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ORIGINAL RESEARCH

Demographic Characteristics, Contributing Risk Factors, and Prognosis of *Acanthamoeba* Keratitis in Eastern China: An in vivo Confocal Microscopy-Based Fifteen-Year Study

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Purpose: To investigate the demographic characteristics, contributing risk factors, and prognostic outcomes of *Acanthamoeba* keratitis (AK) in Eastern China in the recent 15 years using in vivo confocal microscopy (IVCM).

Patients and Methods: This single-center, retrospective study included 145 patients (147 eyes) diagnosed with AK based on IVCM findings at the Eye & ENT Hospital of Fudan University from April 2009 to September 2024. Demographic information, clinical features at presentation, contributing risk factors (if identified), treatment strategies, and final visual outcomes were retrieved in the medical records and analyzed using descriptive statistics.

Results: The median age of patients was 51 years old, with 98.6% of infections being unilateral. Corneal trauma (62.1%) was the leading risk factor overall, whereas contact lens wear was the independent risk factor among children and adolescents. The most common clinical features at presentation were stromal infiltrate (60.6%) and deep stromal ulcers (36.5%). Anti-AK therapy was mainly composed of polyhexamethylene biguanide (PHMB), chlorhexidine, propamidine isethionate (Brolene) and metronidazole. Surgical interventions were required in 24 eyes, with evisceration/enucleation identified as an independent predictor of poor visual prognosis.

Conclusion: This study provides valuable epidemiological insights into AK in Eastern China, underscoring the need for improved prevention, early diagnosis, and evidence-based treatment protocols to guide clinical management.

Keywords: *Acanthamoeba* keratitis, in vivo confocal microscopy, demographic characteristics, contributing risk factors, prognosis

Introduction

Acanthamoeba keratitis (AK) is a severe, vision-threatening corneal infection caused by the protozoan *Acanthamoeba*,[1] which is widely distributed in natural environments such as water, soil, dust and the water-air interface, making human exposure nearly unavoidable.[2,3] Despite its relatively low incidence of approximately 2.9 per million annually,[4] AK typically has an insidious onset and is often misdiagnosed as other forms of infectious keratitis, particularly herpes simplex keratitis (HSK). Delayed diagnosis and treatment can result in permanent visual impairment.[5,6]

Early diagnosis of AK remains clinically challenging. Corneal scraping and *Acanthamoeba* culture, though widely used and considered as the diagnostic gold standard, are invasive and time-consuming. Moreover, its sensitivity has a considerably large variation (7–66.7%).[7–9] Molecular diagnostic techniques, such as polymerase chain reaction (PCR)

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and metagenomic next-generation sequencing (mNGS), are limited in clinical practice due to high costs and reliance on specialized laboratory facilities. In contrast, in vivo confocal microscopy (IVCM), a non-invasive, real-time three-dimensional imaging tool of the ocular surface, is recommended to be preferable in the diagnosis of AK, offering high sensitivity (77–100%) and specificity (84–100%).[7,10,11]

Previous studies indicate that contact lens use and corneal trauma are the primary risk factors for AK in developed and developing countries, respectively.[12–14] Despite reports suggesting an increasing incidence of AK worldwide,[4,14–16] comprehensive data on its epidemiological profiles and clinical outcomes in China remain limited. Therefore, we conducted this retrospective study to systematically analyze the demographic characteristics, contributing risk factors and visual prognosis of AK patients diagnosed using IVCM over the past 15 years. This study aims to provide new evidence to update clinical practice, prevention strategies and patient education during AK management.

Materials and Methods

Study Population

This single-center retrospective study was conducted at the Eye & ENT Hospital of Fudan University, which is the biggest eye center in Eastern China and accepts referral patients from the entire region. Patients diagnosed with AK between April 2009 and September 2024 were included. The diagnosis was made based on the identification of characteristic double-walled *Acanthamoeba* cysts measuring 10–15 μm in diameter under IVCM (HRT3-RCM, Heidelberg Engineering, Heidelberg, Germany),[4] and was simultaneously confirmed by two independent experienced ophthalmologists.

The study was approved by the Ethics Committee of Eye & ENT Hospital of Fudan University [protocol code EENTIRB-20190301] and adhered to the principles of the Declaration of Helsinki. The need for written informed consent was waived because the study involved a retrospective review of anonymized medical records, and no identifiable personal data were used. All patient data were handled in strict accordance with institutional ethical guidelines to ensure confidentiality and privacy.

Data Collection and Processing

Medical records of eligible patients were reviewed and the following data were collected: demographic characteristics, contributing risk factors, clinical features at presentation, therapeutic strategies, and visual outcomes. According to the clinical manifestations, the severity of AK is classified into three stages.[10] The early stage is presented as subepithelial infiltrates or superficial punctate keratopathy, sometimes accompanied by pseudodendritic epithelial defects, radial perineuritis, or small (<4 mm) superficial stromal ulcers. The progressive stage shows typical or incomplete ring infiltrates and grayish-white stromal haze, with possible deep stromal involvement. The late stage involves deep stromal ulcers, corneal thinning or perforation, or limbal/scleral extension with hypopyon. To facilitate subgroup comparisons, patients were stratified into three age groups: children and adolescents (≤18 years old), adults (>18 and ≤60 years old), and older people (>60 years). The study period was divided into three intervals: 2009–2014, 2015–2019, and 2020–2024. Visual prognosis was assessed based on two parameters: the final best-corrected visual acuity (BCVA) at the last follow-up and the change of BCVA (ΔBCVA) that was calculated using final BCVA minus initial BCVA at the first visit. Snellen BCVA were converted to the logarithm of the minimum angle of resolution (LogMAR) format as previously reported:[17] counting fingers = 2.0, hand motion = 2.3, light perception = 2.8, and no light perception = 3.0.

Statistical Analysis

All statistical analyses were performed using Stata 17.0 (StataCorp, College Station, TX, USA). Continuous variables were presented as mean ± standard deviation (SD) if normally distributed, or as medians with interquartile ranges (IQR) if non-normally distributed. Categorical variables were analyzed using Fisher's exact test or the Chi-squared test, as appropriate. Univariate and multivariate linear regression analyses were performed to identify potential predictors associated with visual prognosis. A two-tailed P-value < 0.05 was considered statistically significant.

Results

Patient Demographics

A total of 145 patients (147 eyes) were included in the study, with a median age of 51 years old (9–90 years old). The number of male patients (91, 62.8%) was almost twice as many as females (54, 37.2%) (Table 1). The majority of cases were unilateral (143 eyes, 98.6%), among which the number of the left eye and the right eye involved was 57 (39.9%) and 86 (60.1%), respectively.

Table 1 Baseline Demographics, Initial Clinical Features, and Therapeutic Regimen in Patients with AK

Parameter	Value
Age (years)	51 (9–90)
Sex	
Male	91 (62.8%)
Female	54 (37.2%)
Initial BCVA (LogMAR)	2.0 (0.2–3.0)
Initial clinical signs	
Subepithelial infiltrate	12 (11.5%)
Superficial punctate keratopathy	8 (7.7%)
Pseudodendritic epithelial defects	2 (1.9%)
Radial perineuritis	5 (4.8%)
Corneal epithelial defects	21 (20.2%)
Ring infiltrate	21 (20.2%)
Stromal infiltrate	63 (60.6%)
Deep stromal ulcers	38 (36.5%)
Hypopyon	24 (23.1%)
Clinical staging at the initial visit	
Early stage	17 (16.3%)
Progressive stage	59 (56.7%)
Late stage	28 (26.9%)
Co-infections	
Virus (HSV and/or VZV)	9 (8.7%)
Bacteria (including *S. aureus, A. lwoffii, P. aeruginosa*)	6 (5.8%)
Virus + Bacteria	1 (1.0%)
Fungus + Bacteria	1 (1.0%)
AK-related complications	
Secondary glaucoma/hypertension (IOP-lowering medications needed)	16 (15.4%)
Corneal staphyloma	3 (2.9%)
Proptosis	1 (1.0%)
Corneal perforation	6 (5.8%)
Therapeutic regimen	
Pre-diagnosis medications	
Antibiotics	44 (42.3%)
Antivirals	36 (34.6%)
Immunosuppressants	28 (26.9%)
Topical corticosteroids	20 (19.2%)
Antifungals	11 (10.6%)
Anti-AK therapy	
Chlorhexidine (0.02–0.04%)	22 (21.2%)
Propamidine isethionate (Brolene, 0.1%)	3 (2.9%)
PHMB (0.02–0.04%) + Chlorhexidine	3 (2.9%)
Metronidazole	89 (85.6%)

(*Continued*)

Table 1 (Continued).

Parameter	Value
Adjuvant Therapy	
Antibiotics	
Fluoroquinolones	85 (81.7%)
Aminoglycosides	21 (20.2%)
Norvancomycin hydrochloride	2 (1.9%)
Immunosuppressants	77 (74.0%)
Antifungals	50 (48.1%)
Surgical Interventions	
Corneal debridement	3 (2.9%)
Conjunctival flap covering	4 (3.8%)
AMT	3 (2.9%)
PKP	11 (10.6%)
Evisceration/enucleation	8 (7.7%)

Notes: Data are presented as n (%) unless otherwise specified; age and initial BCVA are given as median (range). Age and sex were recorded for the overall cohort (145 patients, 147 eyes); initial BCVA was available for 55 patients (56 eyes); other initial clinical features and therapeutic regimen were recorded for 102 patients (104 eyes).

Abbreviations: AK, *Acanthamoeba* keratitis; BCVA, best-corrected visual acuity; LogMAR, logarithm of the minimum angle of resolution; HSV, Herpes simplex virus; VZV, varicella-zoster virus; S. aureus, Staphylococcus aureus; A. lwoffii, Acinetobacter lwoffii; P. aeruginosa, Pseudomonas aeruginosa; PHMB, polyhexamethylene biguanide; IOP, intraocular pressure; AMT, amniotic membrane transplantation; PKP, penetrating keratoplasty.

The number of AK cases ranged from 4–14 per year (median 8), which remained stable during the study period ($P = 0.400$). However, a significant difference regarding age distribution was identified ($P = 0.041$). The proportion of children and adolescents increased almost 9.5 folds from 1.9% (2015–2019, 1/53) to 18% (2020–2024, 9/50) ($P = 0.006$, Figure 1). No significant temporal changes were detected in the other two age cohorts.

Contributing Risk Factors

Identifiable contributing risk factors were documented in 58 eyes (40.0%), with corneal trauma (both water and non-water related) accounting for 62.1% (36 eyes) of these cases (Figure 2). Age-stratified analysis revealed significant

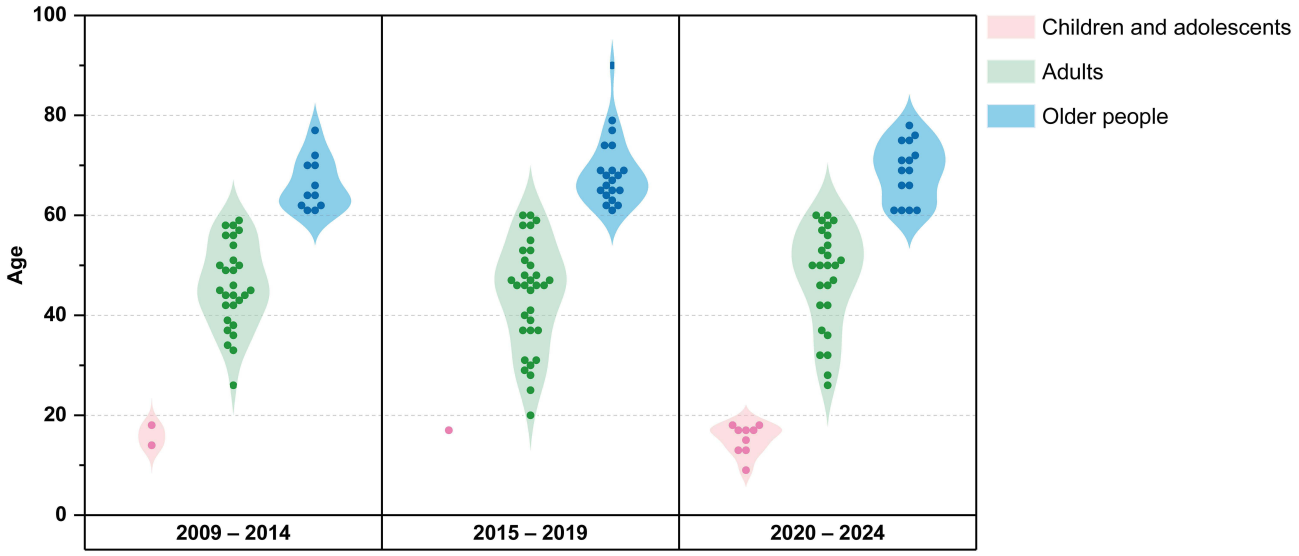

Figure 1 Age and temporal distribution of *Acanthamoeba* keratitis cases.

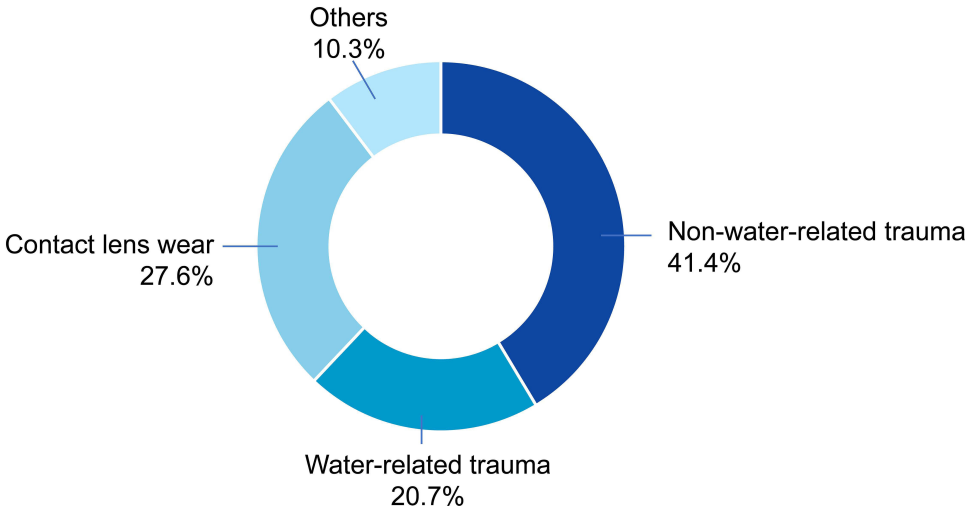

Figure 2 Distribution of contributing risk factors among *Acanthamoeba* keratitis patients.

differences in the distribution of contributing risk factors across age groups ($P < 0.0001$). Notably, contact lens wear was the exclusive risk factor identified in children and adolescents, and the number of contact lens-associated cases in this group increased remarkably during the recent five years (Figure 3). In contrast, no significant temporal changes were observed in the other two age subgroups ($P = 0.976$ and 0.880, respectively).

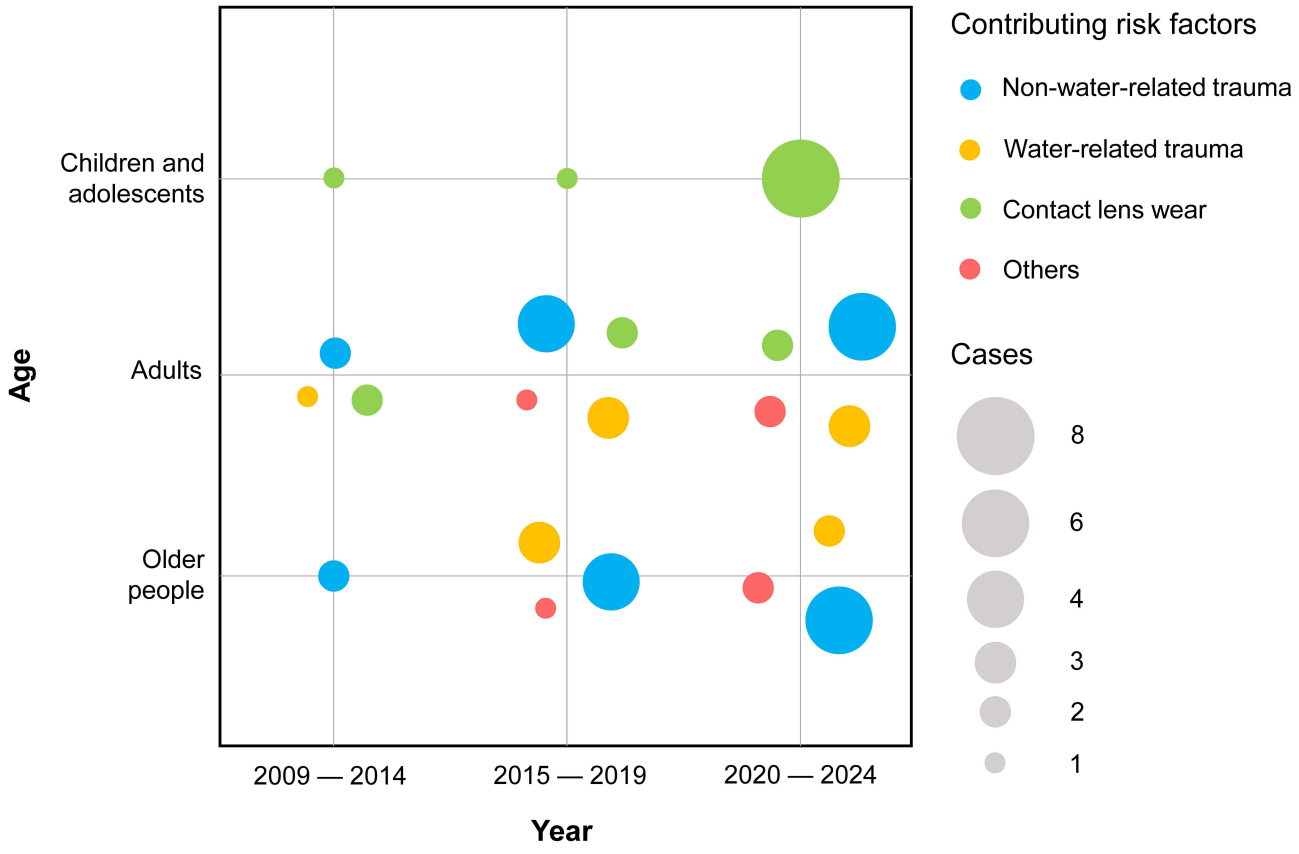

Figure 3 Age-stratified analysis of contributing risk factors.

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Initial Clinical Features and Therapeutic Regimen

The median time from symptom onset to the initial clinical visit was 30 days (IQR, 14–47.5 days), with no significant seasonal variation observed ($P = 0.213$). The most frequently reported symptoms were ocular redness (68.5%) and pain (64.8%), followed by decreased visual acuity (48.1%), tearing (13.0%), photophobia (13.0%), mild ocular discomfort (7.4%), and foreign body sensation (5.6%).

The median interval from symptom onset to AK diagnosis was 34 days (IQR, 20–60 days). Most patients (56.7%) did not ask for medical care until the disease was at a progressive stage. The most common clinical signs observed under slit-lamp biomicroscopy were stromal infiltrate (60.6%) and deep stromal ulcers (36.5%), with ring infiltrate found in 21 eyes (20.2%). Co-infections with virus and/or bacteria pathogens, which were diagnosed based on corneal smear, culture or PCR, were identified in 17 eyes (Table 1).

Among 104 eyes with completely-documented medical history, antibiotics were the most frequently prescribed agents before the diagnosis of AK was confirmed by IVCM findings (42.3%), followed by antivirals (34.6%), immunosuppressants (26.9%), topical corticosteroids (19.2%), and antifungals (10.6%). The first-line anti-AK therapy was adopted in 28 eyes (26.9%) after diagnosis, which consisted of either the monotherapy of chlorhexidine or propamidine isethionate (Brolene), or the combined therapy of chlorhexidine with polyhexamethylene biguanide (PHMB). Nevertheless, due to the shortage of commercially available chlorhexidine, PHMB and Brolene eye drops in mainland China, metronidazole was used in most cases (89 eyes, 85.6%). Immunosuppressants were prescribed in 77 eyes (74.0%). Surgical intervention was performed in 24 eyes, with penetrating keratoplasty (PKP) in 11 eyes and evisceration/enucleation in 8 eyes (Table 1). The median duration of anti-AK therapy was 122 days (IQR, 68.5–209 days), and the median follow-up period was 186 days (IQR, 93–283 days).

Visual Prognosis

Visual outcomes were available for 55 patients (56 eyes), with final BCVA ranging from 0.2 to 3.0 (median 2.0) and ΔBCVA ranging from –2.2 to 2.6 (median 0). At the initial visit, only 1 eye presented LogMAR BCVA better than 0.3 and 44 eyes had BCVA worse than 1.0; at the final visit, 4 eyes reached BCVA≥0.3 and 40 eyes remained <1.0. For one patient with bilateral infections, only the right eye was analyzed because the visual acuity and contributing risk factors were almost identical in both eyes.

In order to explore the potential predictor of final BCVA, univariate linear regression was performed with 29 exploratory variables included. It turned out that age, contributing risk factors, surgery, clinical staging at the initial visit, and anti-glaucoma medications during AK treatment were statistically significant ($P = 0.0018$, 0.0370, 0.0148, 0.0012 and 0.0291, respectively). Initial BCVA and prior topical corticosteroid use were not potentially associated with final BCVA. The variables with $P < 0.05$ were included in the multivariate analysis, which revealed that "contributing risk factors other than trauma and contact lens use", "evisceration/enucleation", and "late stage at the initial visit" were independently associated with worse final BCVA ($R^2 = 0.5499$, $P = 0.0002$) (Table 2).

Table 2 Univariate and Multivariate Linear Regression for Final BCVA in 55 Patients with AK

Variables	Univariate Linear Regression			Multivariate Linear Regression		
	β (95% CI)	SE	*P*	β (95% CI)	SE	*P*
Age	0.022 (0.009–0.035)	0.007	0.002	0.013 (−0.005–0.031)	0.009	0.146
Contributing risk factors						
No specific	Reference			Reference		
Non-water-related trauma	0.274 (−0.295–0.842)	0.283	0.338	−0.002 (−0.565–0.560)	0.279	0.993
Water-related trauma	0.522 (−0.187–1.232)	0.353	0.145	0.118 (−0.495–0.731)	0.304	0.700
Contact lens wear	−0.733 (−1.554–0.088)	0.409	0.079	0.210 (−0.833–1.253)	0.517	0.687
Others	1.100 (−0.203–2.403)	0.649	0.096	1.743 (0.589–2.898)	0.572	**0.004***

(*Continued*)

Table 2 (Continued).

Variables	Univariate Linear Regression			Multivariate Linear Regression		
	β (95% CI)	SE	*P*	β (95% CI)	SE	*P*
Surgery						
No	Reference			Reference		
Conjunctival flap covering	0.658 (−1.082–2.398)	0.866	0.451	0.646 (−0.884–2.176)	0.758	0.399
AMT	0.458 (−0.573–1.490)	0.513	0.376	−0.223 (−1.225–0.779)	0.496	0.655
PKP	0.081 (−0.559–0.720)	0.318	0.801	−0.410 (−1.066–0.246)	0.325	0.214
Evisceration/enucleation	1.358 (0.602–2.115)	0.377	0.001	0.854 (0.160–1.548)	0.344	**0.017***
Clinical staging at the initial visit						
Early stage	Reference			Reference		
Progressive stage	0.507 (−0.186–1.201)	0.346	0.148	0.593 (−0.127–1.313)	0.357	0.104
Late stage	1.335 (0.572–2.098)	0.380	0.001	1.195 (0.405–1.986)	0.392	**0.004***
Anti-glaucoma drugs during AK treatment						
No	Reference			Reference		
Yes	0.677 (0.072–1.283)	0.302	0.029	0.495 (−0.108–1.099)	0.299	0.105

Notes: β represents regression coefficient; *$P < 0.05$ was considered statistically significant in multivariate analysis. "Reference" indicates the reference group for categorical variables; Multivariate model for final BCVA: $R^2 = 0.5499$, $P = 0.0002$.

Abbreviations: AK, *Acanthamoeba* keratitis; BCVA, best-corrected visual acuity; CI, confidence interval; SE, standard error; AMT, amniotic membrane transplantation; PKP, penetrating keratoplasty.

Table 3 Univariate and Multivariate Linear Regression for ΔBCVA in 55 Patients with AK

Variables	Univariate Linear Regression			Multivariate Linear Regression		
	β (95% CI)	SE	*P*	β (95% CI)	SE	*P*
Contributing risk factors						
No specific	Reference			Reference		
Non-water-related trauma	0.416 (−0.255–1.086)	0.334	0.219	0.454 (−0.208–1.117)	0.329	0.174
Water-related trauma	0.607 (−0.229–1.443)	0.416	0.151	0.159 (−0.644–0.962)	0.399	0.693
Contact lens wear	−0.376 (−1.344–0.591)	0.482	0.438	−0.273 (−1.160–0.614)	0.440	0.539
Others	1.974 (0.438–3.510)	0.765	0.013	2.334 (0.899–3.770)	0.713	**0.002***
Surgery						
No	Reference			Reference		
Conjunctival flap covering	0.614 (−1.443–2.671)	1.024	0.552	0.323 (−1.618–2.264)	0.964	0.739
AMT	0.381 (−0.839–1.600)	0.607	0.534	0.241 (−0.957–1.438)	0.594	0.688
PKP	0.069 (−0.687–0.826)	0.376	0.854	−0.514 (−1.306–0.278)	0.393	0.198
Evisceration/enucleation	1.564 (0.669–2.459)	0.445	0.001	1.246 (0.311–2.181)	0.464	**0.010***
Complications						
No	Reference			Reference		
Yes	1.056 (0.064–2.048)	0.495	0.037	0.751 (−0.247–1.750)	0.496	0.137

Notes: ΔBCVA represents final BCVA minus initial BCVA; Multivariate model for ΔBCVA: $R^2 = 0.3953$, $P = 0.0039$.

For ΔBCVA, univariate analysis (28 variables, excluding initial BCVA) identified contributing risk factors, surgery, and complications as potential contributors ($P = 0.0453$, 0.0208, and 0.0375, respectively). Multivariate analysis showed that "contributing risk factors other than trauma and contact lens use" and "evisceration/enucleation" were independent predictors of worse ΔBCVA ($R^2 = 0.3953$, $P = 0.0039$) (Table 3).

Discussion

It is somewhat surprising that corneal trauma remains the leading contributing risk factor for AK in this Chinese cohort given rapid urbanization and increasing prevalence of contact lens use in Eastern China. The most possible reason is that

our hospital, the biggest tertiary eye center in Eastern China, receives numerous referral patients from the provinces nearby, especially those from primary and secondary rural/county healthcare units. Moreover, a considerable large number of rural labors take part-time jobs in urban areas when the agricultural activities are not busy such as in winter. The present study showed that in the cases with identified causes of trauma, the proportions related to agricultural (13.8%) and industrial (10.3%) activities were similar, indicating that occupational exposure might pose higher risks than the habitation/residence.

Although the overall number of AK cases remained relatively stable over the past 15 years, a significant increase has been found among children and adolescents in the past five years. In this subgroup, contact lens wear was the only identified contributing risk factor. Despite the rising incidence of AK globally over recent decades,[4,14–16] few studies have stratified data for children or adolescents and conducted specific analyses. The growing incidence of pediatric AK observed in our study aligns with high prevalence of juvenile myopia in China,[18] which had been deteriorating since the COVID-19 pandemic because of prolonged digital device usage for online education and reduced outdoor activities,[19] and consequently increasing adoption of contact lenses, especially orthokeratology lenses, for myopia management in this population.[20–22] Although orthokeratology lenses are considered effective and safe, inappropriate usage and care may increase the risk of corneal infections especially AK.[14,23–25] Our findings highlights the importance of targeted education on lens hygiene and care for pediatric contact lens users and their parents.

Despite being the predominant contributing risk factors, trauma and contact lens wear did not independently predict worse visual outcomes. The possible reason was that patients with such histories easily evoked alertness from our clinicians and had a suspected diagnosis of AK, thereby undergoing diagnostic examinations on pathogens such as IVCM early and repeating examinations even the initial results were negative. They were more likely to have early diagnosis and prompt treatment, thus improving the visual outcome. In contrast, AK cases without these risk factors often had atypical features or confounding comorbidities (such as a history of HSK) that might potentially cause a misled or delayed diagnosis. Rapid disease progression in these cases and untimely anti-AK therapy led to an increased risk of irreversible corneal damage and worse visual outcome. Nevertheless, this finding should be interpreted with caution and require validation in larger, multi-center cohorts.

In this study, IVCM was adopted as a predefined diagnostic criterion because the positivity rate of corneal scraping was only 7.4% and all *Acanthamoeba* cultures were negative, as retrieved in the medical records. Since *Acanthamoeba* often invades the deep stroma, corneal scrapings often yield false negative results especially in late-stage AK after topical antimicrobial therapy or in mixed infections.[1,26] Although culture remains the diagnostic gold standard with 100% specificity, its sensitivity is fairly variable (7–66.7%) and highly dependent on sampling quality and culture methods.[7,8] In contrast, IVCM was reported to have high sensitivity (77–100%) and good specificity (84–100%) with non-invasiveness and good repeatability. It offered many advantages for the late-referral cohort in this study, in which prior antimicrobial therapy might compromise the sensitivity of corneal scraping and culture. However, IVCM still has the limitation especially missing some cases due to morphological variability of *Acanthamoeba* trophozoites. Moreover, the interpretation of IVCM images was highly dependent on the experience of examiners. In this context, emerging molecular technologies such as mNGS serve as valuable complementary tools, particularly for patients with repeatedly negative IVCM results or atypical clinical presentations, potentially improving diagnostic accuracy in challenging cases.

Multivariate linear regression analyses of final BCVA and ΔBCVA revealed that evisceration/enucleation was an independent predictor of worse visual outcomes in AK patients. These eyes, with a median 33 days from symptom onset to correct diagnosis in this cohort, typically exhibited rapid progression, extensive corneal and intraocular involvement, and poor response to medical therapy. It was reported that early diagnosis (≤14 days from symptom onset) and therapeutic epithelial debridement were independently associated with better visual prognosis.[6] The current study was in agreement with previous investigation, underscoring the importance of timely diagnosis and intervention in preventing irreversible visual damage.

Prompt first-line anti-AK therapy, including biguanides (such as chlorhexidine and PHMB) and diamidines (such as Brolene), is critical for improving prognosis.[10] However, their limited availability in mainland China poses a major treatment challenge. The use of corticosteroids in AK remains controversial. Early use before diagnosis may worsen outcomes,[1,24,27,28] whereas cautious application may be beneficial in cases with severe inflammation or scleritis.[24,29] In our cohort, pre-referral diagnostic details were frequently incomplete, and many patients were documented as "keratitis" or "infectious keratitis

(pathogen unclear)" before IVCM examination. Empirical antiviral and/or antibiotic therapy was common, and 19.2% had received topical corticosteroids prior to definitive diagnosis. Corticosteroids were often prescribed in clinically ambiguous cases misdiagnosed as HSK, suspected autoimmune keratitis, or severe bacterial keratitis with stromal inflammation. Although linear regression analyses did not confirm the potential influence of corticosteroid usage (before and after diagnosis) on visual prognosis possibly due to the limitations of the retrospective design, they remained potential contributors to poor outcome. Its safety and efficacy in AK cases requires further investigation.

This study has several limitations. First, some variables were missing due to incomplete documentation before the full implementation of electronic medical record (EMR) in 2014 and challenges in obtaining accurate patient-reported information, particularly among older people and low-literacy patients. Second, referral bias cannot be completely excluded because all cases were drawn from a single tertiary-care hospital. Future multi-center studies involving all tertiary eye centers in Eastern China are necessary to provide a complete and comprehensive epidemiological assessment of AK in this region.

Conclusion

This 15-year retrospective study provides important epidemiological profile and clinical insights into AK in Eastern China, which highlights the critical need for increased awareness in AK management and emphasizes the necessity for age- and region-specific preventive strategies, early diagnosis, standardized treatment protocols, and targeted patient education particularly in high-risk patients such as pediatric contact lens users. These findings merit clinical practice and support the development of future management guidelines to improve visual outcome and prognosis.

Data Sharing Statement

The datasets generated during and/or analyzed during the current study are not publicly available to protect patient privacy but are available from Professor Qihua Le (corresponding author) upon reasonable request.

Ethics Approval and Informed Consent

The study was approved by the Ethics Committee of Eye & ENT Hospital of Fudan University [protocol code EENTIRB-20190301] and adhered to the principles of the Declaration of Helsinki. The need for written informed consent was waived because the study involved a retrospective review of anonymized medical records, and no identifiable personal data were used. All patient data were handled in strict accordance with institutional ethical guidelines to ensure confidentiality and privacy.

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Author Contributions

All authors made substantial contributions to the conception, design, execution, data acquisition, analysis and interpretation of this work; participated in drafting, revising or critically reviewing the manuscript; and gave final approval of the submitted version. All authors agree to be accountable for all aspects of the work. Specifically, Chuwei Lu was responsible for study execution, data collection and analysis, and original draft writing. Jiajia Wang took part in study execution, data collection and analysis. Jiaxu Hong, Jianjiang Xu, and Xujiao Zhou provided critical revisions of the manuscript. Lijia Tian contributed to study design, manuscript revision, and project administration. Qihua Le was responsible for study design, manuscript revision, project administration, and funding acquisition.

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Disclosure

The authors report no conflicts of interest in this work.

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