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Ultrasound Detection of Iatrogenic Injury During Peribulbar Eye Block: A Cadaveric Study

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ABSTRACT

BACKGROUND

Ophthalmic eye blocks, such as retrobulbar, peribulbar and sub-Tenon's, are traditionally conducted "blind". Complications are rare but potentially devastating. Life-threatening complications include brain stem anaesthesia and local anaesthetic toxicity, whereas sight-threatening complications include globe perforation, optic nerve damage and ocular muscle damage. Ultrasound permits a view of orbital structures and can be used to guide needle placement. The ultrasound appearances of unintended local anaesthetic injection into vital orbital structures have not been documented. This study aimed to record the ultrasound appearances of unintended injection locations.

METHODS

The spherical shape of the eyeballs of three soft-fix Thiel embalmed human cadavers were restored using glycerol. Iatrogenic injury in peribulbar block was then simulated through injection of printers' ink mixed with Thiel embalming fluid. Ultrasound was used to guide the needles and the tips were re-directed to lie within the globe, lateral rectus and optic nerve. Ultrasound images were recorded during injection. The orbital cavities were then dissected via a superior approach to record the location and extent of injectate spread.

RESULTS

Real-time globe rupture, ocular muscle injection and optic nerve injection were visible using ultrasound. Characteristic appearances were identified in each case. Dissection confirmed needle and injection placement.

CONCLUSIONS

The ultrasound appearance of block complications is important to document and should be an integral part of regional anaesthesia training. This study is the first to provide such images for ophthalmic nerve blocks. It offers ophthalmic anaesthetists and ophthalmologists the potential to diagnose severe complications rapidly and accurately with a potential impact on patient safety.

INTRODUCTION

Ophthalmic surgery is routinely performed under regional anaesthesia eye block. Three blocks are used in practice (retrobulbar, peribulbar and sub-Tenon's), but most are conducted "blind".

Operators use surface landmarks and tissue feedback in order to guide needles to target areas.

Complications are rare but potentially devastating, and account for 5% of regional anaesthesia malpractice claims.¹ Life-threatening complications include brain stem anaesthesia and local anaesthetic induced convulsions, whereas sight-threatening complications include globe perforation, optic nerve damage, ocular muscle damage and retrobulbar haemorrhage². For example, globe perforation occurs in 1 in 12,000 patients during retrobulbar block and 1 in 16,000 patients during peribulbar block.^{3,4}

In order to improve the safety profile of ocular blocks, peribulbar and sub-Tenon's blocks have largely superseded retrobulbar block. Retrobulbar and peribulbar blocks differ according to the site of local anaesthetic injection and volume of local anaesthetic.⁵ A retrobulbar block entails the direct injection of local anaesthetic into the ocular muscle cone, whereas a peribulbar block depends on spread of higher volumes from the peribulbar to the retrobulbar compartment.⁶ A recent meta-analysis comparing both blocks showed no difference in side effects and the quality of anaesthesia.⁷ Sub-Tenon's block has a different pattern of spread.⁸ Local anaesthetic is injected into the potential episcleral space between Tenon's capsule and the sclera, and thus avoids introduction of a sharp needle into the orbit.⁹

Ultrasound guidance has been used to conduct retrobulbar, peribulbar and sub-Tenon's blocks because it provides a view of the globe, optic nerve and extraocular muscles.¹⁰ Successful anaesthesia was associated, on ultrasound images, with accurate needle tip placement^{11,12} and, in the case of peribulbar block, good local anaesthetic spread.^{6,12,13}

To date, however, the ultrasound appearance of unintended local anaesthetic injection into vital structures of the orbit has not been documented. Therefore, the aim of this study was to document the ultrasound appearance of simulated unintended injection into the globe, optic nerve and lateral rectus muscle.

METHODS

Three human cadavers embalmed using the Thiel soft-fix method were provided by the Centre for Anatomy and Human Identification (CAHID), Dundee. Thiel cadavers are immersed in tanks containing a mixture of monopropylene glycol, ammonium nitrate, potassium nitrate, sodium sulphite, boric acid, and chlorocresol for 6 months during the embalming process.¹⁴ On removal, Thiel cadavers are flexible, soft, durable, and exhibit similar tissue elasticity and strain displacement to patients. They therefore provide excellent simulation for regional anaesthesia training.¹⁵

Hypotonic Thiel solution deflates the eyes of cadavers, so the elasticity of the eyes was restored by performing two injections: first, a 22g needle was inserted into the globe and 1-2ml Thiel fluid injected; then, 5ml glycerol solution was injected through a 10g needle and the puncture sealed with Loctite[®] superglue. Full inflation of each eye was confirmed by manual pressure.

A Zonare Z-one ultrasound machine (Zonare, Palo Alto, CA) with a 4 to 10 MHz linear transducer was used to take images of the eye. The transducer was covered with a sterile sleeve and lubricated with gel (Optilube, Optimum Medical, UK). Stimuplex 22g 50mm ultrasound needles with extension set (BBraun, Sheffield, UK) were used for the injections.

Each eye was scanned with the ultrasound probe placed gently and transversely over the globe. A caudad tilt allowed visualisation of the floor of the orbit. An initial scan was performed to identify major anatomical structures contained within the orbit – the globe, the lateral and medial rectus muscles and the retrobulbar space containing the optic nerve. The ultrasound needle was inserted out of plane using a standard peribulbar approach at the junction of the lateral and medial thirds of the inferior orbital rim and then directed superomedially towards the muscle cone. It was further

directed to lie either peribulbar or within the globe, lateral rectus or optic nerve. The exact positioning of the needle was carried out as follows:

1. Globe: The needle tip was positioned as for a standard peribulbar injection under ultrasound guidance, then redirected superomedially into the globe.
2. Lateral rectus: Following positioning of the needle as for a standard peribulbar injection, the needle was guided deeper and more medially towards the orbital cone until the tip was seen located within the lateral rectus muscle.
3. Optic nerve: The needle tip was inserted as for a standard peribulbar injection, then placed superomedially through the orbital cone until the tip was seen within the optic nerve.

Once placement was acceptable, a 5ml mixture of Thiel solution and green printers' ink was injected. Ultrasound images were recorded throughout.

At the end of the experiment, the orbit was dissected via the cranial cavity and through the roof of the orbit in order to visualise the location and spread of injectate. After removal of the meninges, the orbital plate of the frontal bone was carefully chiselled away to expose the orbital fascia, which was then removed. Reflection of the levator palpebrae superioris and superior rectus allowed visualisation of the optic nerve sheath, which was transected to view the optic nerve.

RESULTS

Three eyes were used to optimise the injection technique and three eyes to conduct the study. The globe, optic nerve and lateral rectus muscle were readily identified using ultrasound (Fig 1A, Fig 1B). The appearance of each was similar to that of a patient eye.

Globe perforation

A slight “give” was felt as the globe was punctured. Injection into the globe was rapid and clearly visualised on ultrasound (Fig 2A, Fig 2B). Resistance increased over the course of the injection until the superglue seal on the eye broke, when resistance suddenly decreased. The entire globe was stained green (Fig 2C), with some external leakage reflecting loss of the seal. Upon dissection and lifting of the orbital conjunctiva, the dye was visualised within the globe (Fig 2D).

Lateral rectus injection

There was significant resistance to injection in this location. On ultrasound, flow could be seen within the muscle with clear medial displacement of the retrobulbar structures including bending of the optic nerve (Fig 3A, Fig 3B). On dissection, dye was visible in the orbital fascia with the lateral rectus most deeply stained (Fig 3C).

Intraneural injection

Upon injection there was significant resistance, with ultrasound showing rapid distortion of optic nerve architecture (Fig 4A, Fig 4B). On dissection, staining was seen in the orbital fascia with the darkest areas at the apex of the orbit. Both the optic nerve sheath and the optic nerve were dyed green (Fig 4C).

DISCUSSION

The study demonstrated real-time globe rupture, optic nerve injection and ocular muscle injection using ultrasound, with the location of the needle tip and spread of injectate identified at all times. The ultrasound characteristics of each injection were location-specific.

The glycerol-based globe inflation technique allowed sustained pressure from the ultrasound probe without leakage, and provided images similar to those seen in patients. However, the principal limitation, common to all types of cadaver, was reduction in periorbital subcutaneous tissue. Globes lie deep in the orbital cavity, so that ultrasound transducers had to be placed on the globe rather than the lower eyelid, and tended to contact the orbital rim, impeding manoeuvrability. This meant that although all the intended ultrasound images were obtained, scanning proved more challenging than in patients.

The wet properties of the Thiel cadaver risked seepage of dye into other tissue spaces, so cadaver position was maintained for three days before dissection in order to check that this did not occur. In fact, it was found that dye distribution was limited to anatomical spaces, with injection points retaining the highest concentration of staining. Observations in this study suggest that little fluid movement occurred post-injection.

Manipulation of the needle shaft could be challenging. For example, globe injection was easy to achieve, whereas optic nerve insertion required considerable dexterity. The operator had to displace the globe anteriorly in order to obtain a suitable anterolateral angle for needle advancement.

Dissection through the superior orbit seemed arduous at first, but proved to be ideal, as eye movement and tissue disruption was minimised.

The sub-Tenon's block has become the most commonly used block in ophthalmic regional anaesthesia practice in the UK. Given the lower incidence of serious sight-threatening complications with the sub-Tenon's technique², this study may be seen as less relevant to current practice. However, globe rupture, optic nerve injection and optic muscle damage have all been reported following sub-Tenon's block¹⁵. The sub-Tenon's block is also not suitable for all patients; it should be avoided in patients with thin sclera, scleral scarring or chronic eye inflammation and in situations where chemosis, conjunctival haematoma or disruption are undesirable.¹⁵

The Thiel cadavers represent an important resource for medical simulation. Their usefulness for training in ultrasound-guided regional anaesthesia elsewhere in the body has been demonstrated¹⁶, but no literature currently exists investigating their role in ophthalmic anaesthesia training. The recognised obstacle is that the embalming process leaves the globes deflated with potentially reduced realism. However, the glycerol-based injection technique used in this study proved robust and realistic, and allowed repeated ultrasound assessment and needle insertion.

Translation of these results to clinical practice may present challenges to anaesthetists keen to undertake eye anaesthesia. The orbit has ideal properties for scanning, but a high frequency transducer is needed that sits comfortably on the eyelid and has sufficient resolution to identify orbital contents and needles accurately. Moreover, it is important to purchase an ultrasound device that limits heat energy transfer to the eye.

When performing peribulbar and retrobulbar nerve blocks, the anaesthetist uses specific equipment, meticulous technique and indirect observations to help reduce complications. This includes having the patient's head in a neutral position with a plane parallel to the ground to ensure the needle is directed in the appropriate planes, using a needle of appropriate length, and looking for signs of

needle trespass into muscle or the globe, which would include tugging of the eyeball as the needle is advanced, a rapid change in compliance during injection and evidence of rapid vis-a-tergo or anterior movement of the eye with injection. The eye can also be balloted for changes in compliance during and after injection. It follows that ultrasound imaging can add a further layer of patient safety by enabling accurate needle tip placement^{11,12}, visualisation of local anaesthetic spread^{6,12,13} and, as demonstrated in this study, aiding diagnosis of injection in an unintended location.

In conclusion, this study has demonstrated that ultrasound can show real-time globe rupture, optic nerve injection and ocular muscle injection in the Thiel embalmed cadaver. The ultrasound appearance of block complications is important to document and should be an integral part of regional anaesthesia training. This study is the first to provide such images for ophthalmic nerve blocks and should be valuable in offering ophthalmic anaesthetists and ophthalmologists sufficient knowledge to diagnose severe complications accurately and rapidly. Early recognition of such complications with ultrasound could have an impact on patient safety.

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Fraser Cullen, Medical Student, University of Dundee

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FIGURE LEGENDS

Figure 1A. Ultrasound image of the orbit and contents.

Figure 1B. Ultrasound image of the orbit with key structures labelled (G – globe; LR – lateral rectus muscle; ON – optic nerve).

Figure 2A. Ultrasound image of globe perforation and fluid injection

Figure 2B. Ultrasound image with labelling of fluid injected (I), lateral rectus (LR) and optic nerve (ON)

Figure 2C. Following perforation the globe was dyed green

Figure 2D. Dissection revealed a green stained globe (G) with unstained optic nerve (ON).

Figure 3A. Ultrasound image of lateral rectus injection.

Figure 3B. Ultrasound shows expansion of the lateral rectus (LR) and bowing of the optic nerve (ON)

Figure 3C. On dissection, dye is seen throughout the intraconal region with the lateral rectus most deeply stained (LPS – levator palpebrae superioris; LR – lateral rectus; MR – medial rectus; ON – optic nerve; SOA – supraorbital artery; SO – superior oblique; SR – superior rectus).

Figure 4A. Ultrasound image of optic nerve injection.

Figure 4B. Ultrasound shows expansion of the optic nerve (ON). Globe (G), Lateral rectus (LR).

Figure 4C. On dissection with division of the optic nerve showing staining within (ON).

Conflicts of Interest: The authors declare no conflicts of interest.