Improving Care in Globe and Adnexal Trauma

A thesis submitted to fulfil the requirements for the degree of Master of Philosophy

Dr Christopher Bartimote

Faculty of Medicine and Health

The University of Sydney

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This is to certify that to the best of my knowledge; the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged

Dr Christopher Bartimote B App Sc (Phys) MD

Abstract

The assessment of globe and adnexal trauma can be complex. Understanding the nature of globe and adnexal trauma including ophthalmology involvement will assist the development of preventative and management strategies. To understand the role of ophthalmology services in tertiary trauma centres we report on the aetiology, acute assessment and management of globe and adnexal trauma at two tertiary trauma centres in Sydney, New South Wales Australia

A retrospective case series was completed at Royal North Shore Hospital (RNSH) and Royal Prince Alfred Hospital (RPAH) on patients admitted between January 2015 and December 2019. The International Classification of Disease, Tenth Revision codes, diagnostic and procedural coding data were used to identify patients. Data extracted from medical records comprised of demographics, details of the trauma mechanism of injury, examination findings and whether ophthalmology assessment occurred.

Over the 5-years, 773 patients with the average age of 53years, were admitted to RNSH and RPAH with globe and/or adnexal trauma. The most common mechanism of injury was falls (n=346, 45%), followed by burns (n=101, 13%). Four-hundred and thirty-eight (57%) patients suffered globe trauma and 228 (29%) were classified as severe. Globe trauma occurred more frequently if orbital/mid-facial trauma was present. Fifty-five-percent of patients only had a gross ocular exam or no exam documented by emergency staff, this increased to 65% in patients between 66-85years and 72% in those older than 85years.

Orbital or mid-facial trauma can indicate an increased risk of globe trauma. Thorough ocular assessment especially if mid-facial/orbital trauma is present is needed to exclude trauma. Specialist ophthalmology review has an important role in assisting medical staff in the acute assessment and management of globe and adnexal trauma. Further, research is required utilising trauma registries to follow the outcomes of patients with globe and adnexal trauma.

Author Attribution Statement

This thesis contains previously published works

Chapter 1 has been published as a literature review in the peer reviewed journal Trauma.
I designed the review, collated the literature, wrote the drafts and final manuscript.
Bartimote C, Fraser CL, Watson S. Integration of ophthalmology in ocular trauma to improve patient care: A narrative review. *Trauma*. 2022;24(1):3-13.

Chapter 2 has been published online and is in press in the peer reviewed journal Injury.
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Dr Christopher Bartimote A/Prof Clare Fraser Prof Stephanie Watson

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1 Introduction

Aims and Hypotheses

We aimed to:

1. Conduct a review of the literature, to examine how the assessment of ocular trauma is placed and prioritised in the major trauma setting.
2. Report the epidemiology, aetiology and risk factors of globe and adnexal trauma in patients admitted at two trauma centres in Sydney, New South Wales Australia.
3. Determine the range of ocular assessments conducted at presentation by medical staff and the extent of specialist ophthalmology involvement in globe and adnexal trauma assessment and management in patients admitted to these trauma centres.

We hypothesised that:

1. A range of patients would be afflicted with globe and adnexal trauma with the mechanism of injury varying amongst different population groups.
2. Globe trauma would occur more frequently in patients who sustained midfacial/orbital fractures.
3. Acute medical staff would perform a range of ophthalmic assessments and that in some cases there may have been no or limited documentation of an ophthalmic assessment in the patient medical record.
4. Ophthalmology specialist assessments of the severely injured patients with multisystem injury would be delayed in many patients' due to the need for life saving treatments.

Globe trauma is one of the leading causes of unilateral blindness(1). Up to 2.4 million globe and adnexal injuries occur in the United States (US) each year(1), most commonly superficial foreign bodies, contusions and corneal abrasions(2, 3). Globe and adnexal trauma often can be managed in an outpatient setting(4, 5). Trauma occurring from mechanisms of injury with high energy, such as motor vehicle accidents, often require complex management and can occur alongside life threatening injuries(3, 6-8). The acute assessment and management of globe adnexal trauma is given a lower priority compared to life-threatening injuries to enable lifesaving treatment(7, 8), delaying referral to ophthalmology services(9).

A trauma service within a hospital is designed to provide high quality care by a well-coordinated multidisciplinary team of health professionals in a well-resourced environment(10). Within a hospital network, trauma centres or hospitals are designed to relieve the burden on smaller, less resourced peripheral centres by preferentially accepting care of severe patients with multisystem injury(11, 12). In Australia, trauma services are organised in tertiary level facilities that have specialised staff and resources to manage

these patients(12, 13). For globe and adnexal trauma, however, there are no universal protocols, guidelines or specialised locations for such patients to be managed. These limitations in the management of globe and adnexal trauma can increase the complexity of managing such cases, especially if the trauma centres do not have specialised ophthalmology services available.

We reviewed the available literature to explore the function of a trauma service, using the Australian trauma services in New South Wales (NSW) as an example, and determine the specialist ophthalmology input in the acute assessment and management of globe and adnexal trauma in trauma hospitals.

Method

The literature was reviewed utilising EMBASE, MEDLINE, CINAHL and Google Scholar to find all literature investigating trauma services, organisation and the integration of ophthalmology in the management of globe and/or adnexal trauma. Extensive search strategies utilising key words and MESH terms were used in MEDLINE, EMBASE and CINAHL (Appendix 1). Google scholar key word searches included globe trauma, ocular trauma, eye injury, adnexal trauma, ophthalmology and trauma services.

The search was restricted to articles in English and no date restrictions were applied. Our review was conducted in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement(14).

Selection of studies

Studies were included if they investigated globe trauma presenting to trauma centres, trauma services and the implementation of specialties within a trauma service. Studies investigating non-globe related trauma were excluded. Duplicates were removed using EndNote version X9.3.3 (Clarivate Analytics, Philadelphia, USA). Titles, abstracts and articles were reviewed to determine inclusion.

Quality analysis

Articles and guidelines were assessed for data and methodological quality using a quality tool(15) to critically appraise the study design. Articles were critiqued for quality by their statement of research or guideline objectives, patient and literature inclusion and exclusion criteria, follow up and statistical analysis.

Data Synthesis and Analysis

Full text review and extraction of data was performed by the lead author. Descriptive analysis of study, protocol design and results was conducted to include in the narrative review.

Results

The search yielded 437 published articles for review with a significant number investigating globe and adnexal trauma. There was no literature found exploring ophthalmology services or the integration of ophthalmology into existing trauma services. Selection criteria for the search were expanded to include general trauma services and other specialty inclusion in trauma services to find data that may inform ophthalmology trauma management. After removal of duplicates and review of titles and abstracts, 49 articles were eligible for full text review. Cross referencing lead to the inclusion of 5 further articles. Of these studies, 30 met criteria inclusion criteria for the review (Figure 1.1). The included literature comprised of guidelines, observational studies, reviews of registry data and the literature from Australia, England, US, Singapore, Iran and Israel (Table 1.1). Common variables noted were visual acuity and mechanism of injury.

Methodological quality of included studies was assessed to determine bias and validity (Table 1.2). The quality of studies was satisfactory in 17 studies as risk of bias was assessed to be low. However, 5 studies excluded patients for missing data leading to a high risk for reporting bias. Selection clarification bias was considered to be high in 2 studies as there was poor or no inclusion and exclusion criteria stated for patients. Three of the review articles were high risk for evidence selection bias as they did not discuss methodology of search strategy or selection criteria. The 6 included guidelines were expert opinions therefore of low quality; however, they were written by reputable sources with clear authorship and construction (Table 1.1).

Figure 1.1: Preferred reporting items for systematic reviews and meta-analyses flowchart

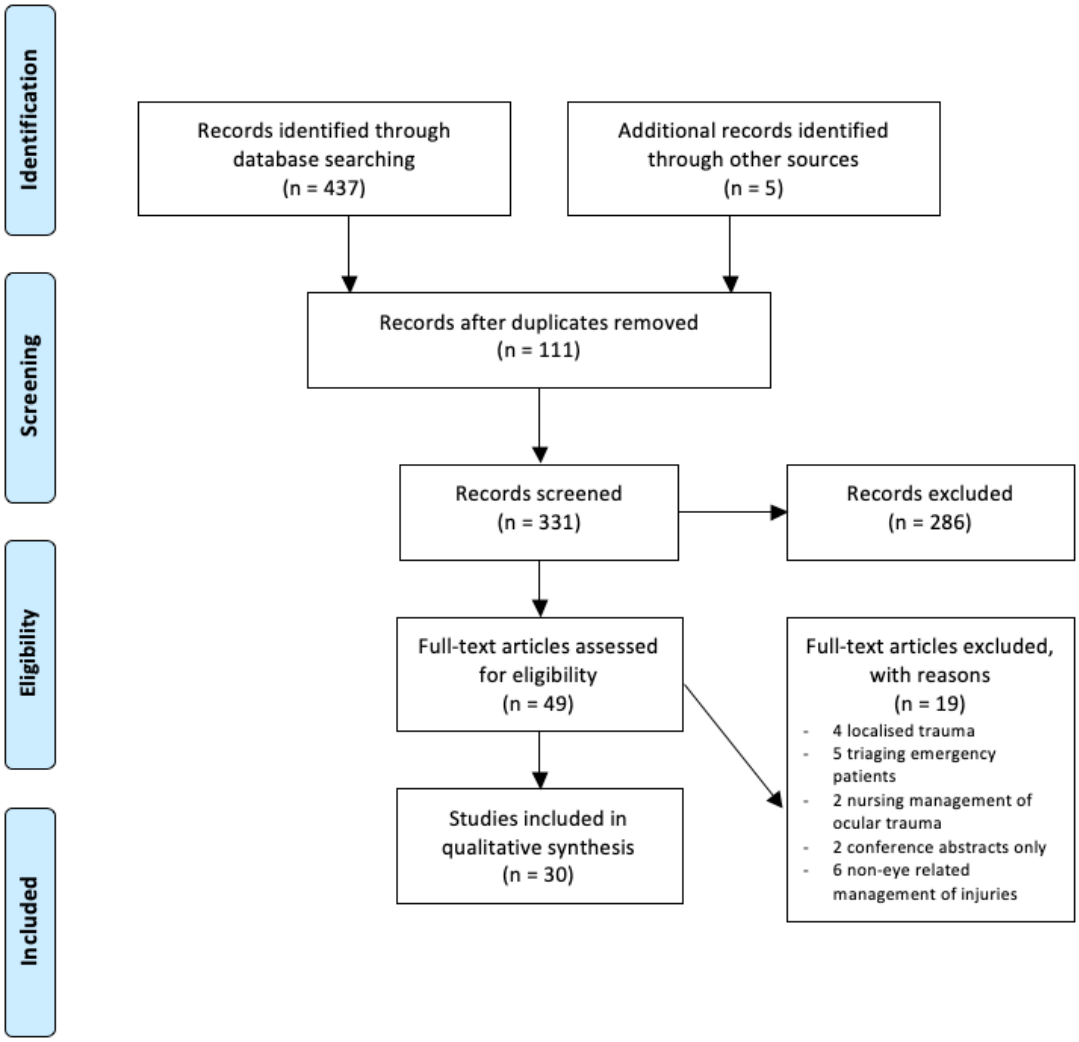

Table 1.1: Characteristics of studies included in literature review (n=30)

Year	Author	Origin	Type	Data Source	Investigation aim
2019	NSW ACI (16)	Australia	Guideline	NSW Institute of Trauma and Injury Management	Improving care of trauma in NSW
2019	Aslan (17)	Turkey	Retrospective Case Series	Alanya Research Hospital	Determining association of clinical findings and findings on CT in suspected ruptured globes
2018	Tovell (18)	Australia	Statistical Report	Australian Institute of Health and Welfare	Epidemiology of Ocular Trauma in Australia
2017	Beshay (19)	Australia	Retrospective Case Series	Sydney Eye Hospital	Epidemiology of open globe injuries presenting to a tertiary referral eye hospital
2017	Ross (20)	Canada	Retrospective Cohort	Montreal General Hospital	Determine ocular injury associated with orbital fractures at a trauma centre
2016	Andrews (21)	US	Retrospective Cohort	Trauma Registry	Identifying high risk signs of ocular injury associated with orbital Fractures
2015	Chaudhary (22)	UK	Retrospective case series	Birmingham Registry	Defining the accuracy of CT in trauma to diagnose and predict prognosis
2015	Shams-Vahdati (23)	Iran	Prospective Cohort	Nikookari Hospital	Determining clinical criteria for ophthalmology review in trauma
2014	Yonekawa (24)	US	Retrospective Comparative Case Series	Ophthalmology presentations to affected hospitals	Ocular trauma after the Boston Bombing and Texas Fertiliser explosion and the trauma system readiness
2014	Tuckett (25)	Australia	Narrative Review	Surgeon Journal	Outlining the management of maxillofacial trauma in emergency
2014	Cheung (26)	US	Retrospective Cohort	Emergency Ophthalmology consults	Determining the type, interventions and outcomes of emergency eye presentations
2014	Rotondo (27)	US	Guideline	American College of Surgeons	Defining the resources and requirements for a trauma service
2014	Northey (5)	Australia	Retrospective & Prospective Case series	Wagga Wagga Base Hospital Emergency presentations	Investigating Ocular Trauma presenting to a regional Base Hospital Emergency Department
2013	Vaca (28)	US	Retrospective Cohort	University of Maryland Shock Trauma Registry	Risk of blindness in open globe injuries with orbital fractures
2012	Scruggs (29)	US	Retrospective Cohort	National Trauma Data Bank	Epidemiology and risk of Ocular Trauma in trauma patients
2011	Georgouli (8)	UK	Retrospective Cohort	Trauma at St James Hospital	Epidemiology of Ocular Trauma in polytrauma presenting to a Trauma centre
2009	Cockerham (30)	US	Review	Literature	Investigating the pathophysiology and rehabilitation of ocular trauma
2009	NSW Health (13)	Australia	Guideline	NSW Health	Australian Trauma Model and services in NSW
2009	Mellema (31)	US	Retrospective Cohort	University of Minnesota Medical Center	Epidemiology of severe ocular injury in visually asymptomatic orbital fractures
2008	Magauran (32)	US	Review	Literature	Emergency presentations requiring ophthalmology consult
2008	Barak (33)	Israel	Retrospective Case Series	Trauma registry from Tel Aviv Sourasky	Investigate ophthalmologists' role in mass casualty trauma
2008	Perry (7)	US	Review	Literature	ATLS examination of facial trauma in multi-trauma
2008	Kubal (34)	US	Review	Literature	Determining orbital anatomy and imaging signs in orbital trauma
2007	Seider (35)	Israel	Retrospective Case Series	Oculoplastic clinic Rambam Medical Center	Enopthalmos and ocular motility issues after multi-trauma and localised trauma
2007	Bell (36)	US	Review & Retrospective Cohort	LEHHC Trauma Registry	Determine the role of oral and maxillofacial clinicians within the trauma service
2006	Guly (37)	UK	Retrospective Cohort	Trauma Audit Research Network	Incidence and cause of ocular trauma in major trauma
2004	Mock (10)	Geneva	Guideline	World Health Organisation	Guidelines for Essential Trauma Care
2001	Voon (2)	Singapore	Prospective Case Series	Singapore General Hospital	Epidemiology of ocular trauma to a tertiary hospital
2000	Cullinane (38)	US	Retrospective & Prospective Case Series	Vanderbilt University trauma database	AION in trauma patients after massive transfusion
1999	Poon (39)	Australia	Retrospective Cohort	RPAH Hospital Trauma	Ocular trauma presenting to a trauma centre

Table 1.2: Assessment of evidence quality of studies included in the literature review (Key: Y = yes, N = no, N/A = not applicable to publication)

Year	Author	Description of Evidence		Internal Validity			External Validity		Analysis and Results			
		Clear design and objectives	Relevant Outcome	Effect of bias described	Effect of confounding or chance described	Results consistent within the study	Completeness of data incl. impact of missing data	Participants identified clearly	Acceptable analysis	Limitations of study described	Results consistent with other evidence	Clear conclusion
2019	NSW ACI (16)	Y	Y	N	N	Y	N/A	N/A	N/A	Y	Y	Y
2019	Aslan (17)	Y	Y	N	N	Y	N	N	Y	Y	Y	Y
2018	Tovell (18)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2017	Beshay (19)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2017	Ross (20)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2016	Andrews (21)	Y	Y	N	N	Y	N	Y	N	Y	Y	Y
2015	Chaudhary (22)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2015	Shams-Vahdati (23)	Y	Y	N	N	Y	N	Y	N	Y	Y	Y
2014	Yonekawa (24)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2014	Tuckett (25)	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y
2014	Cheung (26)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2014	Rotondo (27)	Y	Y	Y	Y	Y	N/A	Y	N/A	N	Y	Y
2014	Northey (5)	Y	Y	N	N	Y	N	N	Y	Y	Y	Y
2013	Vaca (28)	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
2012	Scruggs (29)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2011	Georgouli (8)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2009	Cockerham (30)	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y
2009	NSW Health (13)	Y	Y	N	N	Y	N/A	N/A	N/A	N	Y	Y
2009	Mellema (31)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2008	Magauran (32)	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y
2008	Barak (33)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
2008	Perry (7)	Y	Y	N	N	Y	N	Y	Y	N	Y	Y
2008	Kubal (34)	Y	Y	N	N	Y	N	N	N	N	Y	Y
2007	Seider (35)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2007	Bell (36)	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y
2006	Guly (37)	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y
2004	Mock (10)	Y	Y	Y	Y	Y	Y	Y	N/A	Y	Y	Y
2001	Voon (2)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2000	Cullinane (38)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1999	Poon (39)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Discussion

Trauma Service

The World Health Organisation Guidelines for Essential Trauma Care (2004) outlines the needs of trauma patients, firstly their life-threatening injuries must be managed promptly. Secondly, disability must be minimised by identifying and managing injuries and finally their suffering should be minimised. Since multisystem injury is a significant cause of death and disability worldwide(8, 10, 12), it is beneficial to have trauma centres that are specifically staffed and have access to appropriate resources as they can reduce multisystem injury associated mortality by 15-20%(10).

Trauma centres function to provide the highest quality care for the severely injured while also functioning as key centres for administrative, medical leadership and academic expertise for hospital networks(11). Within the hospital system there are multiple levels of care to enable appropriate patients present to hospitals that are able to manage the severity of their injuries(40). In this way, the trauma centre functions to decrease burden on the community by providing acute care, within a well-resourced and well-staffed facility, that could not be provided at smaller centres(11).

Trauma Services in New South Wales

The NSW Institute of Trauma and Injury Management in Australia created a model of care for multisystem injury(12), comprising of 3 levels, the Major Trauma Service (Level 1) which is usually at a metropolitan tertiary hospital and Regional Trauma Services (Level 2-3) in rural base hospitals(12). In NSW, there are 7 adult major trauma services and 3 paediatric major trauma services. Small community hospitals function within the trauma system as bypass centres as they are not equipped to deal with trauma. Regional Trauma Services care for patients with minor to moderate multisystem injury and can provide initial assessment, stabilisation and facilitate transfer to a major trauma centre when required services are not available. The major trauma service provides care for major and moderate multisystem injury from initial resuscitation and assessment to rehabilitation and discharge(12, 13).

When a major trauma centre is notified of an incoming patient that fulfils the trauma criteria, the trauma team is activated(11). In NSW, the trauma service response consists of Emergency Department Staff Specialist or Senior Registrar, 3 emergency nurses, Trauma Clinical Nurse Consultant, General Surgical Registrar, Anaesthetic Registrar, Intensive Care Registrar, Mobile Radiographer, Wards men, Social Worker and other speciality registrars (Plastics, Orthopaedics, Neurosurgery) as required(12, 13). The aim of this team is to stabilise and assess the patient and provide care in keeping with their injuries.

Globe and adnexal trauma

Trauma teams are well versed in managing life threatening injuries, however, there is minimal ophthalmology input in the acute assessment phase despite the frequency of globe and adnexal trauma in patients with multisystem injury(7, 12, 29). Significant globe trauma associated with multisystem injury, such as open globe injuries, can have great risk for morbidity as up to 70% of patients lose their sight due to their injuries(21, 29, 37, 39). Furthermore, ocular examination in the initial assessment can be challenging as the patient may have decreased level of consciousness and associated facial injury(1, 2, 8, 35, 37). The complicated examination and associated distracting injuries can cause globe trauma to be missed(8, 9, 25).

The assessment of a multisystem injury patient is completed using primary, secondary and tertiary surveys with each assessment more thorough then the last. The primary survey is the initial examination where life threatening injuries are identified and corrected. It is completed systematically using the acronym ABCDE, starting with Airway, moving to Breathing, Circulation, Disability and finally Exposure(41). The systematic assessment allows the team to quickly identify, assess and institute management of life threatening injuries(41).

The initial examination of the eye is often brief and may take place during the Disability or Exposure portions of the primary survey(7). Assessment may include asking the patient 'if they can see', description of visual symptoms followed by examination of pupils, extraocular movements, confrontation, fundoscopy (if able) and gentle palpation of the periorbital area(7, 25). This examination should be able to confidently exclude sight threatening globe trauma requiring urgent treatment(7, 25, 30, 32). Visual acuity is cited as a sensitive test for globe trauma(7, 8, 37), however, there can be numerous challenges in the acute setting. For example, loss of glasses or contact lenses and older patients with presbyopia can compromise the performance of bedside VA assessment(31). Moreover, a patient with severe globe trauma may present with "normal" VA and instead have symptoms such as pain, photopsias, floaters, diplopia or scotomata which can be easily missed if not specifically asked(20, 31). Similarly, irregular pupils can suggest severe globe trauma; yet, abnormal pupils can occur in the context of neurological injury, illicit drug use, alcohol, past ocular disease or surgery, paralysing agents and pain relief, further confounding and misleading clinicians(7, 9, 20, 21).

To combat the complexity of multisystem injury, medical imaging has become an integral aspect of the acute assessment(17, 22). Computerised tomography (CT) scans and ultrasonography (US) are used to pinpoint globe and orbital foreign bodies, orbital fractures and retro-bulbar haematoma(22). However, in circumstances of suspected globe rupture or penetrating globe trauma, ultrasonography is contraindicated and CT should be utilised as the pressure applied to the orbit may worsen the injury(34).

From their initial assessment, emergency physicians are required to determine the need for urgent ophthalmology referrals(23, 32). Georgouli et al retrospectively reviewed all patients with multisystem injury admitted to St James University Hospital in Leeds UK over 10 years(8). Motor vehicle accidents and falls were common mechanisms of injury frequently associated with head, facial and globe trauma. Mid-facial/orbital trauma were a significant risk factor for sight threatening injuries and facial fractures were 6-7 times more likely to have severe globe trauma(8, 37, 39). They emphasised that patients with mid-facial/orbital trauma or visual symptoms should have urgent ophthalmology assessment(8, 21, 28, 31). However, only 26% of the patients were referred to ophthalmology within 2 weeks of admission with the average time until review being 8 days. It was thought that in the presence of life threatening injuries in patients requiring prolonged intensive care admissions; the co-existing globe trauma was overlooked. To prevent missed injuries further education for acute staff would be beneficial to highlight suspicious symptoms and signs requiring urgent ophthalmology assessment(8, 20, 21, 23, 28, 31, 39, 42).

Where delayed ophthalmology examination occurs, changes within the clinical picture can cause or further exacerbate globe trauma(7). The Advanced Trauma and Life Support (ATLS) report discusses the numerous factors within multisystem injury management that affects globe trauma(7). For example, fluid boluses and vasoactive medications used in a shocked patient can increase the risk of or exacerbate intraocular bleeding, conversely, hypotension can cause ischaemic optic neuropathy and retinopathy(38). Similarly, progressive swelling, coughing or vomiting can exacerbate injuries due to raised intraocular pressures (IOP)(7). In situations with life-threatening injury, delayed examination must be expected, as found by Yonekawa et al (2014) when they reviewed the globe trauma from the Boston Marathon Bombing and the Fertiliser Plant explosion in Texas. Of the ophthalmology referrals 86% and 50% respectively occurred when the trauma patient was in the operating theatre receiving lifesaving surgery(42).

Though the assessment and/or management of globe trauma may not be completed immediately(7, 37, 43), globe trauma such as open globe injuries(19, 28) require emergent management to prevent sight threatening complications(32, 43). Open globes must be closed within 24 hours to prevent endophthalmitis(19), comprehensive reconstruction of the globe may be delayed for greater than 24 hours if required but in patients with uncontrollable IOP due to hyphaema, swollen lens or retinal damage, full reconstruction must occur urgently in order to preserve the eye and/or vision(19, 43).

Barak et al investigated the role of ophthalmologists in mass trauma caused by suicide bomber attacks(33). In their hospital, as per protocol all patients that complain of visual symptoms and all unconscious patients with head or facial injuries must be examined by an ophthalmologist. If severe globe trauma such as open globes injuries were found, ophthalmologists would perform primary closure while trauma teams were completing

lifesaving surgery(33). Performing emergency surgery, can be extremely complex as a single patient can have competing and/or conflicting priorities due to the severity of their injuries, medical stability and necessity for surgical intervention. The anaesthetic technique must be formulated on a case by case basis balancing these priorities while preventing harm to the patient(44). Despite patient differences in multisystem injury, the treatment goals for head injuries with or without globe trauma remain similar as one must minimise increases in intracranial and intraocular pressure(45, 46). In spite of this, preventing increases in intraocular pressure through the use of non-depolarising muscle relaxants and choice of anaesthetic agent are only components of an anaesthetic technique that must reflect the primary condition of the patient and prevent situations that may cause that patient harm(45, 47). Therefore, early ophthalmology assessment in complex multisystem injury can facilitate prompt surgical planning and expedite interdisciplinary surgical management in the acute context(7, 20, 35).

Early involvement of ophthalmology following trauma may not occur as patients may not present to appropriately staffed centres(1, 5). Cheung et al retrospectively reviewed ocular emergencies presenting to 3 community hospitals and 2 level II trauma centres between July 2007 and November 2010(1). Trauma centres had more multisystem injury related globe trauma compared to the localised injuries presenting to community hospitals. Unsurprisingly, the trauma centres were more likely to have globe trauma of greater complexity requiring surgical management. Interestingly, up to 50% of the globe trauma managed at the trauma centres were transferred from smaller hospitals without ophthalmology(1).

Globe and adnexal trauma in Australia

Globe and adnexal trauma in Australia is not uncommon with 86,602 people presenting with an globe trauma to emergency departments between 2013-2015 and 51,778 of these patients being hospitalised(18). Moreover, globe and adnexal trauma is the most common cause of ophthalmology presentations to emergency departments(5). The majority of globe traumas are minor and can be managed at lower acuity centres(5, 48). For the management of severe injuries treatment at specialised centres would be more appropriate. Beshay et al conducted a retrospective case review of open globe injuries managed at the Sydney Eye Hospital where 55% of the injuries were referred from other hospitals within Sydney(19).

However, Sydney Eye Hospital is a low acuity hospital and is not equipped to manage multisystem injury. Therefore, globe trauma occurring in patients with multisystem injury must be managed by ophthalmology services located in the trauma centres. Poon et al investigated the globe trauma occurring in multisystem injury managed at Royal Prince Alfred Hospital, a trauma and tertiary referral centre in Sydney(39). The severity of injuries in the trauma patients required a multidisciplinary approach to their management. Poon et

al in their review of patients with multisystem injury with globe trauma at Royal Prince Alfred hospital advocated for early involvement of ophthalmology if globe trauma was suspected as they found there was a delay in ocular assessment of the severely injured(39). In each circumstance, whether low acuity hospital or trauma hospital, early involvement of ophthalmology in suspected globe trauma can lead to better outcomes(8, 21, 31, 33, 39)

Ophthalmology within a Trauma Service

For localised globe trauma, ophthalmology services operating out of a specialised hospital, can improve patient care by utilising general trauma care models and adapting it to globe trauma. The General Trauma model of care encompasses 4 main categories including injury prevention, prehospital care, acute care and rehabilitation(11-13). Utilising this model, the ophthalmology service would aid in preventing globe trauma by employing public health information(12). For example, advocating for personal protective equipment in the workplace, falls prevention in the elderly and increasing road safety measures as these are frequent mechanisms of injury for significant globe trauma(2, 5, 19). Similarly, the service would establish protocols that lead to timely triage and transport of globe trauma to the appropriate facilities and/or facilitating inter-hospital transfer(12). Similar to the Injury Severity Score used in trauma, using a grading system such as the Globe trauma Score(49) for Open Globe Injuries, would aid in globe trauma bypassing less equipped hospitals and presenting to appropriate facilities. Furthermore, instilling appropriate pre-hospital care for first responders, such as the use of eye shields, could aid in minimising further injury(42, 50). The ophthalmology service must be able to provide care and adequately coordinate a specialist multidisciplinary team comprising of ophthalmology specialists, specialist anaesthetists, orthoptists and nursing staff from the acute phase through to discharge(12, 36).

Where globe trauma occurs in multisystem injury, early referral for ophthalmology by the existing trauma team would be beneficial. Bell advocates for integration of maxillofacial surgery in his retrospective review of trauma patients admitted from 1995-2005 from the Legacy Emmanuel Hospital and Health Centre Trauma Registry. He argues that further integration of subspecialty expertise would improve care for trauma patients and provide a useful resource for trauma teams(36). Likewise, integrating ophthalmology would allow for specialist knowledge and expertise in the assessment and grading of globe trauma(23). The need for referral may be complicated by the inability for thorough examination due to patient instability or life-threatening conditions(20, 32), however, it is important that specialist involvement does occur when there is globe or adnexal involvement to recognise globe trauma and in turn decrease the risk of missed injuries(21, 23, 33).

Conclusion

A thorough assessment of globe and periorbital area is essential to diagnose globe and adnexal trauma. However, the acute assessment and management of globe trauma in a trauma hospital emergency department can be complex. The early involvement of specialised ophthalmology assessment can be utilised to facilitate patient care. Since Poon et al (1999), there has been minimal research investigating the epidemiology and aetiology of globe and adnexal trauma managed at Australian trauma centres. Similarly, there has been minimal investigation into the involvement of ophthalmology in the acute assessment and management of these patients.

2 Globe and Adnexal Trauma in Multisystem Injury

Preface

Globe and adnexal trauma are common presentations to emergency departments of trauma hospitals. They can occur as a localised trauma or part of wider multisystem injury. When occurring as part of multisystem injury, life threatening injuries takes precedence which may lead to delays in ocular examination and diagnosis of globe trauma. Additionally, thorough ocular examination can be difficult in the severely injured due to supine positioning, altered levels of consciousness and competing priorities for emergency staff. Utilising specialist ophthalmology reviews can help support emergency staff in the acute assessment and management of globe trauma in multisystem injury.

Introduction

Globe trauma is a leading cause of unilateral blindness(1, 37). Globe trauma in isolation may be self-limiting and can be managed in outpatient settings(3). Adnexal trauma is injury to the structures surrounding the globe, it may occur in isolation or combined with globe trauma(51). Globe and adnexal trauma occurring in the context of multisystem injury, can cause the diagnosis and management of globe trauma to become complex due to competing priorities(3, 6, 8), as patients with multisystem injuries can have life threatening issues(7, 11). Moreover, in the acute setting examining unstable patients with low and/or fluctuating levels of consciousness and confounding injuries can make ocular assessments difficult(7, 9, 20).

Major trauma assessment follows a systematic survey approach with primary, secondary and tertiary surveys each more detailed than the last, aiming to diagnose all injuries(41, 52). Ocular assessments have a lower priority compared to the diagnosis and management of life threatening injuries such that a thorough ocular examination would occur in secondary or tertiary surveys(52). Due to the timing of ocular assessment in the setting of multisystem injury, delays in diagnosis may impart a greater ocular morbidity to patients(8, 9).

Managing patients with multisystem injury is difficult and requires significant input from specialist services and resources(10). Patients with multisystem injury presenting to low acuity hospitals lacking the required infrastructure or specialist services can have poor outcomes(11). To expedite and optimally care for patients with multisystem injury, appropriately resourced high acuity hospitals develop multidisciplinary trauma services to decrease the burden within the hospital network(12). A trauma team facilitates the organisation and review of investigations, and manages treatment and specialist referrals as required(11, 12, 39). In the acute assessment, the criteria for involvement of ophthalmology can be ambiguous for a trauma team. Further, the role of ophthalmology in trauma

management at tertiary referral centres is not well understood. We aimed to investigate the management of patients with globe and/or adnexal trauma presenting to trauma hospitals including the role of ophthalmology in order to inform guideline development of globe trauma management.

Using a retrospective case series, we aimed to report the epidemiology and aetiology of globe and adnexal trauma managed at two trauma centres in Sydney, Australia. These centres allowed us to include patients with multisystem injury as little is known of the ophthalmological management of this group. In addition, we aimed to determine specialist ophthalmology involvement in globe and adnexal trauma assessment and management in patients admitted to these trauma centres.

Methods

A retrospective case series was performed of patients with globe and/or adnexal trauma admitted to Royal North Shore Hospital (RNSH) and Royal Prince Alfred Hospital (RPAH), which are 2 tertiary referral level one trauma centres located in Sydney, Australia. The catchment for RNSH includes northern Sydney and northern New South Wales (NSW) and for RPAH includes central Sydney, western and far west NSW(53). Each hospital receives patients from lower acuity metropolitan and rural hospitals, in addition to direct retrieval services within their respective catchment areas. Data was collected on patients admitted to these hospitals between January 2015 and December 2019. Ethics and Governance approval (2020/ETH02544) was granted by the South Eastern Local Health District Ethics Committee with site specific approval from RNSH and RPAH committees.

Patient data

Patients were identified using the International Classification of Disease, Tenth Revision codes to search diagnostic and procedural coding data (Appendix 2). Admitted patients were included if globe and/or adnexal injury was present, diagnosed and coded. A globe injury was defined as injury to the eye and/or anterior visual pathway. An adnexal injury was defined as an injury to the orbital contents, orbit, eyelids and soft tissue surrounding the orbit in the area of the orbicularis oculi(54). Patients were classified as multisystem trauma if 2 or more regions of the body were injured(55). Patients must have presented or been transferred to RNSH or RPAH via the emergency department (ED) and subsequently admitted.

All medical records from patients meeting these criteria were reviewed to collect demographic information such as age, sex and past medical history. In relation to the trauma, the history, mechanism and location of the injury, and the use of alcohol and/or recreational drugs at the time of the injury were collected and whether specialist ophthalmology review occurred. Where available details of the initial ocular examination completed by emergency staff was recorded.

Definitions and Classifications

Patients were classified by age with children being below 18 years, adults above 18 years and the elderly over 65 years. At presentation, the ocular examination was defined as; 'no physical exam' if no ocular examination was documented, a 'gross exam' if there was a short description of the appearance of the globe and/or adnexa, and a 'thorough exam' if VA, extra ocular movements, pupils and anterior segment examination were recorded. Ophthalmology involvement was considered 'early' if the patient was reviewed during the emergency presentation.

Globe trauma was classified utilising the Globe and Adnexal Trauma Terminology Survey(51), for example, a rupture was defined as being a blunt injury where as a laceration was caused by a sharp object. Open globe injuries (OGI), lamellar lacerations to cornea or sclera, significant burn or injury to cornea or sclera, internal eye injuries and injuries to the anterior visual system were further classified as severe globe injuries as they have significant risk of permanent vision loss(39, 56). High energy mechanism of injury (MOI) was defined as high levels of kinetic energy being transferred to the patient such as a motor vehicle accident (MVA). Low energy MOI was defined as low levels of kinetic energy being transferred to the patient such as fall from standing height(57). An 'unwitnessed fall' was defined as a fall that occurred without being seen by others. The length of time before patients were found following the fall was recorded and the term 'long lie' used if patients were found on the ground at least 2 hours after the fall(58).

Multisystem trauma patients were classified by the severity of the accident and resultant injuries by retrieval services and/or emergency staff(59). In our included hospitals, severe trauma presentations activated a trauma call which mobilised a multidisciplinary trauma team to facilitate emergent assessment and management. General criteria for a trauma team activation can include MVA with ejection from the vehicle, high speed cyclist accident, fatality in the vehicle, injury of 2 or more limbs and/or penetrating injuries(53, 59).

Statistical analysis

Statistical analysis was performed using Jamovi software, Version 1.6(60, 61), (Jamovi, Sydney Australia). Descriptive statistics were used for continuous data utilising mean (standard deviation (SD)) or median (interquartile range (IQR)) dependent on the distribution of the data. Description of data with percentages in text will be accompanied by the numerical fraction to aid clarification. Categorical data was reported using counts and proportions and compared with Chi-squared tests with Yates correction. Continuous data was compared using one-way ANOVA with Tukey's tests.

Results

The diagnostic and procedural code (Appendix 2) search identified 890 medical records. After removing duplicates the remaining 875 records were assessed against the

inclusion and exclusion criteria. One hundred and two patients without globe or adnexal trauma, who were not admitted or admitted for an elective procedure post-trauma were removed. Figure 2.1 demonstrates the inclusion and exclusion procedure.

Seven-hundred and seventy-three patients admitted between to the two hospitals, 501 patients at RNSH and 272 patients at RPAH between January 2015 and December 2019 met the inclusion criteria.

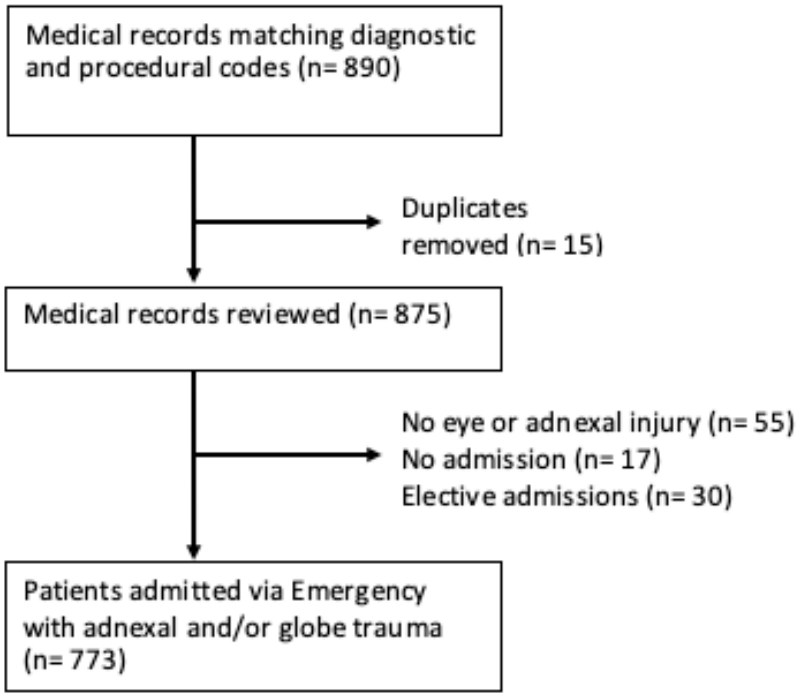

Figure 2.1: Patients with globe and/or adnexal trauma examined according to the inclusion and exclusion criteria (n=773), MOI = mechanism of injury

Demographics

The mean age of patients was 53.2 years (SD 25.7) (Table 2.1). The majority of patients were male (62% male). Bi-modal peaks in the distribution of age amongst the included patients were identified, one in younger patients (25-30 years) and the other in elderly populations (75-80 years) (Figure 2.2).

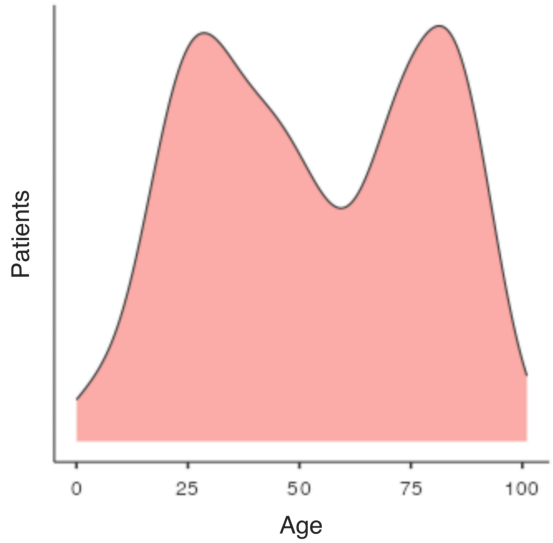

Figure 2.2: Distribution of age with globe and adnexal trauma hospitals (n=773)

Most patients (n=643, 83%), initially presented to RNSH or RPAH and 129 (17%) were referred from other hospitals including regional hospitals, smaller metropolitan hospitals and other tertiary hospitals. Six patients were transferred from interstate or international tertiary centres requiring specialist services such as Burns and Spinal services at RNSH.

Two-hundred and thirty-five (30%) patients had had multisystem injury.

Table 2.1: Demographics of patients admitted with globe and adnexal trauma (n=773)

Characteristics	
Mean age (SD) [range]	53.2 (26 years) [3 weeks – 101 years)
Sex (SD, mean age)	Male 481 (47.7, 24 years) Female 292 (62.2, 25 years)
Age categories (years), n (%)	
0-10	20 (2.6%)
11-18	39 (5%)
19-35	189 (24.4%)
36-65	219 (28.2%)
66-85	211 (27.2%)
86-105	98 (12.6%)
Side of injury, n (%)	
Right	339 (44%)
Left	349 (45%)
Both	85 (11%)
Initial hospital of presentation, n (%)	
RNSH	394 (51%)
RPAH	249 (32%)
Metropolitan hospital	78 (10%)
Rural hospital	29 (4%)
Other tertiary hospital	20 (3%)
International hospital	3 (0.4%)

Mechanism of injury, n (%)	
Fall	346 (45%)
Burn	101 (13%)
Assault	92 (12%)
MVA/MBA	62 (8%)
Sport	56 (7%)
Construction	48 (6%)
Nature	36 (5%)
Other	32 (4%)
Alcohol or illicit drugs, n (%)	116 (15%)

Data on the Injury

The most common mechanism of injury was falls, occurring in 346 (45%) patients, followed by burns with 101 (13%) patients, then assault with 92 (12%) patients, and MVA or motorbike accident (MBA) with 63 (8%) patients. Other mechanisms of injury included sport, cleaning products and construction (n=198, 25%). There was a significant difference in the mean age of patients who fell (70 years, SD 21) compared to patients who had had a MVA/MBA (45 years, SD 22, $p < 0.001$), were assaulted (39 years, SD 17.9, $p < 0.001$) or had sports injuries (29 years, SD 17.8, $p < 0.001$) (Figure 2.3). Falls were responsible for the most adnexal trauma, 36% of these patients had globe trauma. Burns, construction, cleaning products exposures and MVA/MBA often caused severe globe trauma. Data on the globe and adnexal trauma are shown in Table 2.2.

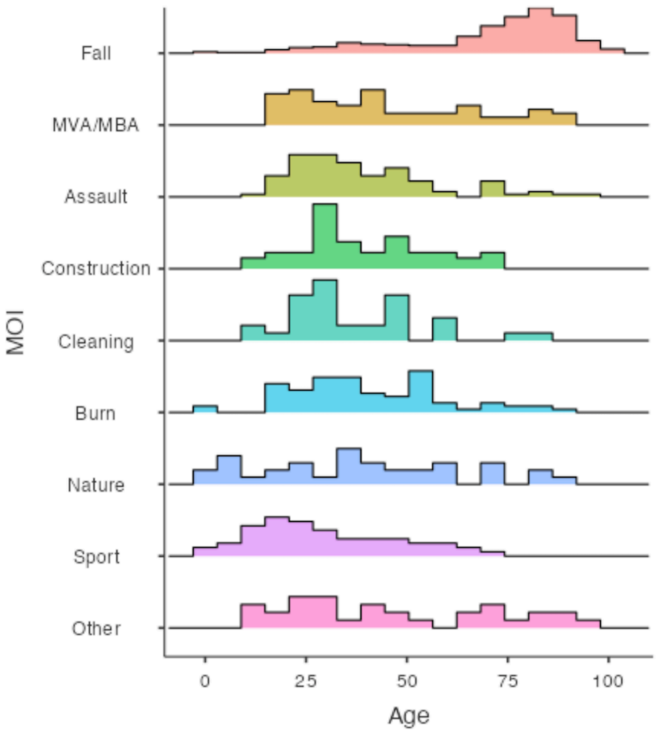

Figure 2.3: Distribution of age for mechanisms of injury of patients (n=773), MOI = mechanism of injury

Table 2.2: Globe and adnexal and trauma in patients admitted to the trauma centres. Key n= number of patients with the injury

Adnexal Trauma	n	Globe Trauma	n
Periorbital haematoma		Conjunctiva	
Alone	201	Subconjunctival haemorrhage	75
Associated with:		Laceration	11
Orbital fracture	159	Cornea	
Globe injury	65	Chemical injury	35
Open globe injury	31	Thermal injury	67
		Keratitis	6
		Lamellar laceration	7
Retro orbital haematoma		Open globe injury	43
Alone	5	Sclera	
Associated with:		Lamellar laceration	4
Orbital fracture	23	Open globe injury	37
Open globe injury	3	Anterior chamber	
		Hyphaema	63
		Traumatic uveitis	2
		Iris	
Orbital fracture		Traumatic mydriasis	14
Alone	80	Iridodialysis	2
Associated with:		Lens	
Open globe injury	14	Traumatic cataract	3
Another globe injury	79	Dislocated lens	6
		Vitreous	
		Haemorrhage	10
		Retina	
Laceration		Detachment	11
Alone	15	Commotio retinae	25
Associated with:		Haemorrhage	6
Other adnexal injury	128	Optic Nerve	
Globe injury	22	Traumatic optic neuropathy	8
		Avulsion	2

Adnexal trauma (n=773, 100%) were more common than globe trauma (n=438, 57%). Periorbital haematomas were the most common adnexal trauma occurring in 456 (59%) patients, and mostly caused by low energy mechanism of injury. Increased severity of the mechanism of injury caused an increased number and severity of adnexal trauma such as orbital or facial fractures. Two-hundred and ninety-eight patients suffered a mid-facial/orbital trauma, 215 (72%) of these patients had a globe trauma with 104 (35%) globe trauma classified as severe.

Four-hundred and thirty-eight (57%) patients suffered a globe trauma and 228 (29%) were classified as severe. One-hundred and eighty-two patients injured their left eye, 201 their right and 55 injured both. Closed globe injuries were the most common with 570 contusions and 50 lamellar lacerations. There were 78 (10%) OGI and this injury carried poor visual prognosis with 71 (91%) of OGI had a visual acuity (VA) less than 6/60 in that eye. There were 39 ruptured globes, 39 lacerations and 8 with intra-globe foreign bodies.

Males were significantly more likely to have severe globe trauma compared to females (63% vs 47%, p=0.002). There were significantly higher number of severe globe trauma in patients with orbital or mid-facial injury compared to no orbital or mid-facial injury (34% vs 26%, p=0.01).

Of the 235 patients with multisystem injury, 121 (51%) suffered globe trauma and 49 (21%) suffered severe globe trauma. Seventy-one (30%) of the patients with multisystem injury met the criteria for a trauma call. The most common mechanism was a MVA which occurred in 56 (79%) patients. Other multisystem injury was from cycling, falls from greater than 5metres and assaults. Forty-three (60%) of the patients with adnexal trauma activating a trauma call suffered globe trauma and 22 (31%) were classified as severe. Fifty-two of the trauma call patients had mid-facial or orbital injuries. Thirty-nine (75%) patients with mid-facial/orbital trauma who activated a trauma call had globe trauma and 20 (38%) classified as severe.

Management

All patients were initially assessed by emergency medical staff. In these initial assessments, there was a documented ocular exam in 78% of patients, of these 45% had a VA recorded. Thorough ocular exams were completed in 69% of patients with globe trauma (Table 2.3). Similarly, when ophthalmology was consulted, 71% of patients had a thorough exam documented in the initial medical assessment. There was no ocular examination documented for 22% of patients; reasons for this included patients were sedated and/or intubated, fluctuating levels of consciousness, delirium, intoxication and/or lack of equipment.

Table 2.3: Ocular Examination in patients with globe and adnexal trauma

Ocular Trauma	Ocular Exam		
	Detailed Exam with Visual Acuity	Gross Exam	No Exam
Yes	305	73	60
No	44	182	110

In the trauma calls, emergency staff were assisted by trauma teams consisting of general surgery, intensive care, anaesthetics and other specialist teams, such as neurosurgery, orthopaedics and ophthalmology as required. In the acute assessments of the trauma call patients, there was a documented ocular exam by the trauma team for 56 patients (66%) and only 26 of these patients had a thorough ocular exam recorded.

Lateral canthotomy and cantholysis were performed in 6 periorbital haematomas and 15 retro-orbital haematomas. The reasons for the lateral canthotomy and cantholysis were decreased optic nerve function, relative afferent pupillary defect, raised intraocular

pressure and proptosis with tension on the optic nerve seen on computerised tomography imaging.

Ophthalmology specialist assessment

Ophthalmology was involved in the assessment and management of 452 (58%) patients. Reasons for ophthalmology review included abnormal VA, concerning mechanism of injury and a suspected or diagnosed globe injury. Eighty percent of patients with mid-facial or orbital trauma were referred to ophthalmology. Eighty-six percent of patients who had globe trauma and 96% of patients with severe globe trauma were reviewed by ophthalmology, with the vast majority of reviews (97%) occurring within the first 24 hours. The referrals to ophthalmology were made by emergency medical staff (71%), intensive care unit (18%) and other specialist teams (11%) shortly after admission to hospital.

Ophthalmology was activated as part of the trauma team being present and/or involved in the initial assessment for 23 (27%) and in the subsequent management of 49 (41%) patients where a trauma call was made. Additionally, ophthalmology was consulted intra-operatively for 5 patients; these patients had been taken straight to theatre bypassing usual assessments. Severe globe trauma that was found in these examinations included injuries such as retrobulbar haematoma requiring lateral canthotomy, traumatic cataract, globe rupture and traumatic optic neuropathy.

There were 3 patients with globe trauma that were not diagnosed at presentation. One patient suffered a large surface area burn including the face, they were intubated by the retrieval team and remained intubated in ED. Once extubated, the patient reported blurred vision. An ophthalmology review was arranged and a moderate burn to the cornea diagnosed. With intensive lubricant eye drops the patient made a full visual recovery. Two elderly patients from nursing homes presented following a fall with head strike and the other with a scald burn to the face. They underwent gross examinations by emergency staff and were discharged home. Each patient represented after a few days due to ongoing eye pain. At this stage ophthalmology review was performed, one of the elderly patients was noted to have a large epithelial defect and the second elderly patient had a subconjunctival haemorrhage and small epithelial defect.

Discussion

In our study, 773 patients with globe and/or adnexal trauma were admitted to 2 trauma hospitals in Sydney, Australia between January 2015 and December 2019. The patients were typically male and middle aged, however, the demographics varied with mechanism of injury. Four-hundred and thirty-eight (57%) patients sustained globe trauma and 228 (29%) were classified as severe globe trauma. Specialist ophthalmology reviews were conducted in 452 (58%) patients during their initial presentation or early admission.

Most referrals to ophthalmology were initiated by emergency staff due to concerns that arose from their initial assessments.

Our findings of increased incidence of globe trauma with the presence of mid-facial/orbital injury are consistent with Poon et al. (1999) who conducted a review of globe trauma occurring in patients with multisystem injury at RPAH between 1990-1997. They found that patients with orbital or mid-facial injury had an increased risk of globe trauma(39) and recommended that these patients require ophthalmology reviews to exclude globe trauma(21, 28). In our study, 298 patients who suffered an orbital or mid-facial injury, the proportion of globe trauma (215, 72%) or severe globe injury (104, 35%) increased. Despite Poon et al. highlighting this in 1999, we found that not all of our patients with orbital or mid-facial injuries were initially referred to ophthalmology; there remains a need for ongoing education in this area.

We found that emergency staff identified and escalated injuries for ophthalmology assessment, a finding which was consistent with Shams-Vahdati et al (2015). Shams-Vahdati et al. conducted a blinded cross-sectional study comparing emergency physicians' triaging the urgency of all patients with multisystem injury with severe globe trauma for ophthalmology assessment. This was then compared to the opinion of on call ophthalmologists of the same patients. They found similar triages by both practitioners demonstrating the ability of emergency physicians to diagnose and appropriately triage severe trauma(23).

In the emergency environment, time pressure and lack of equipment to thoroughly examine the eye can lead to missed injuries(9, 25). Indeed, in 3 of our patients the diagnosis of the globe trauma was delayed. This emphasises the need for specialist ophthalmology involvement if there is suspicion of a globe trauma raised by mechanism of injury, history and/or examination(21, 23, 33).

The management of the severely injured patients with multisystem injury can be complex with the trauma team having to balance competing priorities(1, 42). Of the patients with multisystem injury that activated a trauma call, 60% with adnexal trauma also suffered globe trauma. The globe injuries were diagnosed in ED, ICU and even the operating theatre. In some circumstances, the only assessment completed was the primary survey before life threatening injuries were diagnosed requiring immediate management, thus delaying further examinations(42). Nonetheless, 23 patients (27%) received ophthalmology assessment during the initial surveys assisting the trauma teams. The mechanism of injury and retrieval handover lead to activation of ophthalmology as part of the trauma teams' management, allowing for early specialist review and intervention(23, 33).

To date there has been minimal research into the role of ophthalmology in Australian trauma centres. Poon et al. (1999) investigated globe trauma in patients with multisystem injury at RPAH and emphasised the need for ophthalmic assessment in patients with multisystem injury with suspected globe trauma. The RPAH study was completed 24 years ago and was from a single centre. Our study provides up to date data on the globe and adnexal trauma managed at 2 trauma centres in Sydney, Australia. Our data includes patients with multisystem injury and highlights the importance of a thorough ocular examination in cases where globe trauma is suspected, especially in cases of orbital or mid-facial injury. As well as the need for ophthalmology involvement in the assessment of patients, and the role of ophthalmology in assisting the trauma teams in the acute assessment of multisystem injury(23, 33).

Conclusion

In patients with multisystem injury, globe trauma may be diagnosed late or not identified. An orbital or mid-facial injury indicates that a patient has an increased risk of globe trauma. In patients with multisystem injury, ophthalmology review has an important role in diagnosing and managing globe trauma. Research is required to follow the outcomes of multisystem injury that have ophthalmology operating within the trauma team.

Multisystem injury, especially caused by high energy mechanism, is a subset of patients that are unique to tertiary referral trauma hospitals. Despite this, of the population admitted at these trauma centres it was found that the most common mechanisms of injury causing globe and adnexal trauma was falls and burns. The subsequent chapters will further explore these common causes of globe and adnexal trauma.

3 Globe and Adnexal Trauma associated with Falls

Preface

Falls are a frequent cause of globe trauma in the elderly. The elderly are at high risk of fall-related globe and adnexal trauma due to the frequency of falls and their underlying comorbidities. In younger populations alcohol is often associated with falls related globe and adnexal trauma. The presenting symptoms of globe and adnexal trauma can be broad and it may be difficult for elderly patients to effectively communicate their symptoms. Thorough ocular examinations can assist medical staff in forming a comprehensive picture as reliance on history alone with minimal examination may lead to delays in the diagnosis of globe trauma.

Introduction

Falls occur frequently in the elderly, greater than 30% of people aged over 65years reported a fall in the preceding 12 months with 50% being recurrent fallers(62). The elderly often have multiple risk factors predisposing them to falls, such as impaired cognition, polypharmacy, reduced balance and poor lower limb strength (62-65). Chronic disease such as Parkinson's disease, ischaemic heart disease, chronic obstructive pulmonary disease and depression can further increase the risk of falls(62, 64, 66, 67). In younger adults, falls are highly influenced by the consumption of alcohol and illicit substances(68), as they increase the likelihood of risk taking behaviours and accidents(69, 70). Pre-ambulant children can also be at greater risk of falls while developing their coordination and strength(71, 72).

The risk of trauma is increased in the elderly due to the frequency of falls and underlying comorbidities(62, 63). Ten percent of falls in the elderly cause serious trauma, such as limb fractures and head and globe injuries(62, 64, 73). In elderly populations, falls are one of the greatest causes of globe and adnexal trauma(65, 74), and a frequent cause of unilateral blindness(1). If the fall does not cause injury, the psychosocial impact from loss of confidence often leads to decreasing activity, independence and quality of life(62, 63, 66, 67, 73). Moreover, elderly patients with globe trauma are at risk of nursing home admission and institutionalisation(64).

Lee et al (2020) conducted a 10-year review of globe trauma associated with falls from standing-height in the elderly at a trauma centre in Melbourne, Victoria Australia(75). Apart from this study there has been minimal research into falls-related globe and/or adnexal trauma across all age groups and in other locations in Australia.

To investigate the epidemiology and aetiology of globe and adnexal trauma caused by falls across all age groups, we performed a retrospective case series at two tertiary

referral hospitals in Sydney, New South Wales (NSW), Australia. In addition, we aimed to determine the ophthalmology input in the acute assessment of these patients.

Methods

A retrospective medical record review was conducted of patients with falls-related globe and/or adnexal trauma from two tertiary hospitals, Royal North Shore Hospital (RNSH) and Royal Prince Alfred Hospital (RPAH), in Sydney, NSW Australia between January 2015 and December 2019. The catchment for these hospitals included metropolitan Sydney, central and northern regional NSW.

Patient Data

Using the International Classification of Disease Tenth Revision codes, hospital diagnostic and procedural coding data were searched to identify patients (Appendix 2). Inclusion criteria were patients admitted to either hospital after suffering globe and/or adnexal trauma resulting from a fall. Globe trauma was defined as an injury to the globe or optic nerve and adnexal trauma as injury to the orbital contents, orbit, eyelids and surrounding soft tissue(54). Patients were classified by age with children aged 18years and below, adults above 18years and the elderly over 65years. Patients with a mechanism of injury aside from falls and elective admissions bypassing emergency were excluded.

Medical records were reviewed to confirm fall-related globe and/or adnexal trauma, and to extract demographic data, risk factors for falls, ocular examination and specialist ophthalmology referral. The medical record was review was conducted by a single abstractor who was not blinded to the study aims and used a standardised abstraction form.

Definitions and Classifications

Ocular examinations were classified as ‘no exam’ if no ocular examination was documented, a ‘gross exam’ if there was a short description of the appearance of the globe and periorbital area, while a ‘thorough exam’ included documentation of the visual acuity, extra ocular movements, pupils, and anterior segment examination. An ‘unwitnessed fall’ was defined as a fall that occurred without being seen by others. The length of time before patients were found following the fall was recorded and the term ‘long lie’ used if patients were found at least 2 hours after the fall(58).

A high-energy mechanism of injury was defined as a mechanism that resulted in a large amount of kinetic energy being transferred to the patient such as fall down a flight of stairs. A low-energy mechanism of injury was defined as a mechanism that caused a small amount of kinetic energy being transferred to the patient such as fall from standing-height(57).

Patients' injuries were classified using the Globe and Adnexal Trauma Terminology Survey(51). Internal globe trauma, lamellar lacerations to the eye, open globe injuries and injuries to the optic nerve were further classified as severe globe trauma, due to the increased risk of vision loss from these injuries(39, 56).

Multisystem trauma was defined as injury to two or more areas of the body(59). The severity of the multisystem trauma was classified by retrieval services and emergency staff according to the accident and subsequent injuries(53, 59). At RNSH and RPA, trauma presentations meeting criteria, such as fall from greater then 5metres, penetrating injuries and spinal cord injury, activated a trauma call which mobilised a multidisciplinary team to provide emergent management(59).

Statistical Analysis

Statistical analysis was performed using Jamovi software, Version 1.6(60, 61) (Jamovi, Sydney Australia). Descriptive analysis of the data was used to describe continuous data utilising mean (standard deviation (SD)) or median (interquartile range (IQR)) dependent on the distribution of the data. The categorical data was reported using counts and proportions and compared with Chi-squared tests.

Results

A search of the medical records at RNSH and RPAH using International Classification of Disease codes yielded 890 patients. All duplicates were removed and patients with no globe or adnexal trauma, elective admissions and patients that sustained trauma from another mechanism of injury other than falls were excluded (Figure 3.1). Three-hundred-and-forty-six patients were admitted to RNSH and RPAH with globe and/or adnexal trauma resulting from a fall between January 2015 and December 2019 (Table 3.1).

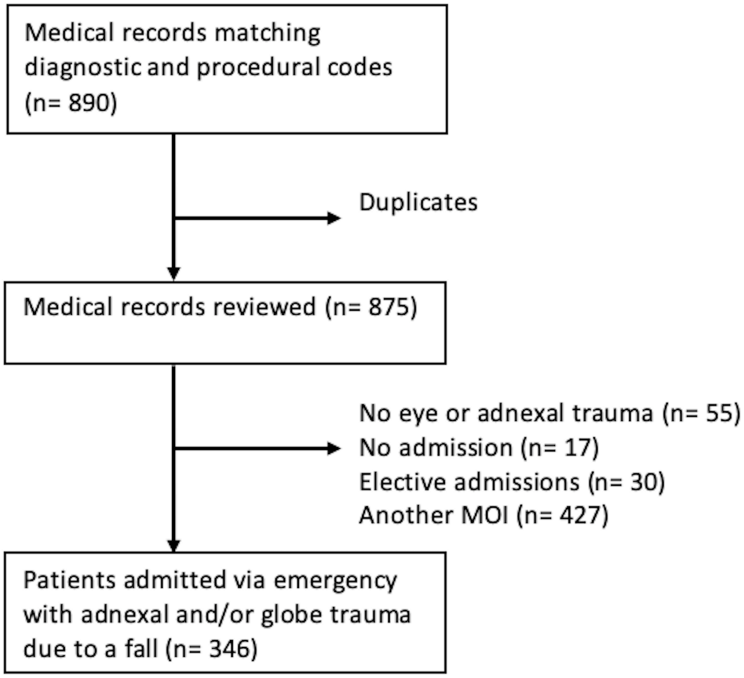

Figure 3.1: Patients with globe and/or adnexal trauma examined according to the inclusion and exclusion criteria to determine patients with falls-related globe and adnexal trauma (n=346), MOI= mechanism of injury

Demographics

The median age of patients was 76years (IQR 24years), with a range of 3months to 101years, and the majority of patients (n=186, 54%) were female. Two-hundred-and-fifty-two patients (73%) were aged over 65 years, with the highest proportion of patients being greater then 75years (Figure 3.2).

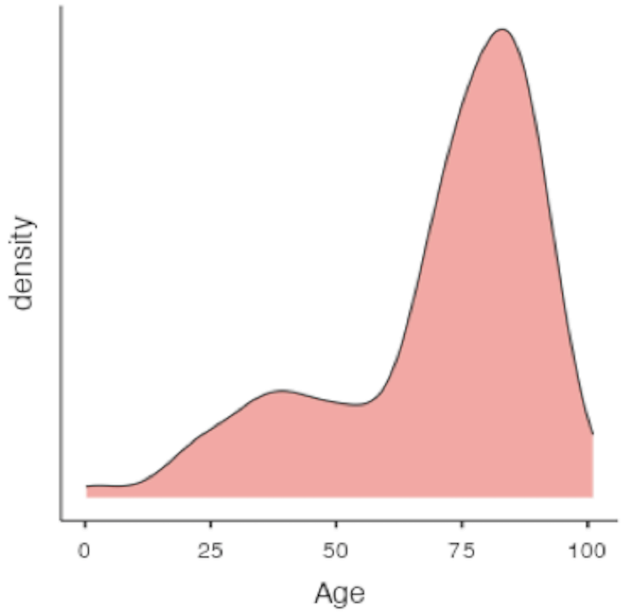

Figure 3.2: Distribution of age of patients with globe and/or adnexal trauma from a fall (n=346, median 76 years, IQR 24 years)

Three-hundred-and-eight (89%) patients initially presented to either RNSH or RPAH, 38 (11%) were transferred from other hospitals. The reasons for transfer from other hospitals included facial burn, multisystem injury and ophthalmology referral for severe globe trauma.

One-hundred-and-six (30%) patients sustained multisystem injury.

Table 3.1: Demographic data on of patients admitted with adnexal and/or globe trauma due to a fall (n=346). RNSH = Royal North Shore Hospital, RPAH = Royal Prince Alfred Hospital

Characteristics	
Mean age (SD) [range]	70 (21) years [3 months – 101 years)
Sex (mean age, SD)	Male 160 (67, 22 years) Female 186 (73, 20 years)
Age categories (years), n (%)	
0-10	3 (1%)
11-18	4 (1%)
19-35	26 (8%)
36-65	61 (18%)
66-85	164 (47%)
86-105	88 (25%)
Side of injury, n (%)	
Left	168 (49%)
Right	158 (46%)
Bilateral	20 (5%)
Initial hospital of presentation, n (%)	
RNSH	175 (51%)
RPAH	133 (38%)
Metropolitan hospital	27 (8%)
Rural hospital	8 (2%)
Other tertiary hospital	3 (1%)
Alcohol or illicit drugs, n (%)	70 (20%)

Data on the injury

One-hundred-and-ninety-four (56%) patients had a fall within the home, such as tripping on carpet, stairs, uneven floors or cords. There were 41 unwitnessed falls and of these patients 13 of the patients had no memory of the fall due to illness and/or cognitive impairment. Ten patients (3%) had a 'long lie' after the fall, with 1 patient lying on the floor for 2 days before being found. The 'long lie' patients lived alone, were elderly and had numerous comorbidities.

The most common risk factor for a fall was age over 65years. Multiple risk factors for falls were present in patients, with all elderly patients having at least 3 risk factors contributing to their fall. Polypharmacy and chronic disease were other common risk factors (Table 3.2). Twelve falls were due to syncope secondary to postural hypotension, arrhythmias or recent change in medication. Most of the patients under the age of 65years

did not have a pre-existing risk factor for falls, apart from 5 patients who suffered from chronic alcohol abuse.

Alcohol and illicit substances were involved in 20% of falls, predominantly in younger populations. The mean age of patients admitted with an alcohol-related fall was 56years (range 15 – 86years), illicit substance-related falls was 50years (range 42 – 57years) and for both alcohol and illicit substance 40years (range 22 – 57years). Alcohol-related falls mostly occurred at home (n=29, 41%) or whilst walking from a local restaurant or licenced venue (n=24, 34%).

Table 3.2: Intrinsic risk factors for falls in patients with globe and/or adnexal trauma (n=346)

Intrinsic risk factors	**n (%)**
Age >65 years	252 (73%)
Chronic disease	165 (48%)
Polypharmacy/high risk medications	144 (42%)
Impaired cognition	56 (16%)
Poor balance/gait/strength	48 (14%)
History of falls	36 (10%)
Visual impairment	34 (10%)
Alcohol/Substance abuse	29 (8%)

Adnexal Trauma

The most common adnexal trauma was periorbital haematoma which occurred in 336 (97%) patients. Mid-facial/orbital fractures occurred in 110 (32%) patients with the following risk factors; falls from a standing-height (11%) when the point of impact was directly to the mid-facial area; and high-energy injuries such as fall from greater than 2metres (4%) or falling down stairs (4%). Sixty-one patients (55%) with mid-facial/orbital fractures had globe trauma and 25 (23%) were classified as severe globe trauma. Table 3.3 details the data on the globe and adnexal trauma.

Globe Trauma

One-hundred-and-twenty-five (36%) patients suffered globe trauma with 48 (14%) classified as severe. Sixty-four patients injured their right eye, 54 injured their left and in 6 the injuries were bilateral. There were 25 open globe injuries (OGIs), 24 ruptured globes and 1 penetrating laceration. Three of the ruptured globes occurred along previous surgical wounds such as post-cataract surgery and corneal transplants. The OGIs carried poor visual prognosis as all injured eyes had a final visual acuity less than 6/60.

There was no significant difference in the rate of globe trauma (39% vs 32%, p=0.246) or severe globe trauma (13% vs 15%, p=0.720) between males and females. Significantly more patients with mid-facial/orbital fractures had globe trauma compared to patients with no mid-facial/orbital fractures (55% vs 36%, p <0.001). Severe globe trauma

occurred at similar rates in patients with and without orbital/mid-facial fractures (23% vs 14%, p=0.103).

Of the 106 patients with multisystem injury, all patients had adnexal trauma, 42 (40%) had globe trauma with 12 (11%) patients globe trauma classified as severe. Ten patients had a mechanism of injury and/or injuries necessitating a trauma call. Six of these trauma call patients had comorbid globe injury including one patient with a severe globe trauma.

Table 3.3: Adnexal and globe injuries occurring from falls (n=346)

Adnexal and globe injuries	**n (%)**
Periorbital haematoma	321 (97%)
Orbital/mid-facial fracture	110 (16%)
Laceration to lids or adnexa	36 (10%)
Open globe injury	25 (7%)
Internal eye injury	25 (7%)
Corneal trauma	15 (4%)
Retro orbital haematoma	8 (2%)
Optic nerve injury	3 (1%)

Management

All patients were initially reviewed by emergency staff. Eighty-nine (26%) patients had a thorough eye exam documented by emergency staff, 157 (45%) had a gross exam documented and for 100 (29%) there was no exam documented.

When globe trauma was diagnosed by emergency staff, 58% of patients had had a thorough ocular exam documented. When only adnexal trauma was diagnosed, 205 (92%) patients had had a gross exam or no eye examination documented (Figure 3.3). Challenges complicating the initial examination of patients included delirium, cognitive impairment, intoxication, non-English speaking backgrounds and altered levels of consciousness.

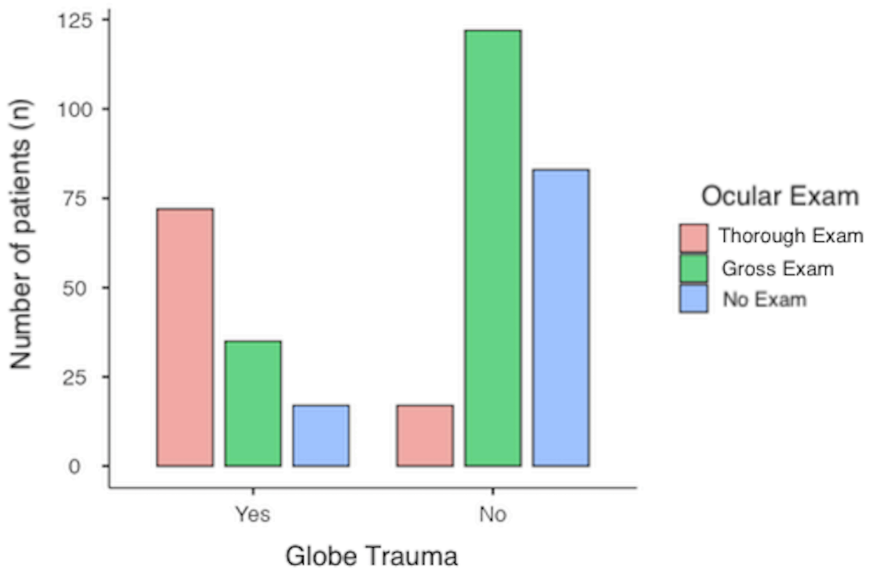

Figure 3.3: Type of eye examination in the presence of globe trauma occurring from falls (n=346)

Ophthalmology were referred 122 (35%) patients by emergency medical staff. Reasons for referral included suspicion of globe trauma, abnormal visual acuity or comorbid mid-facial/orbital fracture (Table 3.4). One-hundred-and-fifteen (94%) patients referred were seen by ophthalmology within 24 hours in the emergency department or in the clinic. Of the patients referred to ophthalmology, 82 (67%) had a thorough ocular examination documented by emergency staff. For the 125 patients with globe trauma, 88 (72%) patients were referred to ophthalmology by the emergency staff at presentation including 45 (92%) patients with severe globe trauma. Seventy-two (65%) patients with mid-facial/orbital fractures were referred to ophthalmology.

There was one patient with globe trauma where the diagnosis was delayed. The patient presented from a nursing home after a fall with head strike. They were reviewed by emergency medical staff and no referral to ophthalmology was made, the patient was then discharged. The patient represented to emergency two days later complaining of eye pain and abnormal vision. A referral to ophthalmology was made on representation and the patient was found to have a subconjunctival haemorrhage and epithelial defect.

Table 3.4: Reasons for ophthalmology referral by acute medical staff(n=125)

Reasons for referral	**n (%)**
Diagnosis of globe trauma	66 (53%)
Mid-facial or orbital fracture	36 (29%)
Suspicion of globe injury	14 (11%)
Reduced visual acuity	10 (8%)
Other eye complaint	2 (2%)

Discussion

Our study demonstrated the spectrum of falls-related globe and adnexal trauma from 346 patients admitted to RNSH and RPAH between January 2015 and December 2019. The majority of patients were elderly, female and had at least 3 risk factors contributing to their falls. Adnexal trauma was more common than globe trauma (100% vs 36% respectively), with 97% of patients suffering periorbital haematomas. Of the 125 patients who suffered globe trauma in 48 (14%) the globe trauma was classified as severe. A mechanism of injury involving a greater impact, for example a fall from a height, was associated with more severe adnexal trauma, such as mid-facial/orbital fractures. If the patient had mid-facial/orbital fractures, they were more likely to have globe trauma than patients without orbital/mid-facial fractures. When severe globe trauma was present or suspected in the acute examination, emergency staff referred the patient for ophthalmology reviews.

The majority of patients with fall-related globe and/or adnexal trauma were female and had the fall occur in the home. This is consistent with previous literature where falls by the elderly in the home were overrepresented(76-79). Additionally, we found that patients most often had at least 3 risk factors such as age, chronic disease and polypharmacy. For younger patients in our study, alcohol was the most frequent contributor to falls. Consequently, for elderly patients presenting with a fall a medical review is recommended and in young patients a drug and alcohol history should be taken to identify any underlying risk factors contributing to their falls

From 2014-2022, the NSW government legislated an amendment to the Liquor Act, colloquially referred to as the 'lockout laws', restricting the service of alcohol to certain time periods in inner Sydney. The 'lockout laws' followed community outcry on alcohol-related injuries and violence. During this period, there was a sustained reduction of alcohol-related serious injury and assaults presenting to St Vincent's hospital located in inner Sydney(70, 80). Although, from 2010-2020 the rate of alcohol-related hospitalisations across NSW increased from 440.1 to 502.9 per 100 000, and alcohol-related falls were the second most common reason for alcohol-related hospitalisation(69, 81, 82). Royal North Shore hospital and RPAH are located approximately five kilometres from the central business district (CBD) of Sydney and receive patients and referrals from inner Sydney. We found that alcohol was involved 20% of the falls-related globe and adnexal trauma, however, only 4 of the patients were injured in the CBD area and the remaining occurred in the patients' local area outside the CBD. The role of alcohol in trauma is important to identify as alcohol management plans may have a future role in preventing globe trauma (69, 82).

In the 110 patients with mid-facial/orbital fractures there was a higher proportion of globe trauma compared to those without these fractures. Our findings are consistent with, Guly et al. (2006) who conducted a retrospective analysis of a Trauma Audit Research

Network database from England and Wales between 1989 and 2004. They found the risk of globe trauma for patients with facial fractures was 6.7 times greater compared to patients with no facial fracture(25, 37). Likewise, Poon et al. (1999) in their review of globe trauma occurring in the context of multisystem injury found that mid-facial/orbital injury significantly increased the risk of globe trauma. Poon et al. recommended that patients with such fractures should be referred for ophthalmology review. Concerningly, only 65% of patients in our study with mid-facial/orbital fractures were referred for ophthalmology review. Our data highlights the association of globe trauma with mid-facial/orbital fractures has remained stable over time. Further education is required on the importance of thorough eye examinations and referral for specialist ophthalmology reviews in these patients(21, 37, 39). Moreover, preventative measures are needed to decrease the incidence of severe trauma.

Only 26% of our patients had a thorough eye exam documented at presentation with most of these occurring in patients with suspected globe trauma. For the remaining patients, a gross examination or no examination was performed, raising the concern for delays in the diagnosis of globe trauma. Notably, one of our patients had a delay in diagnosis of their globe trauma; the injury was diagnosed following representation to hospital. Challenges for emergency staff when assessing patients after trauma include barriers such as language, intoxication, delirium and cognitive impairment(83, 84). Given these challenges, it is vital to perform a thorough ocular examination as patients may be unable to effectively convey symptoms such as decreased vision, diplopia or scotomas(65, 74). Utilising simple tools such as a Snellen chart on a smart phone, support of family members and re-examination by more experienced staff may be useful to prevent delays in diagnosis and missed injuries(8, 74).

Similar to our study, Lee et al (2020) found that globe injuries can result from low impact falls emphasising the need for thorough ocular examination even in seemingly innocuous circumstances(75). We also found that in younger populations, falls were commonly associated with alcohol and illicit substances. Additionally, there were few patients with alcohol-related falls from Sydney's CBD which may have been influenced by the 'lockout laws' in place at the time. Our study provides recent data on the spectrum of globe and adnexal trauma resulting from falls in all ages admitted to two trauma centres. We highlight the need for high index of suspicion of fall-related globe trauma, due to the frequency of falls presentations and significant morbidity that can result.

Conclusion

Elderly female patients were most commonly affected by fall-related globe and adnexal trauma. In the young, alcohol and illicit substances have a role in such injuries. A thorough ocular examination is vital to diagnoses globe trauma following a fall, with mid-facial/orbital fractures increasing the risk of globe trauma. Utilising specialist ophthalmology assessment can aid emergency staff in diagnosing globe trauma. Further, research is required to determine the effect of falls prevention strategies including alcohol management plans in preventing globe trauma.

4 Burns-related Globe and Adnexal Trauma

Preface

Globe and adnexal trauma caused by burns can occur in activities at home or work as commonly used products contain corrosive and toxic substances. Thermal burns to the face or periorbital region, such as from fire and flash burns, are a common cause of globe trauma. When facial or adnexal burns occur as a part of more extensive burn covering large areas of the body, ocular examination can be given a lower priority or overlooked while the patient is stabilised and life-threatening injuries are treated. Early examination and treatment may help to prevent further injury and assist recovery. Utilising specialist ophthalmic assessment can assist emergency staff in managing these patients.

Introduction

Globe and adnexal burns can occur in major accidents, fires and electrocutions(85-88). Additionally, globe trauma and adnexal burns can be caused by household and workplace activities as frequently used products can contain harmful and corrosive chemicals(89, 90). Burns cause 20% of all globe trauma with long term sequalae including vision loss, chronic pain and disfigurement(85, 91).

Burns can be classified based on aetiology, as thermal and chemical burns. Thermal burns occur from heat causing injury to epithelial tissue, with the depth depending on the temperature, time of exposure and proximity to the source(92, 93). Chemical burns are divided into alkali and acidic, based on the pH of the substance(89, 90). Alkali burns are more severe as these chemicals have greater capacity for cell death, softening and penetrance into tissues(89). In contrast, acidic substances damage the outer epithelial layers causing coagulation of the tissues preventing further penetration into tissue(94). Classification of burns to the globe is based on the extent of damage to conjunctiva, limbus and cornea(94, 95). Adnexal burns are classified based on the depth of the burn in the tissues; superficial, partial thickness and full thickness. These classifications are prognostic indicators of the recovery and guide management(85, 92, 96).

The initial management of globe burns, especially following chemical exposure, involves immediate irrigation to remove any irritating substances(89, 94). Minor corneal trauma with minimal limbal involvement generally make good visual recovery(85, 94). If there is a large area of the cornea and limbus affected, the prognosis is guarded. Treatment such as preservative-free lubrication and antibiotic-drops are utilised to decrease risk of progression and infection along with the need for surgery(85, 94). Burns to the globe can increase the risk of infection, scarring and globe perforation(86, 90).

Globe and adnexal burn-related trauma can occur alone or with other injuries to the face and/or body. When associated with multisystem injury, life threatening injuries take precedence, which may lead to delays in assessment and management of globe and adnexal trauma(85, 86). By incorporating early ophthalmology intervention, early diagnosis is enabled to facilitate rapid initiation of intensive treatment for severe injuries(42, 86).

Cabalag et al. (2015) completed a retrospective review of 125 patients admitted with burn-related globe trauma between 2000-2010 at the Alfred Hospital in Melbourne, Victoria Australia(97). Since then there has been no recent literature from Australia on the epidemiology, aetiology and management of globe and adnexal burns. Understanding the initial assessment and management may allow the development of evidence based protocols to improve patient outcomes.

We aimed to improve the understanding of the assessment and management of globe and adnexal burns related trauma by retrospectively reviewing patients who were admitted to two tertiary referral trauma centres in Sydney, New South Wales (NSW) Australia.

Methods

A retrospective case series was performed for patients admitted with burns-related globe and/or adnexal trauma to Royal North Shore Hospital (RNSH) and Royal Prince Alfred Hospital (RPAH) between January 2015 and December 2019. Royal North Shore Hospital and RPAH are tertiary referral level 1 trauma centres located in Sydney, NSW Australia. Royal North Shore is also a burns referral centre providing specialist burns service for northern NSW. Each hospital receives referrals from metropolitan and rural hospitals across northern and western NSW. Ethics and Governance approval (2020/ETH02544) was granted by the South Eastern Local Health District Ethics Committee with site specific approval from RNSH and RPAH committees.

Patient data

Using the International Classification of Disease Tenth Revision codes, diagnostic and procedural coding data was searched to identify patients (Appendix 2). Patients were included if they presented or were transferred to RPAH or RNSH emergency departments and subsequently admitted after suffering globe and/or adnexal trauma from a burn. Other mechanisms of injury and elective admissions bypassing emergency were excluded. Medical records for all included patients were reviewed to confirm trauma, and extract data on demographics, use of alcohol or recreational drugs, ocular examination and whether a specialist ophthalmic assessment was performed.

Definitions and Classifications

Globe trauma was classified as an injury to the eye and adnexal injury as an injury involving the eyelids or soft tissue surrounding the orbit. Thermal injury was defined as an injury caused by heat such as from fire, electric arc, or hot liquid. Chemical injury was defined as an injury caused by a chemical substance. Chemical injury was further classified as alkali, if the substance had a pH greater than 7, or acidic if the substance had a pH less than 7.

Patients were classified as having multisystem trauma if two or more regions of the body were injured or localised injury if a single region of the body was injured(55). Ocular examinations were defined as; 'no exam' if no ocular examination was documented, a 'gross exam' if there was a short description of the appearance of the globe or periorbital area, and a 'thorough exam' if visual acuity and anterior segment examination including the use of fluorescein was recorded.

Chemical corneal burns were graded according to the Roper Hall Classification(98) (Appendix 3) and the Birmingham Eye Trauma Terminology (BETT)(99) was used to describe and classify globe trauma. Open globe injuries, significant burn or injury to cornea, conjunctiva or sclera and internal eye injuries were further classified as severe globe trauma, as they have high risk of causing permanent vision loss.

The extent of a patient's burn was calculated and documented by specialist burns staff using rule of nine's(100). Using this method body parts are given an approximate percentage of body surface area to estimate the total burn surface area (TBSA)(100).

Statistical analysis

Statistical analysis was performed using Jamovi software, Version 1.6(60, 61), (Jamovi, Sydney Australia). Due to the qualitative and quantitative nature of the data, descriptive statistics were used to describe continuous data utilising mean (standard deviation (SD)) or median (interquartile range (IQR)) depending on the distribution of the data. The categorical data was reported using counts and proportions and compared with Chi-squared tests.

Results

The diagnostic and procedural code (Appendix 2) search identified 890 medical records of patients admitted to RNSH or RPAH within the study period. After removing duplicates the remaining 875 records were assessed against the inclusion and exclusion criteria. Seven-hundred-and-seventy-four patients without globe or adnexal trauma, injury caused by another mechanism other than burns, were not admitted or admitted for a procedure post-trauma were removed. Figure 4.1 details the inclusion and exclusion procedure.

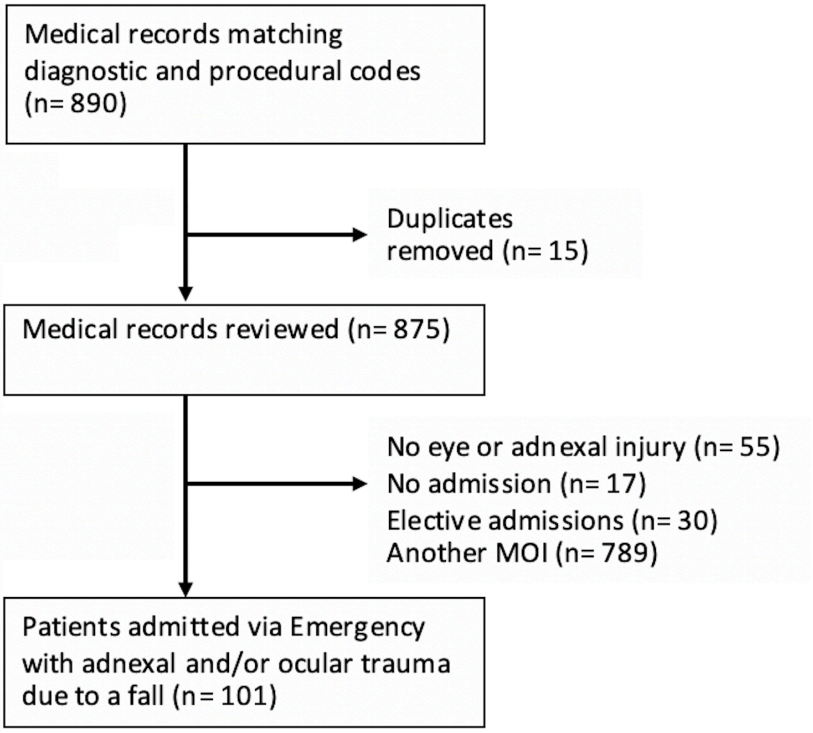

Figure 4.1: Patients with globe and/or adnexal trauma examined according to the inclusion and exclusion criteria to determine patients with burn-related globe and adnexal trauma (n=101), Key: MOI = mechanism of injury

Demographics

One-hundred-and-one patients suffered burn-related globe and/or adnexal trauma. The mean age patients were 37 years-old (SD 18). Most patients were male (n=77, 76%). There were more injured adults (93%) than children (7%). Most patients were aged between 19-65 years-old (n=84, 83%), and the peak incidence of injury was 28years-old. Five patients were intoxicated at the time of injury, two patients had taken methamphetamines and three had consumed alcohol.

Seventy patients (69%) presented initially to RNSH or RPAH and 31 patients were transferred to RNSH from other hospitals to receive specialist burn care. Nine were from other tertiary hospitals in NSW, 12 from metropolitan hospitals in Sydney, 8 from rural NSW hospitals and 2 were international repatriations. Table 4.1 summarises the demographic data for the included patients.

Table 4.1: Demographic information of patients admitted with globe and/or adnexal burns (n=101), SD = standard deviation

Characteristics	
Mean age (SD) [range]	40 (18) years [3 weeks – 87 years)
Sex (mean age, SD)	Male 77 (40, 16 years) Female 24 (42, 23 years)
Age Categories (years), n (%)	
0-10	2 (2%)
11-18	5 (5%)
19-35	40 (40%)
36-65	44 (44%)
66-85	9 (9%)
86-100	1 (1%)
Side of injury	
Right	29
Left	39
Bilateral	33
Initial hospital of presentation	
RNSH	52
RPAH	18
Metropolitan hospital	12
Other tertiary hospital	9
Rural hospital	8
International hospital	2

Circumstances and Mechanisms of Injury

Sixty-six patients were injured from thermal mechanisms and 35 from chemical substances. Twenty-six patients were injured while completing tasks at work, while 48 patients were injured completing tasks at home (Table 4.2). One patient was reported to have worn eye protection at the time of their injury. Four patients were injured from a health procedure, these patients' eyes were exposed to highly concentrated hand sanitiser while under a general anaesthetic.

Table 4.2: Mechanism of Injury for patients with globe and/or adnexal trauma (n=101)

Mechanism	n
Work	26
Cleaning	22
Cooking	13
Household Maintenance	13
Camp fire	10
Motor vehicle accident	5
Health procedure	4
Nature	3
Fireworks	2
Assault	2

Data on the Injury

Adnexal trauma occurred more frequently then globe trauma (100% vs 82%). The most common adnexal trauma was an eyelid-burn (n=59, 58%). Thirty-one eyelids had partial thickness burns and 4 full thickness burns.

Eighty-three (82%) patients suffered burn-related globe trauma and 50 (49%) were classified as severe. Twenty-eight patients suffered trauma to both eyes, 23 injured their right and 32 their left. Fifty-two of the patients with globe trauma were injured at home or at work, 26 were from thermal mechanisms and 26 from chemicals. There was not a significant difference in globe trauma between males and females (83% vs. 79%, p=0.892).

Of the 83 patients with globe trauma, 48 (58%) were thermal injuries and 35 (42%) were chemical injuries. Despite this, patients with chemical exposure to the globe and adnexa were more likely to have globe trauma (100% vs 72%, $p < 0.001$) and severe globe trauma (54% vs 32%, $p = 0.047$) compared to thermal exposure to the globe and adnexa.

Forty-five patients suffered multisystem injury. Patients with burns from thermal mechanisms were more likely to have multisystem injury (63% vs 9%, $p < 0.001$). Thirty-two patients (71%) with multisystem injury had comorbid globe trauma with 13 (29%) classified as severe. Patients who had multisystem injury were less likely to have globe trauma (71% vs 91%, $p = 0.019$) and but did not for severe globe trauma (29% vs 48%, $p = 0.077$) compared to patients with isolated trauma to the face or periorbital area.

There were 7 patients with large burns with total burn surface area greater than 20%, 4 of these suffered globe trauma with 2 classified as severe. In the patients with severe globe trauma, one patient had a visual acuity of count fingers at presentation due to moderate to severe corneal burns from a flash fire burn. After 6 weeks of treatment with intense lubrication, the visual acuity improved to 6/12. The other patient had bilateral globe ruptures after the explosion of a petrol cylinder. One eye was enucleated soon after presentation due to significant loss of the globe contents and the other eye had a very poor visual outcome with persistent no light perception vision at 6 months post-trauma.

Management

All initial assessments and management of globe and adnexal trauma occurred in emergency by emergency staff. Fifty-seven patients had thorough ocular examinations documented and 22 patients had a gross exam documented by emergency staff. For 24 patients, a formal ocular assessment was not documented by emergency staff. A thorough examination was documented by emergency staff when there was clinical suspicion of globe trauma (Table 4.3).

Table 4.3: Ocular examination completed by acute medical staff (n=101 patients)

	Eye Exam		
Globe Trauma	Thorough Exam	Gross Exam	No exam
Yes	51	13	19
No	6	9	3

On presentation, if chemical exposure was noted, pH was assessed using litmus paper and the eye thoroughly irrigated with normal saline. Thermal burns were only irrigated to allow for examination. Each patient that was reviewed by emergency staff and diagnosed with globe burn received chloramphenicol ointment and/or lubricating eye ointment. Patients were assessed by ophthalmology if deemed necessary by emergency or burns medical staff.

Eighty-eight patients were referred to ophthalmology for suspicion of globe trauma. Ophthalmology diagnosed 79 (90%) of referred patients with globe trauma. Referrals were made by emergency and burns medical staff with 97% occurring within the first 24 hours of presentation. Of the 14 patients that did not receive a formal ophthalmology assessment, 9 were deemed to have had no globe involvement by emergency and/or burns medical staff and 3 patients had mild injuries managed by emergency staff. There were 2 patients with globe trauma where the diagnosis was delayed; one was a nursing home resident who had hot water scald to their face. On initial assessment by emergency staff, the patient with the hot water scold was deemed to have only superficial periorbital burns and was discharged home. The patient with the hot water scald represented complaining of visual symptoms and eye pain and on this occasion ophthalmology referral was made and the patient was found to have conjunctival and corneal epithelial defects. The other patient with a delayed diagnosis of globe trauma was not assessed initially as they were intubated soon after presentation to emergency. After extubation, the patient complained of decreased vision leading to an ophthalmology referral and the diagnosis of a mild corneal burn.

Burns to the adnexa, such as the eyelids, were managed by both burns plastic surgical team and ophthalmology. Five patients required surgical debridement and grafting of the eyelids which was carried out by the plastic surgical team. Ten patients developed lagophthalmos which was initially managed conservatively with lubricants and patching and then surgical correction by ophthalmology at a later date.

Table 4.4 shows the grades of the chemical related globe trauma given by ophthalmology using the Roper Hall Classification. Sixteen injuries were classified as mild with a Grade 1 or less and ten patients were graded 3 or higher. Two patients with severe corneal burns, from concrete splashing in their eyes, presented with count-fingers vision. These two patients were treated with vitamin C, doxycycline, intensive drop regimen and amniotic grafting, and their vision improved slowly over 1 year to 6/18 and 6/12.

Table 4.4: Roper Hall Classification of Chemical Corneal Burns (n=35 patients)

Mechanism	Grade			
	1	2	3	4
Basic in eyes	15	12	4	1
Acid in eyes	1	2	0	0

If a burn to the globe was diagnosed by ophthalmology, patients received eye lubrication regime with antibiotic cover, such as chloramphenicol, until the epithelial defect and corneal damage had resolved. Steroids, doxycycline, high dose vitamin C and amniotic grafting were used to manage the corneal trauma if required. One burn to the globe was complicated by herpes simplex virus keratitis that resolved with oral antivirals.

Discussion

Between January 2015 and December 2019, 101 patients with burn-related globe and/or adnexal trauma were admitted to two trauma centres in Sydney, NSW Australia. Patients were typically male and aged between 19-65 years. It was common for globe trauma to occur at home. Chemical exposure to the globe and adnexa was more likely to cause globe trauma and severe globe trauma than thermal mechanisms of injury. Eighty-eight patients were referred to ophthalmology due to suspicion of globe trauma. Ophthalmology diagnosed 90% of these patients with globe trauma. All patients diagnosed with globe burn were placed on preservative-free lubrication and chloramphenicol ointment by emergency and burns staff.

In our cohort, 83 (82%) patients suffered burns-related globe trauma with 40 (39%) classified as severe. Only one patient had a final vision worse than 6/36 in either eye which was caused by globe ruptures from an exploding petrol canister. The visual outcomes after burn-related globe trauma was consistent with a report by Spencer, Hall and Stawell (2002). For their report, they retrospectively reviewed globe and adnexal burns admitted to the Alfred Hospital between 1990 and 2000. Approximately, 50% of patients suffered burns-related globe trauma with only 2% having poor visual outcomes. They proposed the use of early lubrication hypothesised decreased the need for further ocular surgery and improved visual outcomes(85).

In our study, we found that 58% of globe trauma was caused by thermal mechanisms. Contrastingly, Sharma et al (2018) found that chemical-related globe trauma was more common than thermal mechanisms(94). A potential explanation for the difference is that we included patients from RNSH which is a burns referral centre confounding our results as we included more thermal injuries. Furthermore, mild chemical globe trauma may be managed in outpatient settings. However, we did find that patients who had chemical exposures to the globe and/or adnexa were more likely to have globe trauma than patients injured with thermal mechanisms which is consistent with previous literature(88, 90, 94, 101).

Moreover, Sterling Haring et al (2016), investigated chemical related globe trauma from a nationwide emergency database in the United States. They found young children aged 1-3 years were at the highest risk of chemical related globe trauma. It was theorised that this was due to the alkaline agents in household cleaning products being stored at accessible heights for young children(90, 102). Our study did not demonstrate these findings as both RPAH and RNSH would not admit but rather transfer severely injured children to tertiary paediatric centres.

Seven patients suffered a burn with total burn surface area greater then 20%. Four of these patients had comorbid globe trauma and 2 with severe globe trauma. In these types of patients with large multisystem injuries, globe trauma may initially be missed as they can occur alongside life-threatening injuries which require immediate attention(3, 8, 96). Yet, we found that patients with multisystem injury were less likely to have globe trauma than trauma isolated to the face or periorbital area. This is likely explained by the higher frequency of isolated injuries caused by chemical exposures to the globe which have high propensity to cause injury (89, 90, 94).

Regulations and policies

The Work Health and Safety Act(103) requires a person conducting business in Australia to ensure health safety by eliminating safety risks. For chemicals, this can mean substituting chemicals to less hazardous products to eliminate hazards and where unable, providing personal protective equipment meeting relevant standards(104). Despite this legislation, work-related chemical globe trauma remained a significant proportion of globe and adnexal burns, representing 26% of the patients in our study. Education about chemicals and ensuring appropriate labelling according to the Code of Practice(105) and access to and education on the appropriate types of eye protection and use may be beneficial in helping to minimise these injuries(106).

Household chemicals were a significant contributor to globe trauma in our study, with chemicals ranging from bleach to sulfuric acid. Chemicals in Australia are required to be labelled according and Poisons Standard(107) and education plays an important role in ensuring that access and use is appropriately managed. The 19-65year age groups were highly represented with chemical-related globe trauma in our cohort and education targeted at this group may help reduce globe trauma.

Conclusion

Burn-related globe trauma occurred from everyday activities at home or in the workplace. Chemical exposure to the globe and adnexa is a frequent cause of globe trauma and can cause severe injury. Thorough ocular assessments in the acute setting is vital to diagnose trauma and initiate treatment early. We investigated hospitals that have specialised burns staff, further research is required to facilitate referral and treatment pathways for patients with globe and adnexal burns to appropriately resourced centres.

5 Discussion

Globe and adnexal trauma are frequent presentations to Australian emergency departments. Previous literature(39, 75, 77, 78, 97) has explored specific patient groups with globe trauma admitted to Australian trauma hospitals. This thesis is a comprehensive review of all globe and adnexal trauma admitted to two Australian tertiary referral trauma hospitals, as well as the exploration of the input of ophthalmology services in the acute assessment and management of these patients.

Globe and adnexal trauma

Seven hundred and seventy-three patients with globe and/or adnexal trauma were admitted to either RNSH or RPAH between January 2015 and 2019. There were bi-modal peaks in the distribution of age, one in younger age group (25-30years) and the other in elderly populations (80-85years). Admissions in these populations can be explained by both patient and injury factors. In the elderly, underlying comorbidities and increased care requirements following trauma can make patients unsafe to discharge, requiring admissions for optimisation of mobility and care requirements(108). Similarly, in younger populations, globe trauma may require short admissions to provide intensive treatment regimens and frequent assessment to manage injuries(2, 109).

Four hundred and thirty-eight (57%) patients sustained globe trauma and 228 (29%) were classified as severe. In patients with mid-facial/orbital injury, the proportion of globe trauma (72%) and severe globe trauma (35%) increased. Poon et al and Guly et al also demonstrated increased globe trauma in patients with mid-facial/orbital injury. They recommended that patients with mid-facial/orbital injury be referred for ophthalmology review to exclude globe trauma given the higher rate of trauma to the globe in these patients(37, 39). Yet, we found that 20% of patients with mid-facial/orbital injury were not referred to ophthalmology, this increased to 31% in patients older than 65 years and more apparent in patients with falls. Further education of acute medical staff is required due to the importance of ophthalmology assessment in these groups(37, 39, 110).

There were 235 patients with multisystem injury, of these patients, 121 (51%) suffered globe trauma and in 49 (21%) of these patients the globe trauma was rated as severe. Seventy-one (30%) of the patients with multisystem injury met the criteria for a trauma call. Forty-three (60%) of the patients activating a trauma call suffered globe trauma and 22 (31%) were classified as severe globe trauma. The most common mechanism was a MVA which occurred in 56 (79%) patients. Globe trauma in multisystem injury, especially in the severely injured patients, may be placed at a lower priority for assessment and management as life threatening injuries take precedence(1, 42). During the initial surveys assisting the trauma team, 23 trauma call patients received ophthalmology assessment.

Severe globe trauma that was diagnosed during the examinations performed by ophthalmology included retrobulbar haematomas requiring lateral canthotomy, traumatic cataract, hyphaema, globe rupture and traumatic optic neuropathy. Utilising a series of examinations and incorporating early ophthalmology assessment can assist in the diagnosis of globe trauma in the severely injured(23, 33).

Falls were the most common mechanism of globe and adnexal trauma. Patients admitted after a fall were more likely to be female, elderly, fell in their home and have at least 3 risk factors for falls. Seventy-three percent of patients who had fall-related globe trauma were aged over 65 years, with the peak of patients being greater than 75 years. In comparison, falls in younger patients who fell were associated with alcohol consumption. All patients admitted after a fall had adnexal trauma, the most common injury was periorbital haematoma occurring in 336 (97%) patients. Furthermore, 110 (32%) suffered mid-facial/orbital fractures, which were caused by falls from standing-height where the impact was to the mid-facial area; and high-energy injuries such as fall from greater than 2metres or falling down stairs. Significantly more patients with mid-facial/orbital fractures from a fall had globe trauma compared to patients with no mid-facial/orbital fractures (55% vs 36%). A statistically significant relationship was not seen for severe globe trauma (23% vs 14%) due to the small numbers of severe globe trauma diagnosed in this cohort. Nonetheless our data highlights the need for preventative strategies to address falls in the elderly and alcohol consumption in the young to reduce globe and adnexal trauma.

Patients presenting with burn-related globe and adnexal trauma were younger than patients presenting with trauma from other mechanisms. The peak age was 28 years with 90% of patients younger than 65 years. These burn-related injuries often occurred while completing everyday tasks at home or work. In the 83 patients with burns related globe trauma, 48 (58%) were caused by thermal mechanisms and 35 (42%) were due to chemical exposure. Our finding of more patients with globe trauma caused by thermal mechanisms was not consistent with previous literature(90, 94, 101, 102). This disparity is could have been caused by the inclusion of patients from RNSH which receives numerous thermal burn referrals as it is a specialised burns centres. The patients who had chemical exposure to the globe and adnexa were more likely to have globe trauma compared to patients with thermal exposure to the globe and adnexa. Similarly, patients with multisystem injury caused by a burn were less likely to have globe trauma than those with isolated burns to the adnexa as the isolated injuries were often due to chemical exposures and thermal exposure caused multisystem injury. Our data highlights the need to have a high index of suspicion of the presence of globe trauma that may be severe in patients with burns especially when it is caused by chemicals.

Ocular Assessment

In our patients, 55% had a gross ocular exam documented or no exam was documented by emergency staff. This increased to 65% in patients between the ages of 66 and 85 years and 72% in patients aged greater than 85years. Similarly, only 26% of patients who had fall related globe or adnexal trauma had a thorough examination documented. It is interesting that with advancing age patients were less likely to have had a thorough ocular examination; this may have been due to other co-morbidities complicating assessment.

In patients with burns-related injuries, 57 patients had thorough ocular examinations documented and 22 patients had a gross exam documented by emergency staff. For 24 patients with burn related adnexal trauma, a formal ocular assessment was not documented by emergency staff. In patients with burn related trauma, ocular examination can be difficult with periorbital soft tissue swelling limiting the view of the globe. Similarly, it may be overlooked if the patient has a large total body surface area burn that is requiring urgent management.

Similarly, in the acute assessment of patients with multisystem injury necessitating a trauma call, an ocular exam was documented by the trauma team for 56 patients (66%), 30 gross ocular exams and only 26 had a thorough ocular exam recorded. If an ocular assessment was completed, it occurred in secondary or tertiary surveys.

We found that in the elderly or severely injured patients, there were challenges that can make the acute ocular examination difficult such as delirium, non-English speaking backgrounds, altered level of consciousness, life threatening injuries and procedures. Having a structured approach to ocular examination, using tools such as bed side Snellen charts, assistance from family members and incorporating specialist ophthalmology reviews can aid emergency medical staff in acute ocular examinations and prevent delays in the diagnose globe trauma(23, 33, 110).

There were 3 patients where the diagnosis of globe trauma was delayed. Each patient had either a gross examination or no exam was documented on the initial presentation to emergency. Two patients were nursing home residents who represented to emergency with ongoing eye pain and blurred vision. After ophthalmology review they were diagnosed with globe trauma. The other patient had large body surface area burn that was intubated soon after presentation. Concern for globe involvement was not noted until after the patient was extubated and they reported eye pain and blurred vision. They were reviewed by ophthalmology and diagnosed with mild globe burn.

Ophthalmology involvement

At RNSH and RPAH, the ophthalmology services provided access to specialist advice, assessment, treatment and follow up. Four hundred and fifty-two patients were referred

and received specialist ophthalmology assessment and management. Eighty-eight patients with burn related injuries and 122 were from patients after a fall. Reasons for ophthalmology review included abnormal visual acuity, concerning mechanism of injury, mid-facial/orbital injury, suspected or diagnosed globe trauma. These reasons were appropriate as they are factors that can indicate the presence of globe and adnexal trauma

Ophthalmology took part and assisted acute trauma services in the review of severely injured patients. Specialist ophthalmology examination occurred during the initial presentation after the patient was stabilised, usually during secondary surveys. One patient was even examined in theatre while undergoing lifesaving surgery. Our findings support those of prior studies(7, 20, 33, 42). For patients referred to ophthalmology, there is ongoing assessment and specialised management of globe trauma(21, 23, 33). Similarly, ophthalmology services can provide support to the trauma service to assist in the management of severely injured patients to free acute medical staff to focus on other priorities(7, 20, 35).

Clinical Implications

We found that 50% of patients had a gross examination or no examination documented, with the proportion increasing in the elderly. Similarly, 20% of patients with mid-facial/orbital fractures not were not referred for ophthalmology review. These findings raise the concern that some acute medical staff may not have the knowledge or experience to confidently review and/or know when to refer to ophthalmology to exclude suspected globe trauma. Education is recommended for acute medical staff to be able to perform ocular examination, commence initial management for common or sight threatening trauma and indicators for when referral for ophthalmology review is required. The education should increase proficiency using equipment such as the slit lamp and use of eye drops including fluorescein(110).

Primary, secondary and tertiary surveys are used in the assessment of multisystem injury to diagnose all injuries(41). A similar approach of multiple examination could be utilised by emergency staff for the assessment of globe and adnexa trauma as ocular examination can be challenging in patients at presentation with multisystem injury, for example, as they may have altered level of consciousness or distracting injuries. Patients may benefit from senior emergency staff review and/or repeat specialist re-examination as they can utilise tools and expertise that junior emergency staff are yet to develop(23).

Findings on presentation that should alert emergency staff to the need for referral to ophthalmology have been reported to include change in visual acuity from patients' baseline, concerning mechanism injury such as impact directly to globe, suspected injury and mid-facial/orbital injury(21, 23, 33). Indeed, we found 90% of patients that were referred to ophthalmology for these concerns were diagnosed with globe trauma.

Incorporating specialist ophthalmic assessment in the initial stages of presentation and admission can aid early treatment and minimise delays in the diagnosis of trauma(33). In circumstances where specialist assessment may not require immediate review, outpatient ophthalmology follow-up can be organised.

To facilitate referral for patients, emergency staff should complete ocular examination including visual acuity, periorbital areas, extra ocular movements, anterior segment examination. This information coupled with a clear description of the mechanism of injury and underlying past ocular and medical history can aid ophthalmology to appropriately triage and review patients(21, 110).

Limitations of the work

This thesis was limited by its design using the ICD-10 codes as patients that had globe and/or adnexal trauma that were not diagnosed or were given incorrect codes would not have been included in the patient population introducing selection bias. Furthermore, there is potential decrease in generalisability of results as only including admitted patients from RPAH and RNSH, which are both tertiary trauma centres and RNSH a burns referral centre, can increase the severity and number of injuries, especially thermal burns, compared to other centres. Similarly, despite RNSH and RPAH having paediatric wards, very few children were identified in the study as severe trauma in Sydney is typically referred directly to specialist paediatric hospitals. Moreover, the study included patients that were admitted to hospital creating greater bias towards more severe injuries as minor globe and adnexal trauma can be managed in outpatient settings.

To gain a contemporaneous overview of globe trauma clinical registries could be used to gather more comprehensive data (111). The International Globe and Trauma Epidemiology Study (IGATES) registry has been established as an international platform that could be used to collect such data (54, 112) including globe trauma from all patient presentations, clinic reviews and hospital admissions. This comprehensive database of injuries would minimise the introduction of bias seen in retrospective medical record reviews such as incorrectly coded patients, missed or delayed diagnoses.

Directions for future research

The Work Health and Safety Act requires companies in Australia to utilise strategies to eliminate health risk. Despite this, work related injuries in this thesis were common. Further research would be beneficial into the current education, prevention strategies and use of personal protective equipment in work environments and strategies to improve them.

To develop a current overview of all globe and adnexal trauma, the development of registries could be utilised. The International Globe and Trauma Epidemiology Study

(IGATES) registry is being established to allow for greater understanding into the trends of globe and adnexal trauma. Further research utilising this international registry may allow for the development of prevention strategies for globe and adnexal trauma.

Hospitals may not have access to specialist ophthalmology services to urgently review suspected globe trauma. Further research should investigate referral pathways and how to facilitate transfers for reviews at larger centres. Particularly important for rural and remote centres where patients must travel large distances.

Conclusion

Globe and adnexal trauma present to trauma hospitals occurring across a wide range of age groups and are caused by a myriad of mechanisms of injury. The assessment and management of globe trauma is complex, but currently ad hoc. Guidelines which might lead to protocols could be useful. Injury to the mid-facial/orbital region should indicate to emergency staff that a patient has an increased risk of globe trauma. Thorough ocular assessment is required to exclude globe trauma; however, it can be difficult in certain patient populations. A series of examinations may assist in identifying globe trauma especially in the high pressure and fast paced environments of the emergency departments. Ophthalmology services have an important role in assisting acute medical staff in the assessment and management of globe and adnexal trauma in patients in the acute setting.

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Appendix

APPENDIX 1 – Search Strategies

MEDLINE

(Emergency service Hospital OR trauma centers OR ((emergency adj2 (department or accident)) OR (trauma adj2 (center* or centre*))). AND ((eye injuries OR corneal injuries OR corneal perforation OR eye burns OR eye foreign bodies OR eye injuries, penetrating/ OR orbital fractures/ OR zygomatic fractures/) OR (optic nerve injuries/ OR toxic optic neuropathy/) OR ((eye* OR globe OR ocular OR orbit* OR zygoma* OR mid-fac* OR midface* OR cornea OR retina* OR optic nerve*) adj3 (injur* OR fracture* OR perforat* OR enuclea* OR eviscerate* remov* OR penetrat* OR burns OR surg OR operat*)) OR Ophthalmology OR ophthalmologist OR (((eye OR ocular) adj3 (speciali* OR surgeon*)) OR ophthalm*).ti,ab,kw) AND Accidents, Traffic OR ((motor OR car* vehicle* OR truck OR pedestrian* OR traffic OR plane* OR aeroplane* OR aviation OR bus) adj3 (accident* OR crash*)) OR (blast injuries/ OR multiple trauma/ OR fractures, multiple/) OR ((explos* OR ied OR bomb* OR blast* OR multiple OR major) adj3 (trauma or fracture* OR injur* OR burns OR accident*)) AND (patient care team/) AND ((multidisciplinary OR interdisciplinary) adj3 team*),

EMBASE

(hospital emergency service/ OR emergency health service/ OR ((emergency adj2 (department OR accident)) OR (trauma adj2 (center* OR centre*))) AND (((eye injury/ OR exp cornea injury/ OR eye burn/ OR eye contusion/ OR intraocular foreign body/ OR lens capsule rupture/ OR perforating eye injury/ OR retina injury/ OR traumatic cataract/ OR orbit injury/ OR orbit fracture/ OR zygoma arch fracture/ OR optic nerve injury/) OR ((eye* OR globe OR ocular OR orbit* OR zygoma* OR mid-fac* OR midfac* OR cornea* OR retina* OR optic nerve*) adj3 (injur* OR fractur* OR perforat* OR eniuclea* OR eviscerat* remov* OR penetrat* OR burns OR surg* OR operat*)) OR (Ophthalmology/ OR ophthalmologist/ OR (((eye OR ocular) adj3 (speciali* OR surgeon*)) OR ophthalm*)))) AND ((traffic accident/) OR ((motor OR car* OR vehicl* OR truck OR pedestrian* OR traffic OR plane* OR aeroplane* OR aviation OR bus) adj3 (accident* OR crash*)) OR (multiple fracture/ OR multiple trauma/ OR blast injury/) OR ((explos* OR ied OR bomb* OR blast* OR multiple OR major) adj3 (trauma OR fractur* OR injur* OR burns OR accident*)))

CINAHL

(("Eye Injuries+") OR (T1 (((eye* OR globe OR ocular OR orbit* OR zygoma* OR mid-fac* OR midfac* OR cornea* OR retina* OR optic nerve*) N3 (injur* OR fracture* OR perforat* OR enuclea* OR eviscerate* remov* OR penetrat* OR burns OR surg* OR operat*)) OR AB (((eye* OR globe OR ocular OR orbit* OR zygoma* OR mid-fac* OR midfac* OR cornea* OR retina* OR optic nerve*) N3 (injur* OR fracture* OR perforat* OR enuclea* OR eviscerate* remov* OR penetrat* OR burns OR surg* OR operat*)))) AND (("Multiple trauma") OR (T1 (((explos* OR ied OR bomb* OR blast* OR multiple OR major) N3 (trauma OR fracture* OR injur* OR burns OR accident*))) OR AB (((explos* OR ied OR bomb* OR blast* OR multiple OR major) N3 (trauma OR fracture* OR injur* OR burns OR accident*)))) AND ((T1 ophthalm* OR AB ophthalm*) OR (T1 ((eye OR ocular) N3 speciali*) OR AB ((eye OR ocular) N3 speciali*)) OR (T1 non-ophthalmolog* OR AB non-ophthalmolog*)) AND ("Multiple eye injuries+" AND "Multiple Trauma")

APPENDIX 2

International Classification of Disease (Tenth Revision) diagnostic and procedural codes to identify ocular trauma

Diagnostic Codes	Descriptions
H26.1	Traumatic cataract
S05.0	Injury of conjunctiva and corneal abrasion without mention of foreign body
S05.1	Contusion of eyeball and orbital tissues
S05.2	Ocular laceration and rupture with prolapse or loss of intraocular tissue
S05.3	Ocular laceration without prolapse or loss of intraocular tissue
S05.4	Penetrating wound of orbit with or without foreign body
S05.5	Penetrating wound of eyeball with foreign body
S05.6	Penetrating wound of eyeball without foreign body
S05.7	Avulsion of eye
S05.8	Other injuries of eye and orbit
S05.9	Injury of eye and orbit, unspecified
T15.0	Foreign body in cornea
T15.1	Foreign body in conjunctival sac
T15.8	Foreign body in other and multiple parts of external eye
T15.9	Foreign body on external eye, part unspecified
T26.0	Burn of eyelid and periocular area
T26.1	Burn of cornea and conjunctival sac
T26.2	Burn with resulting rupture and destruction of eyeball
T26.3	Burn of other parts of eye and adnexa
T26.4	Burn of eye and adnexa, part unspecified
Procedural Codes	**Description**
162	Repair of perforating wound of eyeball
42551-00	Repair of perforating wound of eyeball with suture of corneal laceration
42551-01	Repair of perforating wound of eyeball with suture of scleral laceration
42551-02	Repair of perforating wound of eyeball with suture of corneal and scleral lacerations
42554-00	Repair of perforating wound of eyeball involving uveal tissue
42557-00	Repair of perforating wound of eyeball involving lens or vitreous

International Statistical Classification of Diseases and Related Health Problems 10th Revision. 2016; Available from: http://apps.who.int/classifications/icd10/browse/2016/en

APPENDIX 3

Table 5: Roper Hall Classification(98)

Grade	Description
Grade 1	Epithelial corneal damage with no limbus involvement
Grade 2	Corneal haze but iris is visible, less than one third of limbus involvement
Grade 3	Epithelial loss, stromal haze and one third to half of limbus involved
Grade 4	Cornea opaque, greater than half of the limbus involved