid and Maxillary bones all contain large air-filled spaces termed Paranasal Sinuses. Significant fracture of these bones, especially the maxillary, can result in prolapse of the ocular structures into these sinuses. Near the apex of the orbits are a number of openings which allow for nerves and blood vessels to supply the ocular structures. Anteriorly, the eyeball is protected by eyelids and eyelashes. Also, the Conjunctiva is a thin membrane that lays on the anterior surface of the eye and is reflected onto the inner aspect of the eyelids.

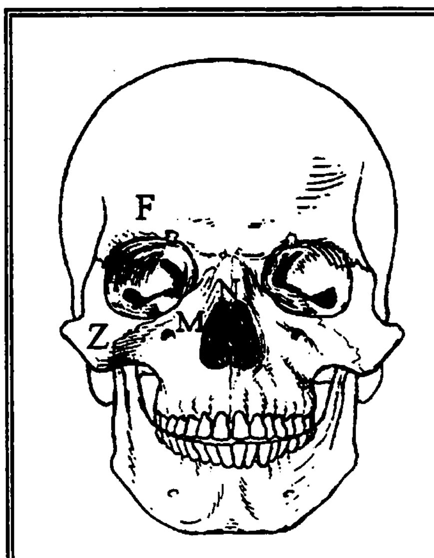

Figure 2 Bony Orbit

Within the orbit, the eyeball occupies approximately the anterior half of the cavity. The posterior portion of the cavity is filled with adipose (fat) and connective tissue packed around and between the nerves, muscles, and ophthalmic vessels that supply the eyeball. There are six extraocular eye muscles that are dedicated to positioning the eyeball. They all insert at the outer fibrous covering of the eyeball - the sclera. Five of these muscles take origin from the apex of the orbit while one originates from the floor of the orbit. These muscles are controlled by Cranial Nerves III (Oculomotor), IV (Trochlear), and VI (Abducens). Displacement of fracture fragments in the orbit may damage the nerves and lead to the inability to move the eyeball in a certain direction.

The eyeball itself is a major sensory organ that focuses light waves and transduces them into electronic signals sent to the brain. It may be most logical to examine ocular (eyeball) anatomy by following the same pathway as the light (See Figure 3). After passing between the eyelids and through the conjunctiva(O), light must enter the eyeball proper. The walls of this globe have three distinct layers- an outer fibrous layer, a middle vascular layer, and an inner nervous layer. Approximately 5/6 of the surface area of the outer layer is the white colored Sclera(S). The anterior 1/6 of this layer is the clear Cornea(C). Notice that the cornea has a smaller radius of curvature than the sclera. The cornea is the first portion of the eye to help focus light. Immediately behind the cornea is the Anterior Chamber(A) which is full of a transparent watery fluid called the Aqueous Humor. This fluid is filtered from blood plasma by structures located in the Ciliary Body(B). Cells in the ciliary body absorb fluid from the blood and deposit it into the Posterior Chamber which is the small space located between the Iris(I) and the Lens(L). The iris and ciliary body are part of the vascular layer of the eyeball along with the Choroid(D) which is the vascular layer located between the sclera and retina.

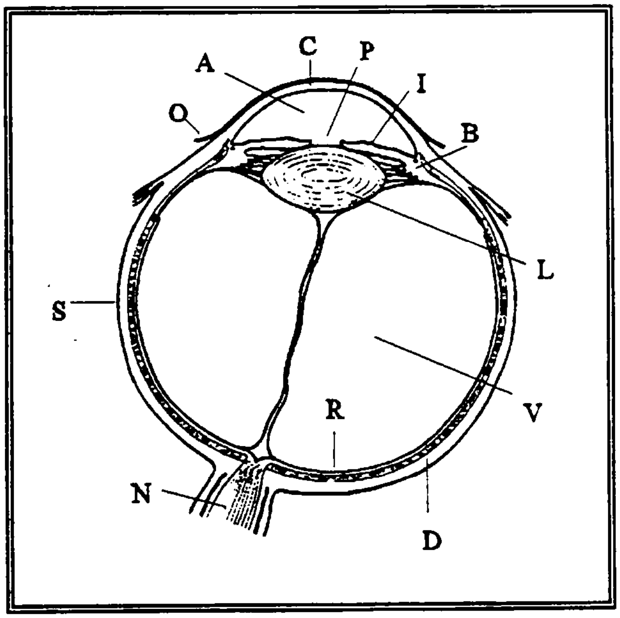

Figure 3 Ocular Anatomy

The aqueous humor flows from the posterior chamber into the anterior chamber and is eventually drained there through small canals (canals of Schlemm) into the venous system. There is less than one milliliter of aqueous humor and it is constantly being produced and drained (complete turnover every 1-2 hrs). The aqueous humor provides an internal pressure that helps maintain the shape of the eyeball and more specifically the cornea. This is referred to as Intraocular Pressure and has a normal range of 10-20 mm Hg. (Donlon 1994, Cogan 1993)

Once light has entered the anterior chamber it must pass through the Pupil(P) which is the aperture formed by the iris. Sphincter and dilator muscles in the iris adjust the diameter of the pupil and thus the amount of light allowed to strike the Lens(L). The lens is the major focusing structure. Muscles in the ciliary body(B) control the shape of the lens allowing it to accommodate for near or distant focus. Focussed light is then transmitted through a gelatinous structure called the Vitreous Humor(V). This transparent gel fills the large cavity posterior to the lens and provides for much of the shape of the scleral portion of the eye. It also plays a role in intraocular pressure. However, unlike the aqueous humor, the vitreous does not undergo much change or turnover. Therefore, it is usually the aqueous humor that plays the most significant role in determination of intraocular pressure.

After light has penetrated the vitreous humor it finally strikes the posterior wall of the orb. The wall has a complex arrangement of epithelium and nervous tissue. The main component is the Retina(R). Nerve cells in the retina have special receptors that transduce light into action potentials (electronic signals) that are passed through a chain of nerve cells. The processes of these nerve cells are what make up the second cranial nerve- the Optic Nerve(N). Ultimately, the signals are fed to the Occipital Lobes of the brain where they are interpreted.

Common Eye Injuries

The eyes may be subjected to numerous forms of trauma. Please note that the discussion of injuries below are not complete. Blunt trauma injuries were of particular interest to these authors but it should be noted that many of the same injuries or responses are common for sharp and penetrating traumas as well.

Blunt force applied to the upper face can result in some rather severe extraocular injuries such as Fracture of the orbital bones. Fracture fragments may then act as additional injuring agents as they impinge upon the ocular muscles, nerves or vessels; or the fragments may be driven into the eyeball itself. As mentioned previously, fractures can also disrupt the continuity of the orbital walls such that ocular structures Prolapse or Herniate into sinuses. Internal ocular structures are also subject to damage from blunt forces. The iris, lens and retina are often jolted with sufficient force as to cause Displacement, Dislocation, or Detachment.

Specific injuries to the fibrous layer of the eye (cornea and sclera) include Abrasions (scrapes), Lacerations (rips or tears due to blunt trauma), Incisions (cuts due to a sharp instrument), and Perforations (punctures). In severe instances, the fibrous layer of the eye may Rupture resulting in leakage of ocular structures.

In reaction to literally any injury, the body mounts an inflammatory response. There are two major reactions that affect the vasculature in a damaged area. Blood vessels tend to dilate and they become more permeable. This gives rise to the four cardinal signs of inflammation which almost always indicate a form of injury:

1) Redness - Vessels in the injured area become engorged with blood in an attempt to bring nutrients and inflammatory cells (white blood cells & macrophages) to the injured area.

2) Heat - Among the many functions of blood, one is to serve as a heat sink (very similar to radiator fluid in a car). The increase in blood flow brings with it a localized increase in heat.

3) Swelling - Blood vessels in a damaged area may be torn and thus leak fluid into the area. In addition, undamaged blood vessels become more permeable to allow for inflammatory cells circulating in the blood to escape from the vessels and help control or repair the damaged tissues. This allows for considerable accumulation of fluid in a damaged area.

4) Pain - Damaged tissues release certain chemicals that stimulate pain nerve cells. In addition, the swelling mentioned above can also contribute to pain by putting excessive pressure on pain nerves.

All of the injuries noted at the beginning of this section will elicit **inflammatory responses** that may be fairly obvious. When the eye region is struck by a blunt object, the region immediately around the eyeball becomes red and swollen. When blood vessels are torn, the bleeding is described as a Hemorrhage. Small hemorrhages in the eyelids may result in the formation of tiny red or purple spots called Petechiae. Larger pooling of blood and it's subsequent decomposition gives rise to Ecchymosis, the darkening of the orbital regions commonly referred to as a "black eye." Massive pooling of blood is termed a Hematoma. Conjunctivitis is reddening of only the thin protective membrane that covers the front of the eyeball. The same term is used to describe the conjunctiva's response to infection which is commonly referred to as "Pink Eye."

The eyeball itself will also exhibit inflammatory responses when injured. Inflammation of the cornea in general is termed Keratitis, likewise inflammation of the sclera is Scleritis. These may be localized as in the case of abrasions and lacerations, or they may be more global as is seen with burns or simple global reaction to blunt strike. When internal structures are disrupted, they tend to bleed or hemorrhage just like any other body area. The bleeding is often described according to the area where the blood pools. For example, blood pooling in the anterior chamber is known as Hyphema. Blood may mix with the aqueous or vitreous humors as well as pool between layers of the walls of the globe. In cases of retinal hemorrhage, the collecting blood may dissect it's way between the choroid and the retina and thus result in varying degrees of retinal detachment.

Examination Techniques

The eye is a major sensory organ and therefore the primary emphasis of clinicians is to investigate the **function** of the eye after injury. When trying to determine the location of a specific injury, medical personnel benefit from the clues left by the inflammatory responses of a living person.

The general order for the components of an ocular examination are clearly explained in a number of medical texts (Vaughan et al. 1995, Pavan-Langston (ed) 1991, Cinotti (ed) 1985, and others). First is always the taking of a thorough "Patient History." Included in this is the determination of the immediate complaint and general observation of gross anatomical structures and injuries. After the history, physiologic deficits are investigated by the use of tests designed to determine visual acuity, astigmatism, color vision, pupillary response and extraocular muscle function. The intraocular pressure or tone of an eyeball may be measured with a variety of simple Tonometers (Schiotz Mechanical Tonometer, Goldman Applanation Tonometer, Pneumotonometer, Air Puff Non-contact Tonometer, etc).

The examination may progress to more thorough visualizations of portions of the eye. The use of a magnifying loupe or slit lamp affords the opportunity to study the anterior segment of the eyeball in considerable detail. Abnormalities of the cornea, sclera, iris and lens are generally easy to see with the loupe or slit lamp. Surface abrasions and lacerations may be made more obvious by the use of a Fluorescein Dye. This orange dye binds to ulcerated (excavated) areas of the cornea or sclera. In the presence of cobalt blue light, the damaged areas shine yellow-green. A Rose Bengal Dye stains dying or dead cells and requires regular white light.

In order to examine deeper eye structures, either the slit lamp or Ophthalmoscope are employed. In the hands of a trained professional, these devices can provide a very detailed glimpse into the region behind the lens. Vitreous hemorrhage and retinal problems may be discovered through ophthalmoscopy, provided the bleeding does not obscure the view.

The most advanced investigative techniques are found in the area of diagnostic imaging. All of the following techniques can be employed when the cornea or fluids are opaque. As is often the case with trauma to any part of the body, one of the first imaging techniques used is Plain Radiography (X-rays). Radiography has the advantage of being a relatively quick and inexpensive method to determine osteological status. Besides illustrating the skeletal system, radiography can be enhanced by the use of dyes that are introduced into the vascular system. This is termed Angiography and it can be applied to patients with orbital/ocular injuries to determine the integrity of the blood vessels in the area. When investigating the orbit, there are a number of different imaging views that are particularly effective. The Lateral X-ray is a side view of the skull. Both orbits are projected upon one another creating a view that is generally too cluttered to identify anything but massive fracturing (See Figure 4). It is however useful for localization of foreign bodies. The Caldwell View is shot with the head in a true posterior-anterior (P-A) position. This view displays the frontal sinuses (S) and orbital rims. The orbital roof is generally perpendicular to the plane of view and thus not visualized particularly well (See Figure 5). The Water's View is obtained when the chin is placed on the X-ray film (See Figure 6). In this view, the orbital floor is obscured by the maxillary bones but the orbital roofs (R) are clearly visible. (Kraft 1970, and others)

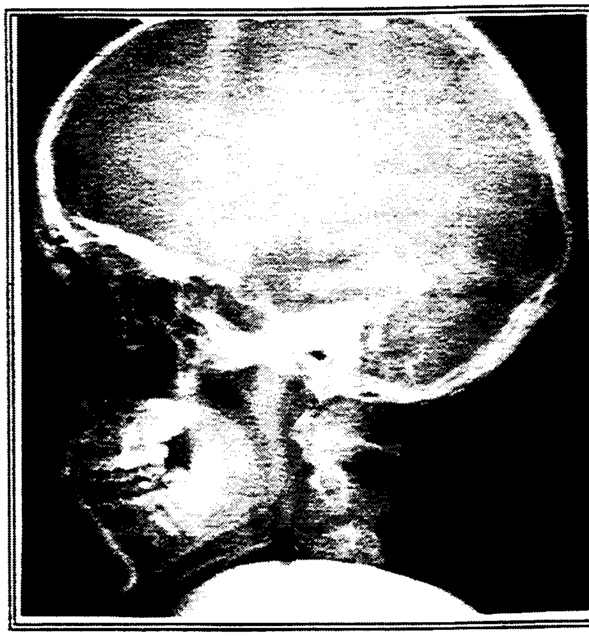

Figure 4 Lateral X-ray of the Skull

Figure 5 Caldwell's View of the Skull

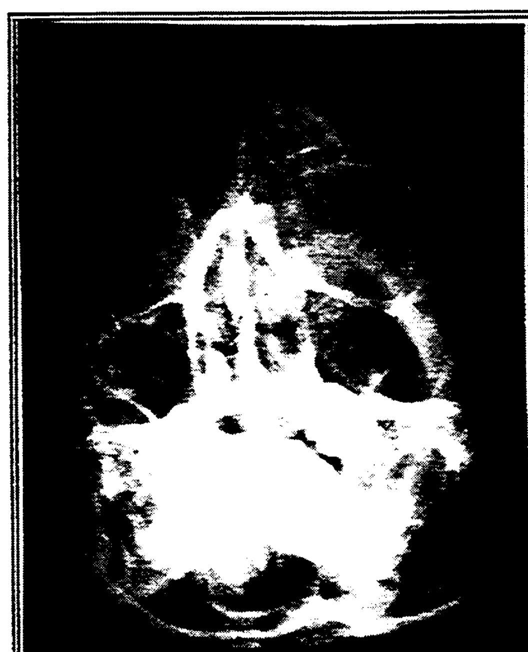

Figure 6 Water's View of the Skull

An advancement over plain radiography is Computerized Tomography- CT Scans (also known as computer assisted tomography- CAT Scans). CT Scans also make use of ionizing radiation or X-rays, but their use is more precise and computer driven such that finer details can be distinguished. The computer also makes possible the visualization of very fine "slices" of the body. These can be reconstructed to form 3-dimensional images. Although it is a great jump in technology, the CT Scan has somewhat limited capability in the ocular region. Since it is still X-ray based, the CT Scan is best suited for determining fine skeletal detail in the orbit. Ocular structures can be seen, but the quality of imaging soft tissues is far from ideal (See Figures 7 and 8 for Frontal and Horizontal CT Scans of a head).

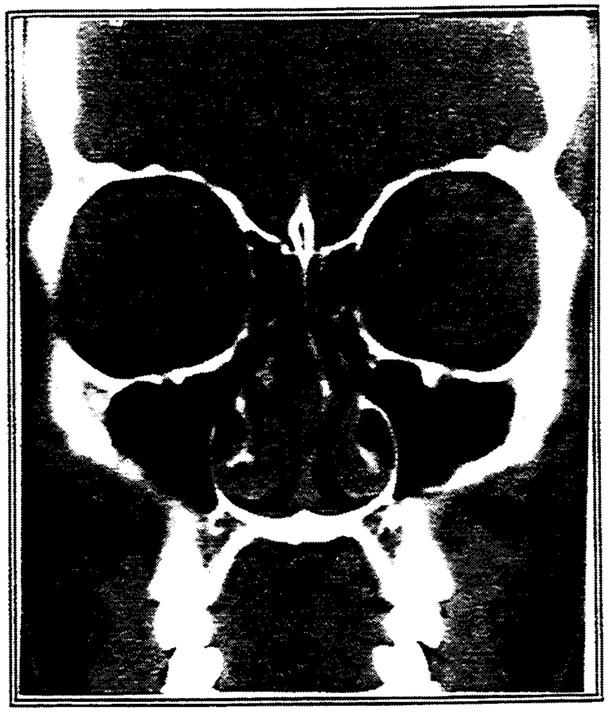

Figure 7 CT Scan Frontal Section of Head

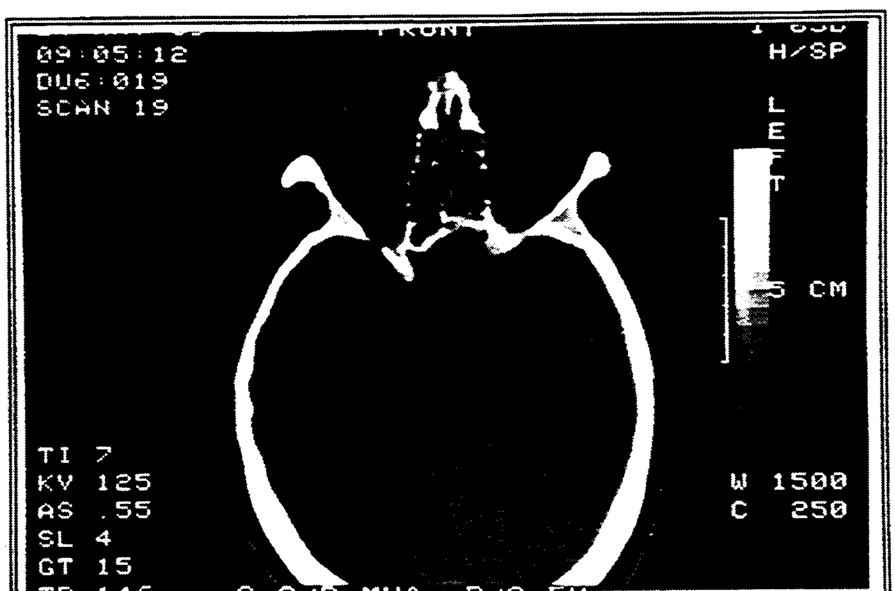

Figure 8 CT Scan Horizontal Section of Head

Magnetic Resonance Imaging- MRI is an extremely valuable and versatile, but very expensive tool. Depending on the "weighting" of the MRI one may visualize a number of soft tissue structures. This includes the inside of the eyeball where one can determine iris, lens and choroid positions as well as note the presence of cataracts, tumors, etc. MRI can also be used to identify problems with the optic nerve or the extraocular muscles and their nervous and vascular supply. MRI is accomplished by placing a patient in a powerful magnetic field (a 1.5 Tesla magnet was used for this study). Spinning nuclei of Hydrogen atoms are "aligned" by this field and radio frequency (RF) energy waves are pulsed towards the patient. The energy is temporarily stored in these miniature nuclear magnets. When the pulse momentarily stops, the excited atoms decay or relax and RF electromagnetic energy is emitted. Special sensors on the MRI tunnel detect and analyze these signals. An image is constructed that indicates different tissues based on their distinctive release of energy. The time between RF pulses (TR) and the resultant echo detection (TE) can be varied. Variation of these factors leads to different "weightings" for the images and thus different signal intensity for tissues. In the T1 weighting shown in Figure 9 notice the bright signal (white) for orbital fat and subcutaneous tissues. Moderate signals are produced for the vitreous, extraocular muscles, optic nerve and cerebrospinal fluid (CSF). Air spaces yield no signal at all- black. (Also note the light signal for brain gray matter and the darker signal for brain white matter.)

A considerable increase in both TR and TE gives rise to a T2 weighted scan as seen in Figure 10. This is the same specimen as shown in figure 9. In a T2 weighting, CSF and vitreous are indicated by very strong signals. In contrast, the firm lens is distinct due to it's low signal. Notice the lack of a ellipsoid lens in the right eye (located on the left of the image). The right eye had an artificial lens implant. Orbital fat, extraocular muscles and the optic nerves are not easily distinct from one another with this weighting.

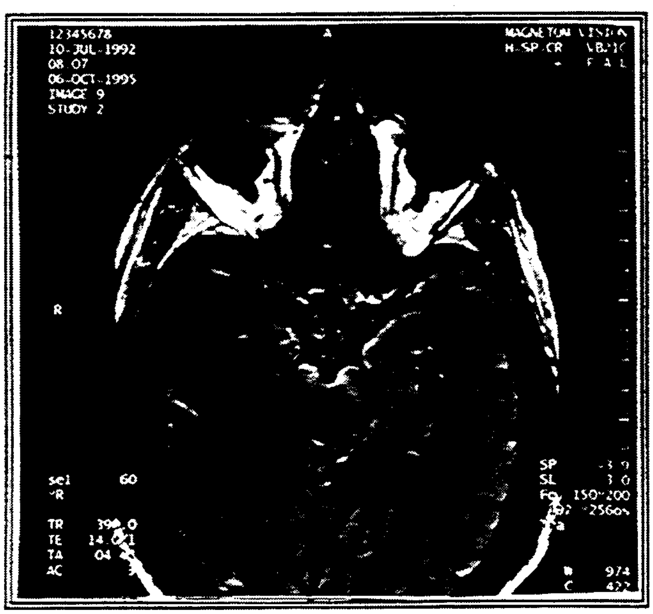
Figure 9 T1 Weighted MRI of a Head

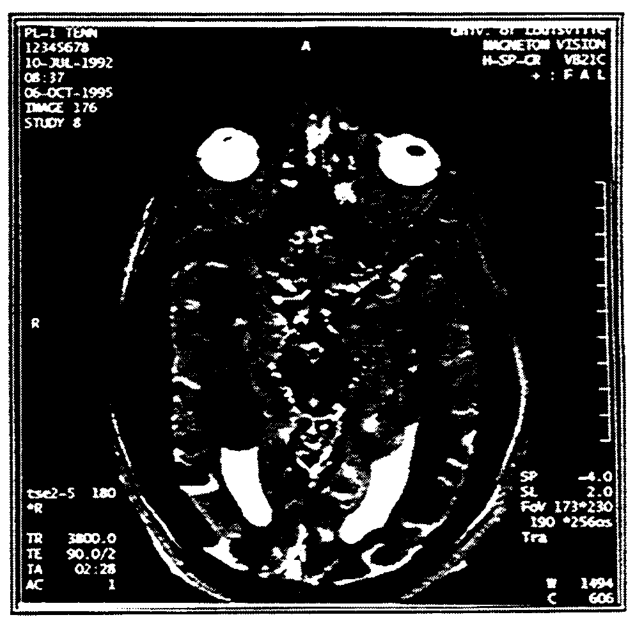

Figure 10 T2 Weighted MRI of a Head

As would be expected with a computer driven system, there are a multitude of permutations available in the weighting system. Figure 11 shows an intermediate weighting IW that was made using a high TR and a low TE value. This image is similar to the T2 but there is much more definition among the extraocular muscles and optic nerve. The Vitreous is still emitting a strong signal while the signal from the lens is weak. Figure 12 shows a Fat Suppression technique that digitally subtracts the fat signal from the resultant image. This yields a fairly strong signal from the choroid and optic nerve. Some details inside the eyeball as well as in the space behind the eyeball are clearer due to the lack of a overpowering signal from vitreous and orbital fat. It is interesting to note that the brain tissue appears to be the strongest signal in this particular scan.
(De Potter et al. 1995)

Figure 11 IW MRI of a Head

Figure 12 FS MRI of a Head

Another diagnostic imaging technique that is popular for investigating eye injury is Ultrasonography. Ultrasound technology dates back to World War II and the inventions of sonar and radar. Like MRI, ultrasound does not make use of ionizing radiation. It is a very low-risk imaging technique. Although the images are not as spectacular as MRI, they may be every bit as useful. Also, ultrasound is very inexpensive (about the same order as X-rays) and the machines are portable. A clear advantage of ultrasound is the fact that images are produced in real time and thus the examination is dynamic. The probe can be manipulated to literally search an area for problems. The basic principle behind ultrasonography is simple sound mechanics. Sound waves are pulsed into an area and the echos are received and modified. The frequency used for orbital examination is generally 8-10 MHZ, while abdomino-pelvic examinations for fetal development and the like are performed at 1-5 MHZ (lower frequency produces longer wavelengths and thus deeper penetration). Ultrasound can be recorded in one dimensional A-mode or two dimensional scanning B-mode (See Figure 13). Although the image is much less distinct than that of an MRI, the posterior portions of the eyeball can be examined rather thoroughly. Detached retina is easily diagnosed with a B-mode ultrasound scan.

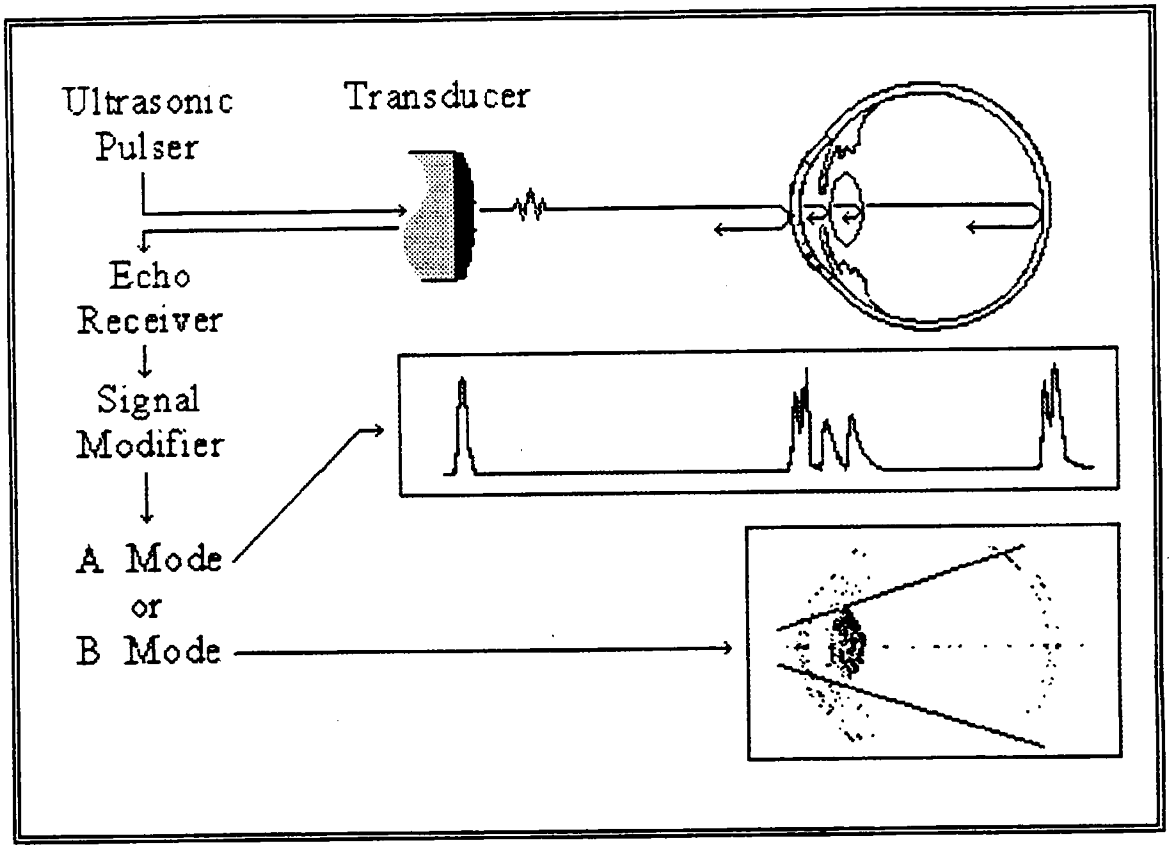

Figure 13 Basic Scheme for Ultrasound Imaging

Figure 14 shows the classic "funnel" shape of a detached retina from the same cadaver specimen that was imaged in the MRI series. The bright crescent shaped signal to the far right of the image is the posterior wall of the eyeball and some of the extraocular structures behind the eyeball. The funnel shape is due to the fact that in most cases the retina detaches from the choroid but not from the optic disk which is where all of the retinal fibers stream into the optic nerve.

Figure 14 Ultrasound Image of Detached Retina

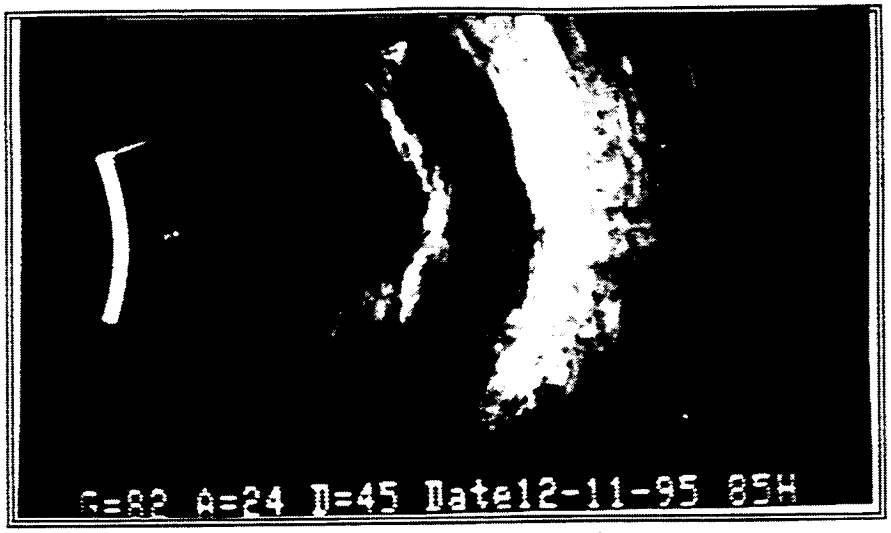

Figure 15 Ultrasound Image of Detached Retina

Figure 15 is the same specimen from a slightly different view. The detached retina is still clear, but the optic disk is not in the plane of section. (Pavlin and Foster 1995, Byrne and Green 1992, Coleman 1977)

Discussion

Physicians have a multitude of examination techniques at their disposal when trying to diagnose orbital or ocular injury in a patient. Researchers investigating eye tolerance and injury threshold levels require a model high in biofidelity. The human cadaver provides an accurate structural model but the tissue response of cadaveric tissue is problematic.

First, all physiologic analyses of injury are basically useless in cadaveric tissue. Most of the basic ocular examination techniques involve determination of the functional integrity of the visual system. Visual acuity, astigmatism, clarity, visual field and depth of field perception, color perception, pupillary response, and extraocular muscle function simply cannot be determined in dead tissue. The use of post-mortem eyes by researchers involves some other serious anatomical obstacles as well.

A) The specimen has no blood pressure and therefore bleeding or hemorrhaging is not likely to occur. Although vessels could be re-pressurized temporarily, ophthalmic vasculature is very small and would likely be plugged with clotted blood. Additionally, the ciliary body would not function to filter fluid from the blood to form the aqueous humor.

B) Shortly after death the cornea, lens and intraocular fluids (vitreous and aqueous humors) begin to cloud. This renders gross observational, ophthalmoscopic, and slit lamp examinations unproductive in cadaver eyes.

C) Loss of fluids, due to evaporation or increased vessel permeability from decomposition, affects the overall shape and intraocular pressure of the eyeball. It is important to note that different tissues decompose at different rates. It is clear that the fragile retina readily detaches from the choroid very soon after death and that this detachment is exaggerated when the specimens are allowed to dehydrate as the shrinking vitreous will pull the retina away from the choroid. However, the tough sclera and cornea are fairly resilient. The authors were able to inject saline via a 30 gauge needle and actually approximate normal intraocular pressure for a short period of time (approximately 10 minutes).

D) Presumably there are other changes associated with the length of storage and the method of fixation (freezing versus embalming) that may also affect biofidelity of the eye during trauma research.

Although the list of obstacles appears daunting, there is still hope for the **limited** use of cadaver specimens in trauma experimentation. Provided normal intraocular pressure can be re-established, external ocular structures could be studied with reasonable confidence. Orbital fractures thresholds are likely to be very similar to those of the living. Provided the decomposition is not advanced, a saline or glycerin injected cadaver eyeball would probably be a good model to study corneal and scleral abrasions and lacerations. However, at this time, it is unclear if fluorescein dye is functional in cadaveric specimens. Preliminary tests have indicated that the dye does not select for damaged areas on post-mortem eyes. Fortunately, abrasions and lacerations may still be detected by other means such as stereoscopic microscopy or computer enhancement of digital images made of the surface of the eye. Clearly, the retina is too fragile to be of value in cadaveric studies as it detaches spontaneously some time shortly after death. But other intraocular structures may still show a dynamic response to blunt trauma that is comparable to that seen in live humans. Iris and lens dislocation could be ascertained via MRI or possibly Ultrasound imaging.

One distinct advantage to studying post-mortem tissue is that it may be thoroughly dissected upon completion of testing. A frontal dissection of the orbit may be useful is studying the anterior segment of the eye but a superior approach (entering the orbit from the cranial cavity) would likely be most advantageous. Figure 16 shows how the orbit can be exposed once the cranial cap and brain are removed. By chipping away the orbital roof, the entire contents of the socket can be displayed. Once extraocular structures are studied the eyeball itself can be carefully incised to expose intraocular structures (See Figure 17). As soon as the vitreous is disturbed, the retina quickly falls from the posterior wall of the eyeball. The lens and iris are readily studied but the dissection is tedious and difficult. Dissections in combination with MRI, Ultrasound and X-ray would be desirable.

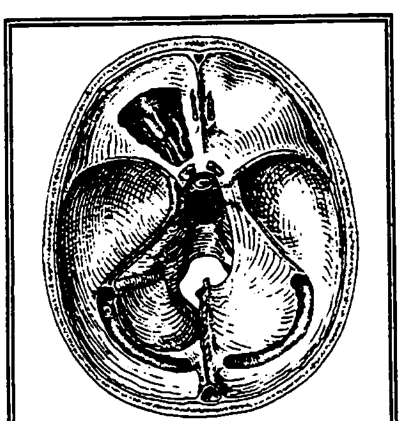

Figure 16 Superior Dissection

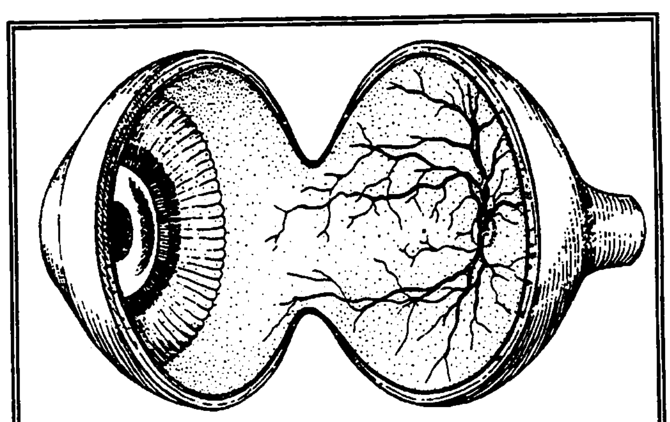

Figure 17 Incised Eyeball - Intraocular Structures

Conclusions

The human cadaver eye is a less than ideal model for determination of eye injuries during trauma experimentation. It is suitable for the determination of massive injuries such as fractures and globe ruptures. It may be suitable, if enhanced, for determination of damage to the fibrous layer of the globe and possibly the iris and lens. It is clearly not a good model for the determination of injuries such as retinal detachment or any injury that relies on inflammatory responses in order to be discovered. However, even with it's problems, it is probably the best model currently available, aside from live animal testing which addresses tissue response issues but presents a completely different set of problems dealing with a structural biofidelity.

Acknowledgments

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DISCUSSION

PAPER: **Determination of Human Cadaver Eye Injuries after Trauma Experimentation**

PRESENTER: David Porta, University of Louisville School of Medicine

QUESTION: N. Yoganandan, Medical College of Wisconsin

I have one comment for this detailed, informative presentation. At the Medical College of Wisconsin in Milwaukee, we are required to protect the identity of the donors, in other words, human cadaver subjects, and we also followed the lengths such as those adopted by CDC when they do human cadaver testing.

I would strongly recommend for the people who do biomechanics or who are into human cadaver research to be careful in showing the kind of slides which show that the identity of the donors.

ANSWER: I understand. And thank you for this comment.

Q: M. Kennedy, Farmington Hills, Michigan

You had mentioned studying eye injuries from air bags. This is all preliminary to that. Is that correct?

A: Yes, Sir.

Q: Do you have any thoughts on what the difference would be if you reduced the force in the air bag and what kinds of change occur?

A: Well, that's a very good question. Right now, I, personally am not sure what injuries are caused if the current force is used so it is very hard for me to determine. Obviously, if we decrease the pressure, it seems that would protect the eye but then are we risking damaging the rest of the person so I can't really answer that until we find out what damage is done at the normal pressures.

Q: Well, I'm strongly recommending reducing the force in the air bag and it may conform to the shape of the nose and eyes so it may get to the eyes a little more than you do in the current one.

A: You think if we reduce the pressure that it could cause more damage.

Q: It may conform to your face more.

A: That may be a possibility but I'm not sure that would actually damage the eye anymore.

Q: Well, I don't know either. It's just a thought. Thank you.

A: Thank you.