Systematic approach to pediatric ocular trauma

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Purpose of review

The aim of this article is to evaluate and review the scientific literature on pediatric ocular trauma from the past several years. Recent advancements have recognized mechanisms of injury that may be unique to children, require different treatment course than adults, and raise multiple public health concerns.

Recent findings

Epidemiologic studies have shown that ocular trauma is a major cause of monocular blindness and potential disability in children worldwide. The mechanisms of injury are quite variable and often found under mundane circumstances. Orbital fractures in children are more likely to cause entrapment of orbital contents due to the structure of orbital bones at an early age and require earlier surgical repair. The management of traumatic hyphema responds well to outpatient care and topical aminocaproic acid. The management of traumatic cataracts has been enhanced with new iris-fixated lens implants. Endophthalmitis after ocular trauma carries a significantly worse prognosis, which may be reduced by early referral and intervention.

Summary

This review broadens our understanding of the mechanisms, treatment, and prognostic indicators in pediatric ocular trauma. This will allow improved clinical care of these injuries.

Keywords

open-globe injury, pediatric ocular trauma, traumatic endophthalmitis, traumatic hyphema

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Abbreviations

IOL intraocular lens
ISS Injury Severity Score

1040-8738

Introduction

The scope of pediatric ocular trauma is quite broad, and encompasses all practitioners involved in the care of children, including the pediatrician, the emergency physician, the general ophthalmologist, and the pediatric ophthalmologist. The evaluation of children involved in traumatic accidents needs to be systematic to avoid overlooking potentially serious vision threatening pathology. The goal of this review is to break down the areas of ocular trauma and review recent advances in our understanding and treatment of these injuries.

Epidemiology

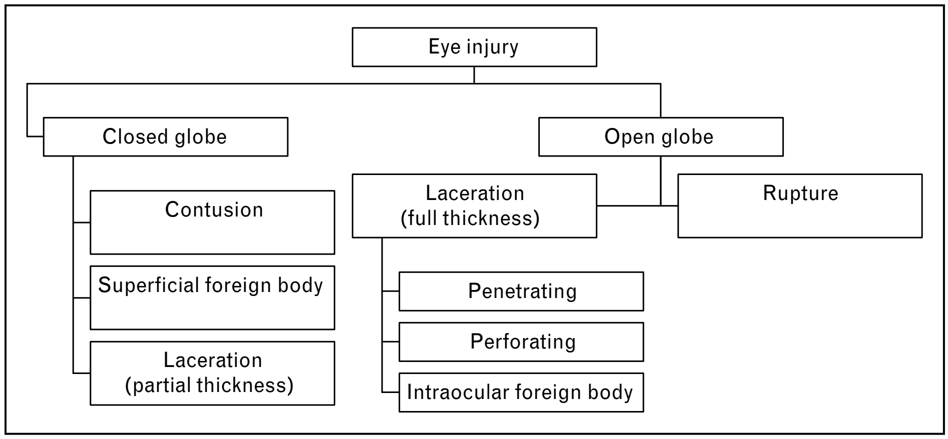
There are an estimated 2.4 000 000 eye injuries in the United States yearly. Thirty-five percent of these injuries occur in children younger than 17 years [1] and 18% in children under the age of 12 years [2•]. Among these injuries, 7% have significant visual impairment and blindness, making ocular trauma one of the most common causes of monocular blindness in children [1,3].

The American Academy of Ophthalmology (AAO) annually reports the results of survey findings on eye injuries [2•]. These findings show the common causes for injury include projectiles (20%), blunt objects (10%), body parts (i.e. fingers, fist) (12%), sharp objects (9%), and motor vehicle accidents (4%). Other reports during the review period cite causes from unusual casuses such as rooster attack [4], pencil tips [5], exploding microwaved eggs [6], door-handles [7,8], chopsticks [9], carbonated beverages [10], and dishwasher detergent [11]. As children are sometimes unpredictable, and often exhibit naïve behavior, their injuries can be caused by activity that is seemingly harmless to adults.

More serious eye injuries were encountered as a result of all-terrain vehicle (ATV) crashes, paintball injuries, and fireworks. The review by Edmondson *et al.* [12] of ATV accidents revealed eye and adnexal injuries including orbital fractures (60%), eyelid laceration (25%), and traumatic optic neuropathy (10%). The accidents resulted in severe neurologic damage from other head injuries sustained, as well as significant permanent vision loss in several patients. None of the 20 patients studied was wearing a helmet at the time of the accident. Listman [13] describes the increasing incidents of paintball injuries in children. The paintball is a dangerous projectile that easily fits within the confines of the orbit in children causing globe trauma versus orbital injury. While eye protection equipment and implementation have

Figure 1 Systematic flow-chart for evaluation and classification of eye trauma

Adapted with permission [19,20].



improved, children often do not use protection, or play in unsupervised and unregulated areas. Forty-three percent of children were found to have worse than 20/200 vision after their paintball injury. The most commonly injured bodily area from fireworks injury was the eyeball (20–35%) by both direct firework activity and among bystanders (22.5%) [14•].

Garcia *et al.* [15,16] studied ocular injuries sustained by children with other major trauma. Children who sustained major trauma were stratified by Injury Severity Score (ISS). An ISS greater than 15 designates severe trauma. In all cases of trauma, 7.7% sustained eye trauma. The most common injuries, regardless of ISS score, were orbital fractures (39%) and eye and adnexal contusions (35%). Children with ISS scores greater than 15 were more likely to have these injuries in addition to basilar skull fractures. Interestingly, a higher incidence of open-globe injury in children with ISS scores of less than 15 was found. This was related to the higher incidence of isolated eye injuries in the children with less severe systemic trauma. The recommendations were consistent with previous reports that an ophthalmologic examination is warranted in many of these children with high ISS scores, especially with associated facial trauma.

Brophy *et al.* [17••] studied pediatric eye-related hospitalization and found that there were over 7500 admissions in the United States as a result of eye injuries in 2000, costing more than US$ 88 000 000. Serrano *et al.* [18] reviewed similar data in Columbia, revealing the worldwide problem with similar epidemiologic data. Both studies confirmed previous data of at least a two-to-one incidence of male to females in ocular trauma. Most of these injuries took place at home or on the road (motor vehicle accidents). The vast majority of these injuries could have been avoided with proper parental supervision, education of both children and parents, and safety eyewear during sports activities.

Classification

To be more consistent in the clinical description and care of ocular injuries, as well as in the scientific literature, several recent studies have promoted classification systems for unambiguous and standardized terminology. Rychwalski *et al.* [19] and Pieramici *et al.* [20] designed classification systems to describe injuries, which can then be used for communication, prognosis, and, finally, publication (Fig. 1 and Table 1). Poor prognostic indicators include poor visual acuity on presentation, vitreous hemorrhage, retinal detachment, and endophthalmitis.

Evaluation of pediatric ocular trauma patients

Ocular trauma patients typically present to either the pediatrician's office or the emergency department for initial evaluation. The evaluating physician's goal should be to quickly ascertain the extent of the injury, without

Table 1 Classification system for ocular trauma

	Open globe classification
Type	A. Rupture B. Penetrating C. Intraocular foreign body D. Perforating E. Mixed
Visual acuity	A. >20/40 B. 20/50 to 20/100 C. 19/100 – 5/200 D. 4/200 to light perception E. No light perception
Pupil	A. Positive relative afferent pupillary defect B. Negative afferent pupillary defect
Zone	I. Isolated to cornea II. Corneoscleral limbus to point 5 mm posterior into the sclera II. Posterior to anterior 5 mm of sclera

Adapted from Pieramici *et al.* [20].

risking further damage to the eye, and the need for further sub-specialist consultation. A visual acuity should be attempted and documented if the child is verbal and conscious. If the globe or eyelid are suspected to be lacerated, a shield should be placed on the eye, the patient should be kept *nil per os*, pain and nausea medication administered, and then the ophthalmologist contacted for further surgical intervention. With any penetrating or lacerating injury to the eye or adnexa, tetanus immunization status should be established and revaccination given if indicated. Appropriate radiologic studies should be obtained if orbital fracture, intraocular or intraorbital foreign body, or other intracranial injury is suspected.

Eyelid and adnexal trauma

Often, the eyelids are injured in isolation or in combination with other ocular trauma. These injuries can range from minor superficial abrasions to full degloving injuries. Proper knowledge of normal anatomy is essential for surgical repair when indicated. Evaluation in a systematic fashion is necessary for proper timing of repair, and evaluating for other associated injury.

Chang and Rubin [21] present a very thorough review of eyelid laceration injury and the proper approach to repair. They note the importance of initial wound evaluation to guide further treatment. Of note, a delay in surgical repair of 12–36 h generally will not alter the outcome of closure, and may prove to be beneficial to the surgeon by allowing periorbital swelling to subside in order to allow better visualization of tissue re-approximation. The authors offer detailed instruction to surgical wound closure, recommending 5-0 or 6-0 polyglactin sutures for deep tissue, 6-0 or 7-0 nylon or silk sutures for eyelid margin approximation, followed by 6-0 silk or nylon sutures for superficial skin closure. In children, however, it may be difficult to remove sutures without additional anesthesia; self-absorbing plain gut sutures may be substituted for the margin and the superficial skin in these cases. Special consideration and a high degree of suspicion should be taken for the involvement of the canalicular system when addressing medial eyelid lacerations. Ice compresses prior to suture can help locate the cut distal end of a canaliculis. Pigtail probes and irrigation from the uninvolved canaliculis can also be helpful to identify the cut end. Stenting with either monocanalicular or bicanalicular silicone tubes should then be performed to maintain the integrity of the lacerated system. Additional eyelid laceration repair then should proceed around the silicone tube. The silicone tube generally is left in place for 3–6 months.

Hogg and Horswell [22•] present a review of soft tissue facial injuries in children. Eyelid lacerations often occur in conjunction with other facial injuries. Care must be taken to explore these wounds with craniofacial, plastics, and oromaxillofacial surgeons to properly address other deep structure injury including the facial nerve. Bites, both animal and human, should be cleaned thoroughly at the time of evaluation, and patients should be given prophylactic antibiotic coverage. Amoxicillin-clavulanate is appropriate coverage. In penicillin-allergic patients, clindamycin combined with trimethoprim-sulfamethoxazole or azithromycin are effective choices. Timely removal of nonabsorbable sutures, and proper wound dressing to reduce tension, will help reduce scarring.

Orbital trauma

Orbital bony fractures are one of the more commonly encountered findings in children who suffer head and face trauma [12,15,16,17••,18]. The types of fractures, mechanism of injury, and timing of possible treatment differ from the adult population [23–26]. Grant *et al.* [24] and Egbert *et al.* [25] demonstrate that most of the orbital floor fractures in children are of the trapdoor type. These are small fractures of the floor that ‘swing-close’ and cause entrapment of extraocular muscle and orbital connective tissue and fat. The bones of the child’s orbit are more elastic than adults’. Forces along the orbital rim are transmitted to the thinner floor, causing an anterior to posterior buckling, creating an overlapping fracture. As the floor returns to its normal position, this ‘trapdoor’ closes pulling orbital contents into the fractured area. Kwon *et al.* [23] demonstrated a higher incidence of clinical entrapment in children than in adults who required surgical intervention.

Indications for surgery remain somewhat controversial [26]. Most authors agree that marked restriction in motility, persistent nausea and vomiting, and excessive pain are indications for more urgent surgical intervention [25–27]. The presence of a fracture alone is not an indication for surgery. Clinical findings of persistent diplopia or motility restriction are less likely to resolve spontaneously in children than in adults, and should be considered for surgical repair.

Timing of surgical repair also remains controversial. Studies [22•,23–27] in the review period recommend surgical intervention within 5–7 days after the injury in children, versus 2 weeks or longer in adults. Matteini *et al.* [28] recommend a subdivision of fractures into categories based on clinical, radiographic, and prognostic criteria (Table 2). They found that surgical timing of these fractures should relate to the anatomic location, cerebrospinal fluid leak or penetrating wounds, patient age, muscle entrapment, and signs of compression or ischemia. Type I and II fractures can be treated without urgency. Type III should be treated promptly, within a few days in children and within 1 week in adults. Type IV

Table 2 Orbital fracture classification system

Orbital fracture subdivision	Description
Type I	Fracture of orbital rim
Type II	Fracture of orbital wall with no functional impairment
Type IIIa	Fracture of orbital wall with diplopia, adults
Type IIIb	Fracture of orbital wall with diplopia, children
Type IV	Fracture with open wound, penetrating object, cerebrospinal fluid leakage
Type V	Fracture of orbital apex or any fracture causing compression of globe or ischemia to the optic nerve

Adapted from Matteini *et al.* [28].

fractures should be treated within 24 h, and type V treated within a few hours after trauma.

Globe trauma: anterior segment

Globe injuries range from minor superficial conjunctival and corneal abrasions, to significant penetrating and perforating open-globes with extrusion of intraocular contents. The emergency physician and pediatrician routinely manage the minor injuries without referral to ophthalmologists. More significant injuries require the care of experienced eyecare providers initially and for their long-term follow-up.

Traumatic cataracts commonly are seen after both open and closed-globe injuries. The management of these cataracts during initial globe repair is variable, with some physicians choosing cataract extraction with intraocular lens (IOL) implantation at the time of primary surgery, while others will leave patients aphakic and return to the operating room for secondary implantation after initial rehabilitation. Chuang and Lai [29] studied 30 patients who underwent secondary IOL surgery after traumatic cataract. Seventeen (56.7%) achieved final best corrected visual acuity of 20/40 or better. This was found to be equally good, but not better, than previous studies of primary IOL implantation. They note that secondary IOL surgery gives the advantage of using the operated eye, rather than the uninjured eye, for biometry measurements. This resulted in 76.7% patients achieving postoperative refractive error within 1 diopter of goal, versus only 60% when the fellow, uninjured eye had been measured. This change in biometry was attributed to secondary intraocular changes from multiple vitreoretinal procedures prior to IOL implantation. Leiba *et al.* [30•] also note longer changes in axial lengths seen in pseudophakic children after traumatic cataracts.

The evolution of IOL implants has allowed for additional options in traumatic cataract management. The Artisan lens is an iris-fixated anterior chamber lens that can be used in phakic or aphakic patients. In traumatic cases, where capsular support may be limited or nonexistent, this implant allows for intraocular aphakic correction where previously a traditional open-loop anterior chamber lens or a sutured posterior chamber lens would have been used. Due to the concerns with endothelial cell loss from traditional anterior chamber implants, and the risk of dislocation of sutured posterior chamber lenses over time, many surgeons opt to leave these children aphakic. Kodjikian *et al.* [31•] showed long-term outcomes of at least 20/30 vision in all nine eyes of their seven patients implanted. Although their patients did have higher degrees of endothelial cell loss compared with the non-operated eye, it was unclear if this was attributed to the IOL or to the initial trauma. They conclude that this is a safe and effective procedure in the treatment of subluxated traumatic lenses. Odenthal *et al.* [32•] compared endothelial cell loss in children who underwent Artisan lens implantations for congenital cataracts and traumatic cataracts. The goal was to determine if the implant alone was responsible for increased cell loss or if this was attributed mostly to the traumatic injury. They found a strong correlation between the size of the initial corneal laceration and the degree of endothelial loss rather than from the IOL implant directly.

Traumatic hyphema management can be difficult in pediatric eye injuries. The goal of treatment is to prevent increases in intraocular pressure (IOP), prevent secondary hemorrhage, and prevent corneal blood staining. Sickle cell anemia can further complicate the clinical picture, causing ischemic intraocular injury at lower IOPs. Lai *et al.* [33] found that African Americans had a higher rate of secondary bleeding, although there was no statistically significant increase among sickle cell patients. Sickle cell patients did show an increased risk of elevated IOP, however. The management of these children as outpatients remains controversial. Inpatient management has the advantage of daily follow-up, improved compliance, and activity restrictions as necessary. Outpatient management requires cooperative parents for medication use, follow-up appointments, and observation for complications. Rocha *et al.* [34] prospectively studied 35 children managed as outpatients for their traumatic hyphema. Parents were given strict guidelines for activity restriction, topical steroid, cycloplegic agent, and glaucoma medication if indicated, and daily examinations for the first 7 days. They found that outpatient management was effective. Worse visual outcomes were associated with the extent of initial injury and the size of the hyphema.

Systemic use of aminocaproic acid (ACA) is shown to decrease the rebleeding rate in traumatic hyphema [35]. Its use has been somewhat limited due to potential systemic side effects of syncope, nausea, vomiting, and hypotension, often requiring inpatient management. Pieramici *et al.* [36] conducted a randomized, placebo-controlled clinical trial on the use of topical

ACA. There was a lower rebleeding incidence in the treated group than the placebo group. Due to inadequate enrollment numbers in the study, this failed to reach statistical significance. The authors argue that the 3.5 times increase in rebleeding in the placebo group is clinically significant nonetheless. There were no significant adverse side effects from the topical treatment. No additional risk to the eye was found, beyond that already sustained by the initial injury.

Globe trauma: posterior segment

Posterior segment injuries, including retinal detachment, vitreous hemorrhage, endophthalmitis, traumatic macular hole [37], and optic nerve avulsion [7,8], are more visually devastating than anterior segment globe injury or other ocular adnexal injury. These injuries, despite adequate and timely treatment when available, continue to leave children with permanent vision impairment after resolution.

Spirn *et al.* [38•] report their findings on children with vitreous hemorrhages. Trauma accounted for 73.1% of their 186 eyes studied, including nonpenetrating trauma (29.6%), penetrating trauma (24.7%), and shaken baby syndrome (8.6%) (a separate entity of pediatric ocular trauma outside the scope of this review) and others (10.2%). Younger children often presented with strabismus, nystagmus, abnormal pupils, or change in red reflex rather than with complaints of change in vision, or even from the initial trauma. Visual outcomes over all causes were generally poor with mean final visual acuity of 20/277. Traumatic causes carried worse prognosis. Half of the patients were observed only and the other half underwent incisional surgery (45.7%) or nonincisional laser or cyrotherapy (4.3%). The authors gave no direct correlation between treatment and clinical outcome.

The incidence of retinal detachment in the general pediatric population is very low [39]. Trauma increases that risk significantly. Sarrazin *et al.* [40] studied 138 children with retinal detachments and compared the outcomes of the 56 children, 4 months to 18 years old (average 11 years and 12.6 years for open and closed injury, respectively) who had a traumatic etiology. Of these, 37 eyes had open globe injury and 23 eyes had closed globe injury. Eighty-six percent of the total retinal detachments were of the rhegmatogenous type. The outcomes for both groups were poor with the only predictor of 20/200 or better final vision in both groups found to be preoperative macular attachment. While the presence of an intraocular foreign body was suggestive of poorer outcome, this was not statistically significant. There was no significant difference between the open and closed injury outcomes. Age, preoperative visual acuity, time of diagnosis, or number of surgical procedures were not found to be significant either. The injuries were generally devastating, with poor functional outcomes even after amblyopia therapy when indicated, despite anatomic success in 46% of the open globe patients and 65% of the closed globe patients. These findings suggest that retinal detachment after trauma is related more to globe compression and decompression rather than to the presence of a penetrating or perforating injury.

Posttraumatic endophthalmitis is known to be a poor prognostic indicator for final visual outcome [20]. Delays in primary repair (24 h or longer from time of injury), ruptured lens capsule, dirty wounds, and rural setting are associated with an increased risk of developing endophthalmitis [41]. Narang *et al.* [42] retrospectively studied 72 children with open globe injuries and found 39 cases of endophthalmitis (54%). Visual outcomes were poor overall, with only 46% of eyes with endophthalmitis and 61% of eyes without achieving functional visual acuity (defined as 3/60, vision needed to ambulate unaided). This difference was not found to be statistically significant, but the authors attribute this to the prompt treatment in the endophthalmitis cases. Delay in primary repair was found to be significant for poor visual outcomes as well as for development of endophthalmitis. They also reconfirmed previous reports of the male to female disparity in these injuries as well as significant increased incidence in rural areas. While prophylactic antibiotics have not been demonstrated to decrease the rate of endophthalmitis, recent studies [41,42] suggest benefit in cases when there are increased risk factors.

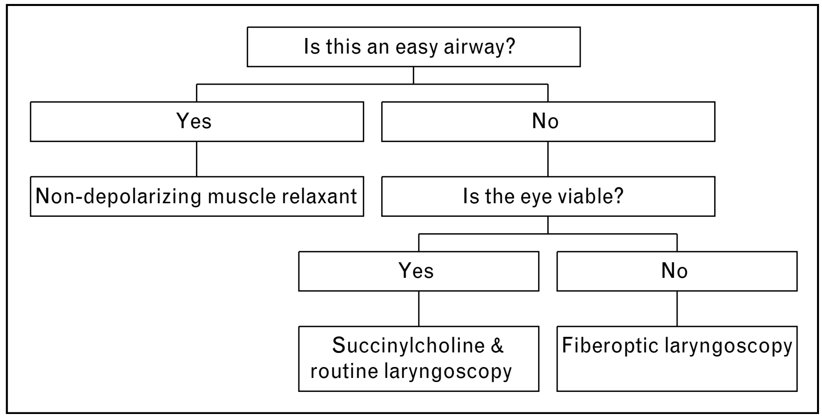
Neuro-ophthalmologic trauma

Cranial nerve palsies, including third, fourth, and sixth nerves, often are found in conjunction with ocular and head trauma in children [43]. Dhaliwal *et al.* [44••] reviewed the outcomes in 93 patients with third, fourth, or sixth nerve palsy following closed head injuries. Craniofacial fractures were found in 49% of this group and intracranial injury was present in 67%. They found third nerve palsies to be associated with more severe closed head injuries and worse clinical outcomes than fourth and sixth nerve palsies. Fourth nerve palsies were associated with worse injuries and outcomes than sixth nerve palsies. Interestingly, it was shown that multiple cranial neuropathies were associated with less severe head injury and more significant extremity injury.

Traumatic optic neuropathy (TON) at times may be the only ophthalmic injury sustained after significant head trauma, yet this can be a particularly devastating injury with poor or no recovery in vision. These injuries are believed to occur in the canalicular portion of the optic nerve, where the nerve sheath is fixed to surrounding bone, making it susceptible to forces transmitted through the skull. Goldenberg-Cohen *et al.* [45] reviewed 40 cases

Figure 2 Flow chart for anesthesia selection for ocular trauma

Adapted with permission [47•].



of TON and showed that visual outcomes were poor, with only 18% achieving better than 20/80 visual acuity despite any of the treatment modalities initiated, including high dose corticosteroids, optic nerve sheath fenestration, and optic canal decompression. Worse visual acuity on presentation was found to be a poor prognostic indicator in final visual outcome. The presence of a relative afferent pupillary defect (RAPD) was found to be the most useful diagnostic test. The authors recommend that treatment be determined on an individual patient basis, yet agree with previous literature that no treatment option appears to be helpful in most cases.

Anesthesia management in ocular trauma

Traditional teaching in anesthetic management in open globe injuries has been to avoid depolarizing muscle relaxants such as succinylcholine because of the risk of raising IOP and promoting further extrusion of intraocular contents. While this has never been supported with controlled studies in the literature, Seidel and Dorman [46•] found that most anesthesiologists polled continue to avoid succinylcholine in these cases. This same survey found that most would also prefer to delay surgery up to 6 h to allow stomach emptying to avoid potential airway problems. Delay in surgery may carry increased risk to eye recovery. Chidiac and Raiskin [47•] offer an algorithm to balance the risk to the patient's airway and the eye. This is summarized in Fig. 2. Of note in this algorithm is the recommendation to use succinylcholine in the viable eye, despite the theoretical risks associated with it, as it allows for faster induction. Fiber optic laryngoscopy takes longer to perform and carries known increased risk of elevated IOP from gagging, retching, bucking or hypercarbia.

Conclusion

Ocular trauma can be a devastating injury, causing a lifetime of disability in children. The poor outcomes of these injuries can be significantly decreased, or even avoided completely, with proper education of children and parents, eyewear protection during high-risk activities, and parental supervision. The American Academy of Ophthalmology and the American Academy of Pediatrics [48] have offered a joint statement on the use of protective eyewear in young athletes that delineates the recommended eye protection for any given activity. Use of these devices can reduce the risk of injury up to 90% when used properly.

When children do sustain an eye-related injury and present to the pediatrician, emergency room, or to the ophthalmologist directly, a systematic approach should be used to evaluate the extent of the injury, determine further diagnostic testing required, proper evaluation by other subspecialists, and then timely and effective treatment. Continued research, as found during this study period, is helping the ophthalmologist better understand and treat these injuries.

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- •• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 434).

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