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Clinical phenotypes and clustering patterns of human toxocariasis in PubMed-indexed case reports: an Antigravity-assisted systematic scoping review

Eun Hee Ha*

College of Medicine, Hallym University, Chuncheon, Korea

Purpose: This study aimed to characterize co-occurrence patterns, statistical associations, and phenotypic clusters of clinical manifestations reported in human toxocariasis case reports indexed in PubMed from 2005 through 2025, inclusive.

Methods: PubMed-indexed case reports from 2005 through 2025 were identified using the query ("Toxocariasis" OR "Toxocara") AND "Case Reports" [Publication Type] AND 2005:2025[dp] AND ffrft[Filter]. Free full-text articles were retrieved through PubMed Central and other links indexed in PubMed using the ffrft filter. After 7 nonhuman reports and 5 reports without objective diagnostic confirmation were excluded, 139 case reports were included. Antigravity was used to support data extraction, standardization, statistical analysis, and figure generation. Clinical features were mapped to standardized symptom and organ-involvement variables. Pairwise co-occurrence was assessed using 2×2 contingency tables and Fisher's exact test; association strength was measured using Pearson correlation coefficients; and k-means clustering was used to identify distinct clinical phenotypes.

Results: Four principal clusters were identified: subclinical disease, ocular larva migrans, visceral larva migrans, and neurotoxocariasis/multisystemic disease. The ocular larva migrans and visceral larva migrans clusters were largely distinct, whereas ocular features were frequently co-reported in the neurotoxocariasis/multisystemic cluster. Eosinophilia was strongly associated with systemic manifestations, including fever, dyspnea, cough, pruritus, hepatomegaly, headache, and meningitis, but was not significantly associated with ocular features. Neurotoxocariasis-related features, including headache, meningitis, and seizures, clustered closely.

Conclusion: This artificial intelligence-assisted scoping review identified exploratory clinical association and clustering patterns in human toxocariasis case reports. These findings may support clinical awareness, but they require validation in curated clinical datasets before they are used for diagnosis, risk stratification, or practice guidance.

Keywords: Toxocariasis; Parasitology; PubMed; Cluster analysis; Artificial intelligence

Introduction

Background/rationale

Toxocariasis is a prevalent zoonotic parasitosis caused by *Toxocara canis* or *Toxocara cati* infection and can present with diverse clinical manifestations, which may contribute to missed or delayed diagnosis [1]. Although toxocariasis is often asymptomatic, it is traditionally classified into 2 well-defined clinical syndromes: visceral larva migrans, which involves systemic larval migration through major organs, and ocular larva migrans, which specifically affects the eye and optic nerve [2]. In addition to these classical syndromes, individual case reports have described atypical manifestations of toxocariasis, including pleural effusion [3]. Although some studies have examined associations between specific toxocariasis manifestations and related clinical features, large-scale systematic analyses evaluating the broader clinical patterns among classical and atypical manifestations reported in toxocariasis case reports remain limited.

*Corresponding email: 20237117@hallym.ac.kr
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Objectives

This study aimed to elucidate correlations and clustering patterns among diverse clinical manifestations reported in toxocariasis case reports indexed in PubMed from 2005 through 2025, inclusive. Specifically, it addressed the following question: What symptoms and organ-involvement patterns are reported in toxocariasis case reports, and how do they cluster?

Methods

Ethics statement

This was a literature-based study; therefore, institutional review board approval and informed consent were not required.

Study design

This systematic scoping review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews guidelines, which are available at https://www.prisma-statement.org/scoping.

Protocol/registration

No review protocol was registered for this scoping review.

Eligibility criteria, information sources, and search strategy

Human toxocariasis case reports indexed in PubMed between January 1, 2005, and December 31, 2025, were identified (n=151) using the query ("Toxocariasis"[Title/Abstract] OR "Toxocara"[Title/Abstract]) AND "Case Reports" [Publication Type] AND 2005:2025[dp] AND ffrft[Filter]. Free full-text articles were retrieved through PubMed Central or other free full-text links provided in PubMed using the ffrft filter. Seven nonhuman case reports involving cats, dogs, a foal, an opossum, or other animals were excluded using Antigravity-supported screening. Subsequently, 5 reports were excluded because objective diagnostic confirmation, such as positive serology, larval identification, histopathologic confirmation, or other explicit diagnostic evidence, could not be verified. The final 139 human case reports were used for data analysis and generation of the results (Dataset 1). All inclusion and exclusion decisions were supported by algorithmic extraction logic and cross-verified by the author.

The final 139 human case reports were analyzed after the following variables had been extracted into a structured CSV format: PubMed identifier, patient age, sex, chief complaint, associated symptoms, eosinophil count, and final diagnosis. Standardization followed a predefined pipeline: free-text symptom descriptors were first normalized into canonical labels and then mapped to Medical Subject Headings (MeSH) terms when applicable, whereas organ involvement was coded separately using explicit evidence statements, such as imaging findings or specialist examination findings, rather than symptom keywords alone.

Selection of sources of evidence

Retrieved records were screened sequentially for human case-report status, relevance to toxocariasis, and objective diagnostic confirmation. For diagnostic confirmation, the mere mention of a diagnostic modality, such as "ELISA performed," was not considered sufficient unless confirmatory results or definitive diagnostic statements were explicitly reported. Nonhuman reports were excluded, as were reports describing suspected or insufficiently documented toxocariasis without clear diagnostic evidence, such as serology, larval identification, histopathology, biopsy findings, or other explicit confirmation. Antigravity supported the initial screening by applying predefined inclusion and exclusion logic, and the author manually verified the artificial intelligence-generated decisions by reviewing titles, abstracts, and full texts. Ambiguous records were assessed conservatively and excluded when the diagnosis or human case-report status could not be confirmed. The final set included 139 confirmed human toxocariasis case reports. Exclusion reasons are summarized in Fig. 1

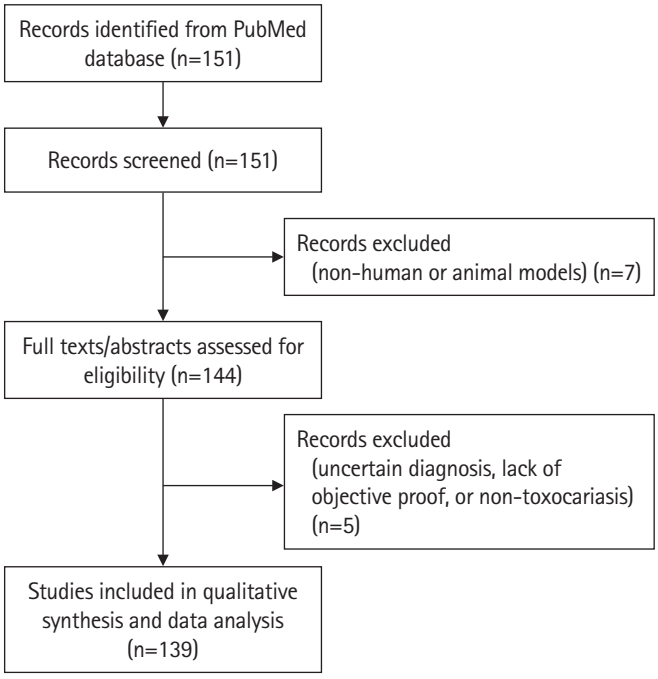

Fig. 1. Flow diagram of the case-report selection process for data analysis, reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews guideline.

and Supplement 1.

Data charting process

A structured CSV-based charting form was developed to extract bibliographic information, patient characteristics, clinical manifestations, eosinophil count or eosinophilia status, organ involvement, diagnostic evidence, final diagnosis, inclusion status, and extraction source. Antigravity generated preliminary extraction outputs from titles and abstracts and then refined these outputs using the retrieved free full-text articles.

Pilot charting was conducted to refine variable definitions, identify false-negative extractions, and standardize heterogeneous clinical terminology. Free-text symptom descriptions were mapped to standardized symptom labels and organ-involvement domains. Missing values were coded as "not reported," "not available," or "unable to extract." The author manually verified the artificial intelligence-generated charting outputs against the original sources and corrected misclassified or incomplete variables. The finalized charted dataset of 139 confirmed human case reports was then used for association analysis, correlation analysis, and k-means clustering.

Data items

Operational definitions were designed to minimize circularity between symptom variables and organ-involvement variables. Organ-involvement variables were coded only when reports explicitly indicated organ involvement, such as through imaging findings, specialist examinations, or diagnostic statements, and were not assigned solely on the basis of symptom terms that were coded separately as symptoms, including cough, dyspnea, headache, seizures, and meningitis.

- Age: expressions such as "years old" and "months old."
- Organ_Eye: Keywords "eye," "ocular," "retina," "vision," "uveitis," "macula," "blindness," "optic."
- Organ_Liver: Keywords "liver," "hepatic," "hepatomegaly."
- Organ_Lung: Keywords "lung," "pulmonary," "pleura/pleural," "pneumon-," "infiltrate," "consolidation," "effusion," "ARDS," "respiratory failure."
- Organ_CNS: Keywords "brain," "central nervous system," "CNS," "cerebral," "intracranial," "encephal-," "myel-," "spinal," "CSF," "meningeal enhancement."
- Organ_Heart: Keywords "heart," "cardiac," "myocarditis."

Because some organ variables partially overlapped with symptom terminology, symptom–organ pairs with direct definitional overlap were not interpreted as independent associations. Non-standard symptom expressions were mapped to MeSH terms. For example, pyrexia, shortness of breath, vision loss, and itching were mapped to fever, dyspnea, blindness, and pruritus, respectively. Eosinophilia values were extracted from full-text sentences that explicitly contained numeric laboratory thresholds or diagnostic terminology such as hypereosinophilia. Manual confirmation by the author identified data that had been misclassified by the artificial intelligence agent. Prompts instructed Antigravity to reevaluate missing data and extract additional information from the full texts.

Critical appraisal of individual sources

Formal methodological quality or risk-of-bias appraisal of individual case reports was not performed. Because this scoping review aimed to map clinical manifestations and clustering patterns rather than synthesize treatment effects or estimate pooled prevalence, no case report was excluded on the basis of reporting quality. However, eligibility required objective diagnostic confirmation of toxocariasis, and artificial intelligence-generated extraction outputs were manually checked by the author.

Synthesis of results

Three exploratory analyses were performed using the finalized binary clinical-feature matrix: (1) pairwise association testing with Fisher's exact test and odds ratios, (2) pairwise correlation analysis using phi/Pearson's r for binary features, and (3) k-means clustering to identify phenotypic patterns. Symptoms and organ-involvement variables were coded as present or absent for each included case report. Variables reported in fewer than 2 cases were excluded from pairwise analysis to reduce instability from sparse cells.

For pairwise association analysis, 2×2 contingency tables were constructed for a prespecified set of clinically relevant feature pairs ($n = 39$) that met the minimum frequency requirement, with each feature reported in at least 2 cases. Fisher's exact test was used to assess departure from independence. Odds ratios and 95% confidence intervals were calculated to estimate the direction, magnitude, and precision of associations. Directional interpretation was not inferred from the Fisher's exact test P-value alone. "Positive" indicated higher observed co-occurrence than expected under independence, generally corresponding to an odds ratio greater than 1; "negative" indicated lower observed co-occurrence than expected, generally corresponding to an odds ratio less than 1. Given the exploratory nature of this scoping review, Bonferroni or false discovery rate corrections were not applied to individual P-values because the primary goal was pattern identification rather than hypothesis testing. Unadjusted P-values should therefore

be interpreted with caution. Confidence intervals for odds ratios were computed using an exact method; therefore, nominal P-values and confidence intervals may not align perfectly after rounding, particularly for sparse tables.

Pearson correlation coefficients were calculated between binary feature pairs. For 2 binary variables, Pearson's r is equivalent to the phi coefficient. Correlation heatmaps summarized association strength and direction, whereas Fisher's exact test summarized statistical evidence against independence. K-means clustering was then applied to the binary clinical-feature matrix, with k = 4 selected on the basis of clinical interpretability and data-driven validation metrics, including the elbow method and silhouette score (Supplement 2). This analysis identified 4 clinically interpretable phenotypic groups: subclinical disease, ocular larva migrans, visceral larva migrans, and neurotoxocariasis/multisystemic disease. Analyses were performed using Python libraries, including pandas, SciPy, and scikit-learn. The source code for the Antigravity-supported analysis used in this study is available in Supplement 3.

Results

Selection of sources

The case-report selection process for data analysis is shown in Fig. 1.

Characteristics of sources of evidence

The final evidence set included 139 confirmed human toxocariasis case reports indexed between 2005 and 2025. The included reports contained patient-level information on age, sex, chief complaint, associated symptoms, eosinophil count or eosinophilia status, organ involvement, diagnostic evidence, and final diagnosis. Full-text articles were used for extraction. The reports covered diverse clinical presentations, including ocular larva migrans, visceral larva migrans, neurotoxocariasis or multisystemic disease, and subclinical or oligosymptomatic presentations. Detailed source-level characteristics and inclusion status are summarized in Supplement 1.

Critical appraisal of sources of evidence

No formal appraisal was performed; therefore, no appraisal results are presented.

Results of individual sources

Individual source-level charting results are presented in Supplement 1. The charted variables included PubMed identifier, title, patient age, sex, chief complaint, associated symptoms, eosinophil count or eosinophilia status, final diagnosis, raw abstract, and inclusion status. The included reports covered heterogeneous toxocariasis manifestations, including ocular, visceral, neurologic, cardiopulmonary, hepatic, and subclinical or oligosymptomatic presentations. Aggregate co-occurrence, association, and clustering findings are reported separately below.

Synthesis of results

Pairwise co-occurrence and association analysis

Pairwise co-occurrence and association analyses were performed using the binary clinical-feature matrix derived from the 139 included human toxocariasis case reports. Table 1 presents co-occurrence counts, odds ratios, 95% confidence intervals, Fisher's exact test P-values, and directional classifications for selected pairs of toxocariasis-related clinical features. Directional classification was based on observed-versus-expected co-occurrence under independence and the corresponding odds ratio, not on the Fisher's exact test P-value alone.

The highest co-occurrence counts were observed for eosinophilia with fever, blindness with uveitis, dyspnea with eosinophilia, cough with eosinophilia, eosinophilia with pruritus, and eosinophilia with headache. Pairs classified as positive showed higher observed co-occurrence than expected under independence and odds ratios greater than 1. Pairs classified as negative showed lower observed co-occurrence than expected under independence and odds ratios less than 1. Fisher's exact test was used to assess the nominal statistical significance of departure from independence.

The "Interpretation" column reflects observed-versus-expected co-occurrence, not a direct output of Fisher's exact test. Fisher's exact test provides the P-value for independence. Because many feature pairs were sparse, odds ratios and confidence intervals were estimated using exact methods and are reported with rounding. In rare instances, different feature pairs can yield numerically similar estimates after rounding. The underlying 2 × 2 tables for all reported pairs are provided in Supplement 4. An infinite odds ratio indicates a zero-cell count in the corresponding 2 × 2 table, and the Haldane-Anscombe correction was not applied.

To summarize nominal evidence against independence, clinical-feature pairs were grouped according to Fisher's exact test P-values. P-values were classified into descriptive tiers ($0.01 < P \leq 0.05$ and $P < 0.01$) without adjustment for multiple comparisons; these tiers were intended for descriptive reporting only (Table 2). These classifications were used only to summarize the distribution of P-values across feature pairs.

Cluster analysis

Table 1. Co-occurrence counts, ORs, 95% CIs, and Fisher's exact test results for pairwise associations between toxocariasis-related clinical features

Feature 1	Feature 2	Co-occurrence count	OR (95% exact CI)	P-value	Interpretation
Eosinophilia	Fever	40	7.04 (2.44–24.56)	< 0.0001	Positive
Blindness	Uveitis	32	Inf (31.00–Inf)	< 0.0001	Positive
Dyspnea	Eosinophilia	25	Inf (4.41–Inf)	< 0.0001	Positive
Cough	Eosinophilia	24	17.45 (2.62–732.42)	0.0001	Positive
Eosinophilia	Pruritus	24	17.45 (2.62–732.42)	0.0001	Positive
Eosinophilia	Headache	22	7.60 (1.71–69.05)	0.0019	Positive
Fever	Hepatomegaly	21	12.83 (4.30–42.38)	< 0.0001	Positive
Dyspnea	Fever	19	10.72 (3.57–35.58)	< 0.0001	Positive
Asthma	Eosinophilia	18	12.00 (1.76–510.18)	0.0034	Positive
Cough	Dyspnea	18	39.31 (10.84–148.27)	< 0.0001	Positive
Cough	Fever	17	6.53 (2.33–19.19)	< 0.0001	Positive
Eosinophilia	Myocarditis	17	Inf (2.59–Inf)	0.0006	Positive
Fever	Headache	17	7.55 (2.60–23.46)	< 0.0001	Positive
Fever	Pruritus	15	4.20 (1.55–11.57)	0.0019	Positive
Asthma	Fever	13	5.96 (1.89–20.51)	0.0009	Positive
Headache	Meningitis	13	18.23 (5.28–64.50)	< 0.0001	Positive
Blindness	Strabismus	12	25.80 (3.52–1,115.25)	< 0.0001	Positive
Cough	Hepatomegaly	12	6.09 (2.08–17.48)	0.0003	Positive
Fever	Myocarditis	12	6.47 (1.91–24.92)	0.0007	Positive
Asthma	Cough	11	10.41 (3.13–34.77)	< 0.0001	Positive
Asthma	Dyspnea	11	10.41 (3.13–34.77)	< 0.0001	Positive
Asthma	Pruritus	11	10.41 (3.13–34.77)	< 0.0001	Positive
Dyspnea	Hepatomegaly	11	4.81 (1.64–13.69)	0.0016	Positive
Hepatomegaly	Pruritus	11	4.81 (1.64–13.69)	0.0016	Positive
Cough	Pruritus	10	4.40 (1.46–12.73)	0.0035	Positive
Dyspnea	Myocarditis	10	10.19 (2.92–36.00)	< 0.0001	Positive
Strabismus	Uveitis	10	15.76 (3.57–93.60)	< 0.0001	Positive
Fever	Seizures	9	7.58 (1.74–45.25)	0.0020	Positive
Headache	Seizures	8	13.88 (3.18–68.27)	< 0.0001	Positive
Meningitis	Seizures	8	19.17 (4.21–96.45)	< 0.0001	Positive
Eosinophilia	Hepatomegaly	22	2.85 (0.95–10.27)	0.0462	Positive
Eosinophilia	Meningitis	18	5.88 (1.30–54.03)	0.0108	Positive
Blindness	Headache	14	2.84 (1.05–7.81)	0.0351	Positive
Fever	Meningitis	11	3.06 (1.04–9.10)	0.0361	Positive
Cough	Headache	9	3.71 (1.21–10.87)	0.0156	Positive
Asthma	Headache	7	3.53 (1.02–11.36)	0.0234	Positive
Dyspnea	Seizures	5	3.82 (0.86–15.46)	0.0411	Positive
Blindness	Myocarditis	2	0.19 (0.02–0.89)	0.0297	Negative
Hepatomegaly	Uveitis	2	0.22 (0.02–0.98)	0.0400	Negative

OR, odds ratio; CI, confidence interval.

K-means clustering with k = 4 identified 4 phenotypic clusters among the 139 included case reports (Table 3). Cluster 1 included 62 cases and was labeled subclinical disease. The only distinguishing feature reported in more than 15% of cases in this cluster was eosinophilia. Cluster 2 included 29 cases and was labeled ocular larva migrans. The distinguishing features were blindness, uveitis, eosinophilia, and strabismus. Cluster 3 included 30 cases and was labeled visceral larva migrans. The distinguishing features were fever, eosinophilia, hepatomegaly, dyspnea, cough, asthma, pruritus, myocarditis, and headache. Cluster 4 included 18 cases and was labeled neurotoxocariasis/multisystemic disease. The distinguishing features were eosinophilia, blindness, meningitis,

Table 2. Descriptive tiers of nominal pairwise associations between toxocariasis-related clinical features

Feature 1	Feature 2	P-value	Nominal P-value tier
Asthma	Cough	< 0.0001	Nominal (P < 0.01)
Asthma	Dyspnea	< 0.0001	Nominal (P < 0.01)
Asthma	Eosinophilia	0.0034	Nominal (P < 0.01)
Asthma	Fever	0.0009	Nominal (P < 0.01)
Asthma	Headache	0.0234	Nominal (0.01 < P ≤ 0.05)
Asthma	Pruritus	< 0.0001	Nominal (P < 0.01)
Blindness	Headache	0.0351	Nominal (0.01 < P ≤ 0.05)
Blindness	Myocarditis	0.0297	Nominal (0.01 < P ≤ 0.05)
Blindness	Strabismus	< 0.0001	Nominal (P < 0.01)
Blindness	Uveitis	< 0.0001	Nominal (P < 0.01)
Cough	Dyspnea	< 0.0001	Nominal (P < 0.01)
Cough	Eosinophilia	0.0001	Nominal (P < 0.01)
Cough	Fever	0.0001	Nominal (P < 0.01)
Cough	Headache	0.0156	Nominal (0.01 < P ≤ 0.05)
Cough	Hepatomegaly	0.0003	Nominal (P < 0.01)
Cough	Pruritus	0.0035	Nominal (P < 0.01)
Dyspnea	Eosinophilia	< 0.0001	Nominal (P < 0.01)
Dyspnea	Fever	< 0.0001	Nominal (P < 0.01)
Dyspnea	Hepatomegaly	0.0016	Nominal (P < 0.01)
Dyspnea	Myocarditis	0.0001	Nominal (P < 0.01)
Dyspnea	Seizures	0.0411	Nominal (0.01 < P ≤ 0.05)
Eosinophilia	Fever	< 0.0001	Nominal (P < 0.01)
Eosinophilia	Headache	0.0019	Nominal (P < 0.01)
Eosinophilia	Hepatomegaly	0.0462	Nominal (0.01 < P ≤ 0.05)
Eosinophilia	Meningitis	0.0108	Nominal (0.01 < P ≤ 0.05)
Eosinophilia	Myocarditis	0.0006	Nominal (P < 0.01)
Eosinophilia	Pruritus	0.0001	Nominal (P < 0.01)
Fever	Headache	< 0.0001	Nominal (P < 0.01)
Fever	Hepatomegaly	< 0.0001	Nominal (P < 0.01)
Fever	Meningitis	0.0361	Nominal (0.01 < P ≤ 0.05)
Fever	Myocarditis	0.0007	Nominal (P < 0.01)
Fever	Pruritus	0.0019	Nominal (P < 0.01)
Fever	Seizures	0.0020	Nominal (P < 0.01)
Headache	Meningitis	< 0.0001	Nominal (P < 0.01)
Headache	Seizures	0.0001	Nominal (P < 0.01)
Hepatomegaly	Pruritus	0.0016	Nominal (P < 0.01)
Hepatomegaly	Uveitis	0.0400	Nominal (0.01 < P ≤ 0.05)
Meningitis	Seizures	< 0.0001	Nominal (P < 0.01)
Strabismus	Uveitis	< 0.0001	Nominal (P < 0.01)

headache, fever, seizures, cough, dyspnea, asthma, pruritus, myocarditis, hepatomegaly, and strabismus.

The high prevalence of blindness in Cluster 4 suggests that some ocular larva migrans cases may have overlapped with this predominantly systemic/neurotoxocariasis cluster. This overlap reflects the hard boundaries imposed by k-means clustering; therefore, these programmatic clusters should be interpreted with the understanding that ocular larva migrans and neurotoxocariasis have distinct pathophysiological mechanisms.

Heatmap-based synthesis

Fig. 2 presents the co-occurrence counts for pairs of toxocariasis-associated clinical features. The diagonal represents self-co-occurrence and was set to zero by design to improve visualization of off-diagonal values. Higher co-occurrence counts are represented by darker cells.

Fig. 3 presents the statistical significance of pairwise associations using $-\log_{10}$-transformed P-values derived from Fisher's exact test. Lower P-values correspond to higher $-\log_{10}$-transformed P-values and darker cells in the heatmap.

Fig. 4 presents Pearson correlation coefficients between binary clinical features. For 2 binary variables, Pearson's r is equivalent to the phi coefficient. The correlation heatmap was used to summarize the strength and direction of association between feature pairs, whereas Fisher's exact test was used to assess departure from independence.

Discussion

Summary of evidence

This Antigravity-assisted systematic scoping review summarized co-occurrence, association, correlation, and clustering patterns among clinical features reported in 139 human toxocariasis case reports indexed in PubMed. The findings suggest that reported manifestations of human toxocariasis can be organized into several clinically recognizable phenotypic patterns, including subclinical or oligosymptomatic presentations, ocular larva migrans, visceral larva migrans, and neurotoxocariasis/multisystemic disease.

The pairwise association and clustering results indicated that ocular and visceral phenotypes were relatively distinct in the included case reports. Ocular features, particularly blindness, uveitis, and strabismus, tended to cluster together, whereas systemic features such as fever, dyspnea, cough, hepatomegaly, pruritus, and eosinophilia aligned more closely with visceral or multisystemic presentations. These findings are consistent with the established clinical distinction between ocular larva migrans and visceral larva migrans [2]. However, because the data were derived from case reports rather than a prospectively assembled clinical cohort, these patterns should be interpreted as descriptive and hypothesis-generating.

In pairwise Fisher's exact tests, eosinophilia was not statistically significantly associated with ocular features; however, eosinophilia was reported in a subset of ocular cases, and multivariate clus-

Table 3. Summary of the 4 phenotypic clusters identified by k-means clustering

Cluster	Clinical label	No. of cases	Distinguishing symptoms or features (prevalence > 15%)	Descriptive feature profile
1	Subclinical disease	62	Eosinophilia (48.4%)	Characterized by mild, atypical, or incompletely documented presentations.
2	Ocular larva migrans	29	Blindness (100.0%), uveitis (100.0%), eosinophilia (55.2%), strabismus (31.0%)	Characterized by concentrated ocular inflammation and subsequent severe visual impairment.
3	Visceral larva migrans	30	Fever (93.3%), eosinophilia (86.7%), hepatomegaly (63.3%), dyspnea (46.7%), cough (40.0%), asthma (33.3%), pruritus (33.3%), myocarditis (33.3%), headache (16.7%)	Distinguished by a pronounced systemic inflammatory presentation, including fever, together with major liver and cardiopulmonary involvement.
4	Neurotoxocariasis/ multisystemic disease	18	Eosinophilia (100.0%), blindness (83.3%), meningitis (77.8%), headache (77.8%), fever (72.2%), seizures (55.6%), cough (50.0%), dyspnea (44.4%), asthma (38.9%), pruritus (33.3%), myocarditis (16.7%), hepatomegaly (16.7%), strabismus (16.7%)	Distinguished by central nervous system involvement accompanied by multisystemic manifestations. Ocular features were also frequent, including blindness in 83.3% of cases.

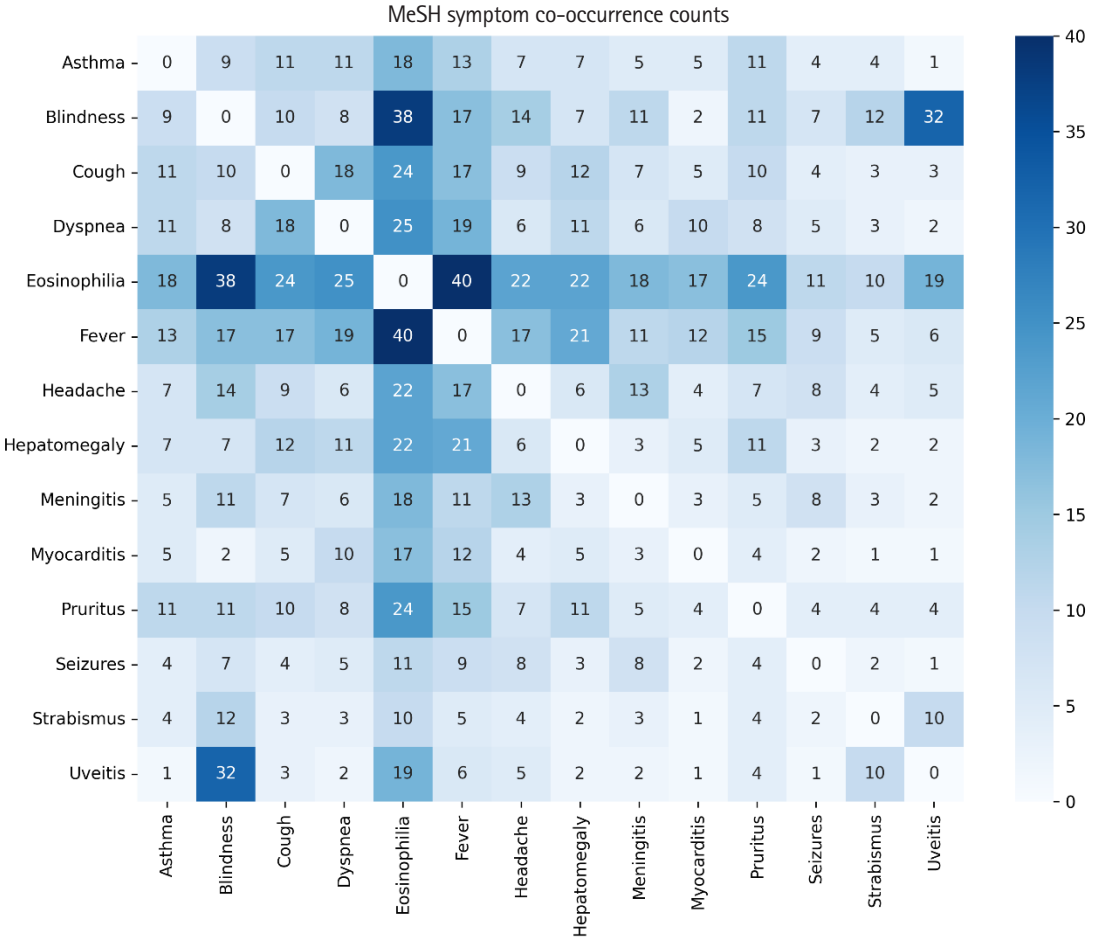

Fig. 2. Heatmap of co-occurrence counts for toxocariasis-associated clinical features.

tering can group cases with partial overlap across domains. This discrepancy reflects the difference between univariate, feature-by-feature association testing and clustering, which groups cases according to overall similarity across multiple features.

This finding suggests that eosinophilia may be more informative for systemic toxocariasis presentations than for isolated ocular disease. Previous reports have also described variability in eosinophilia among patients with ocular toxocariasis [4,5]. Nevertheless, the presence of eosinophilia in some cases assigned to the ocular larva migrans cluster indicates that ocular-predominant cases may

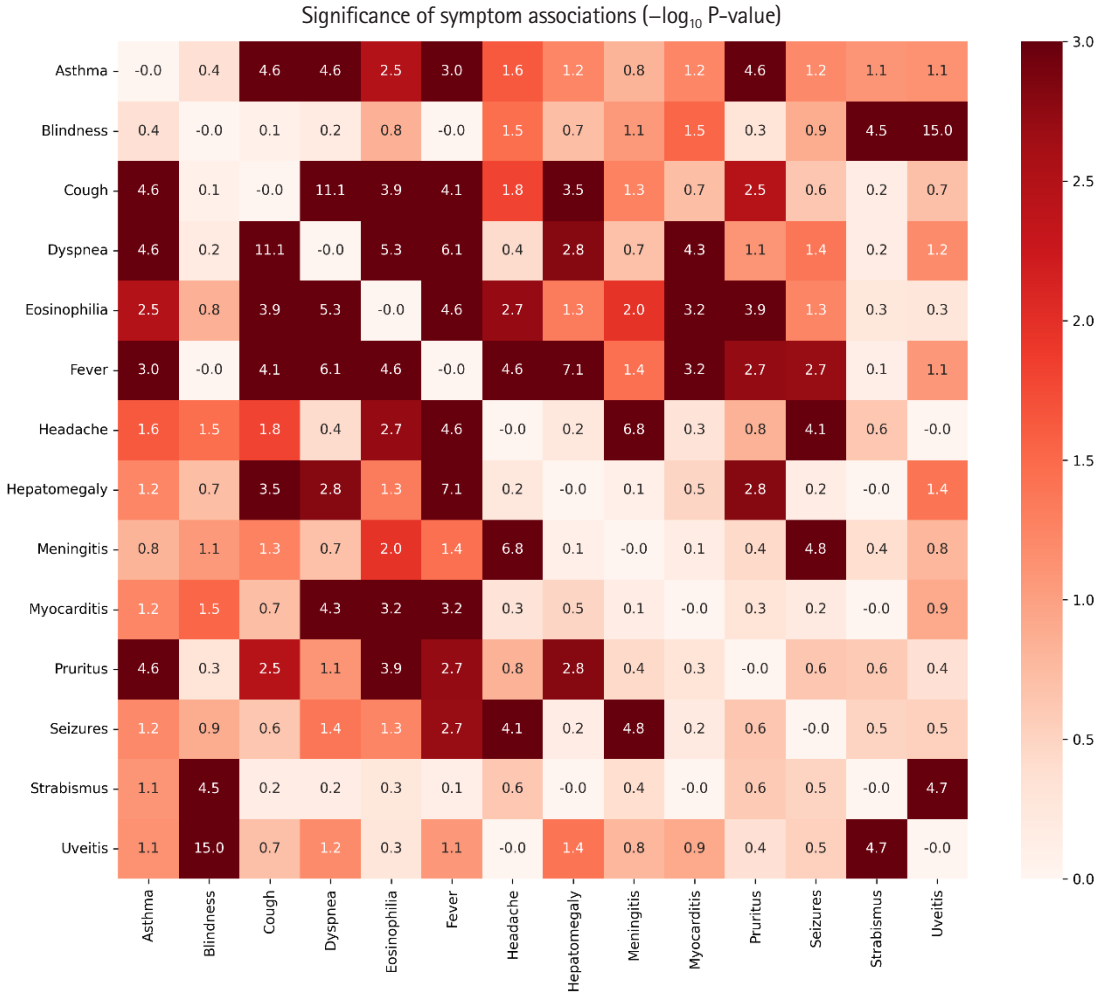

Fig. 3. Heatmap of $-\log_{10}$-transformed P-values for associations between toxocariasis-associated symptoms and features, calculated using Fisher's exact test.

overlap with systemic manifestations. Therefore, eosinophilia should not be used alone to distinguish ocular from visceral toxocariasis.

The neurotoxocariasis/multisystemic cluster included central nervous system features, including headache, meningitis, and seizures, alongside systemic and ocular manifestations. This pattern suggests that neurotoxocariasis reported in the case-report literature may often occur in a broader multisystemic clinical context rather than as an isolated neurologic presentation. The observed clustering pattern should be interpreted cautiously because k-means clustering groups cases according to overall feature similarity and does not assign strict clinical diagnoses.

The complementary use of Fisher's exact test, odds ratios, Pearson correlation coefficients, and k-means clustering provided different perspectives on the same binary clinical-feature matrix. Fisher's exact test assessed departure from independence, odds ratios estimated the direction and magnitude of associations, Pearson correlation coefficients summarized association strength, and k-means clustering identified exploratory phenotypic groupings. These methods support descriptive pattern recognition but do not establish causality, diagnostic performance, or clinical prediction.

Limitations

This study has several limitations. First, the analysis was restricted to case reports indexed in PubMed and filtered by free full-text availability, which may have introduced database, language, publication, and full-text availability biases. Mild, asymptomatic, or common presentations may have been underrepresented because case reports typically emphasize unusual or severe manifestations. Second, data were extracted from published narratives rather than standardized clinical records. Symptoms, eosinophil counts, diagnostic methods, organ involvement, treatment, and outcomes

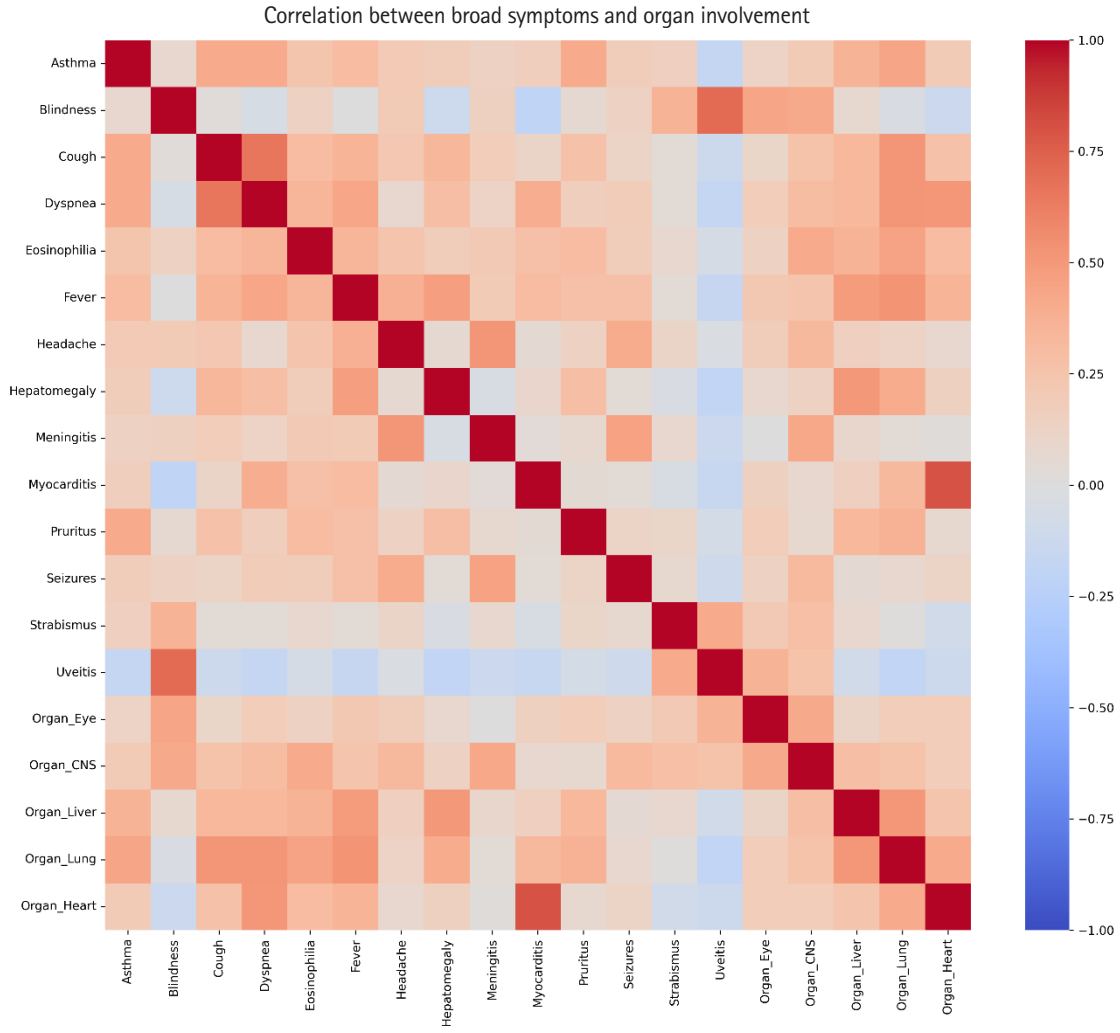

Fig. 4. Heatmap of Pearson correlation coefficients, equivalent to phi coefficients for binary clinical features, between toxocariasis-associated symptoms and organ-involvement variables.

were reported inconsistently, and unreported findings could not always be distinguished from true absence. Third, binary coding of heterogeneous clinical descriptions enabled association and clustering analyses but reduced clinical granularity and may have introduced misclassification during symptom mapping. Fourth, the statistical analyses were exploratory. Multiple pairwise comparisons were performed, P-values were interpreted descriptively, and odds ratios or confidence intervals may be unstable for sparse feature pairs. Pearson correlation coefficients for binary variables are also influenced by marginal prevalence. Fifth, k-means clustering grouped reports according to overall feature similarity rather than strict clinical diagnosis; therefore, clusters should be interpreted as exploratory phenotypic patterns, not validated disease subtypes. Finally, artificial intelligence-assisted extraction may have missed or misclassified information despite human verification and requires independent validation in curated datasets.

Suggestions for future research

Future studies should validate these exploratory findings using larger and more systematically curated datasets. Searches should be expanded beyond PubMed and PubMed Central to include additional bibliographic databases and regional literature sources, such as KoreaMed. Including non–free full-text reports may reduce selection bias and improve representativeness.

Further research should also standardize data extraction for age, sex, exposure history, diagnostic method, eosinophil count, organ involvement, treatment, and clinical outcome. Age-specific analyses may be useful because ocular larva migrans and visceral larva migrans may differ by age group [2]. Exposure-related variables, including geophagia, ingestion of raw animal liver, and regional dietary practices, should also be considered because such factors have been described in previous studies [6-11].

Future analyses should compare artificial intelligence-assisted ex-

traction with independent manual extraction to quantify the sensitivity, specificity, and error patterns of the workflow. Prospective clinical datasets or registry-based studies would be needed to determine whether the observed phenotypic patterns can support diagnosis, risk stratification, or clinical decision-making.

Conclusion

This Antigravity-assisted systematic scoping review identified exploratory co-occurrence, association, correlation, and clustering patterns among clinical manifestations reported in human toxocariasis case reports. The findings suggest relative separation between ocular and visceral phenotypes, frequent alignment of eosinophilia with systemic manifestations, and a multisystemic pattern among neurotoxocariasis-related reports. However, the results should be interpreted as hypothesis-generating rather than diagnostic or practice-guiding evidence. Artificial intelligence-assisted approaches may support data extraction and pattern recognition in scoping reviews, but human verification and validation against independently curated clinical datasets are required before clinical application.

ORCID

Eun Hee Ha: https://orcid.org/0009-0007-7137-0331

Authors' contribution

All work was completed by Eun Hee Ha.

Conflict of interest

The commercial program mentioned in this study is discussed for informational purposes and not for promotion. No other potential conflicts of interest relevant to this article were reported.

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Data availability

Data files are available from Harvard Dataverse: https://doi.org/10.7910/DVN/33GBYE

Dataset 1. Data from the final 139 toxocariasis articles used for analysis.

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None.

Supplementary materials

Supplementary files are available from Harvard Dataverse: https://doi.org/10.7910/DVN/33GBYE

Supplement 1. Table of toxocariasis case reports indexed in the NCBI PubMed database (2005–2025) containing the following categories: PMID, title, patient age, sex, chief complaint, associated symptoms, eosinophil count, final diagnosis, raw abstract, organ involvement, symptoms (MeSH), and inclusion status.

Supplement 2. Elbow method and silhouette score cluster-validation metrics supporting the selection of $k = 4$ as the optimal number of phenotypic clusters for the k-means analysis.

Supplement 3. Python code used for the data analysis in this study. All figures and Markdown files were generated using Antigravity.

Supplement 4. The underlying 2×2 contingency tables detailing the observed absolute cell counts (mutual presence, singular presence, and mutual absence) for all pairwise combinations of the analyzed toxocariasis-related clinical features.

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