



## Narrative review

## A plague like no other: beyond the buboes in Thucydides' account of the Plague of Athens

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## ABSTRACT

**Background:** The Athens Plague (430–427 BCE) was a devastating outbreak during the Peloponnesian War, described in detail by Thucydides. Although there is ongoing discussion, the specific cause of the epidemic remains undetermined.

**Objectives:** This review re-examines the Athenian Plague through historical and microbiological lenses, reassessing diagnostic hypotheses and proposing the plausibility of an ancient pneumonic strain of *Yersinia pestis*.

**Sources:** We analysed Thucydides' original account alongside interdisciplinary literature from classical studies, paleopathology, epidemiology, and microbiology. We gathered sources from PubMed, JSTOR, Google Scholar, and the Perseus Digital Library, covering works from 1634 to 2024.

**Content:** The clinical progression described by Thucydides—fever, conjunctivitis, bloody cough, gastrointestinal symptoms, rash, and high mortality—is compared with the presentations of typhoid fever, smallpox, epidemic typhus, measles, and plague. This review considers archaeological and paleogenomic findings, including controversial evidence of *Salmonella enterica* and the evolutionary history of *Y. pestis*. Special emphasis is placed on early strains of *Y. pestis* that lacked flea-borne virulence factors but may have caused pneumonic forms transmitted between humans.

**Implications:** The epidemic's significant demographic, political, and social impacts highlight the broader consequences of infectious diseases in ancient history. This review emphasizes the necessity of employing a multidisciplinary approach in historical epidemiology and advocates for reassessing pneumonic plague as a likely contributor to the outbreak that occurred in Athens. **Pere Domingo, Clin Microbiol Infect 2025;31:1639**

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A Dorian War shall come, and with it, a Plague

(ἢξει Δωριακὸς πόλεμος καὶ λομὸς ἄμ' αὐτῷ)

Ancient Greek Oracle

## Search strategy and selection criteria

For this historical review, our search strategy involved examining historical sources, scholarly studies, and medical hypotheses regarding the Plague of Athens. We specifically emphasized the accounts of those living in ancient Greece, particularly Thucydides' History of the Peloponnesian War, along with contemporary interdisciplinary research that includes areas such as Classical Studies, Epidemiology, and Paleopathology. We compiled these sources by searching historical archives and academic databases while prioritizing materials from 1634 to 2024. We tracked PubMed, Google Scholar, JSTOR, and the Perseus Digital Library to identify relevant journals, monographs,

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and reports from their inception until 2024. The cited references were bibliographically traced through key sources and their secondary literature to ensure a comprehensive review. We analysed archaeological and paleomicrobiological studies focused on mass graves in Athens related to the epidemic. Although a few non-scientific sources were consulted, only empirical records and compelling documents were utilized.

Search words included: “Plague of Athens,” “Thucydides” plague, “ancient epidemics,” “infectious disease in antiquity,” “measles,” “historical epidemiology,” “epidemic typhus,” “typhoid fever,” “*Yersinia pestis*,” “smallpox,” “viral hemorrhagic fevers,” “zoonotic diseases,” and “paleopathology.” Literature was reviewed in English, French, German, and Spanish.

## Introduction

In 430 BCE, Athens was raided for the first time by an enemy with no predecessors: the catastrophic Plague of Athens. This epidemic was devastating to the city-state socially, politically, and militarily during the years of the Peloponnesian War [1,2]. It killed civilians and soldiers, significantly altering the progression of the war. Thucydides (Fig. 1), an Athenian general, historian, and survivor of the plague, documented the disaster and provided valuable information concerning the disease and its effects on society [1].



Fig. 1. Bust of Thucydides. This Roman copy, dating to about 100 AD, is based on an early 4th-century Greek original at Holkham House in Norfolk, United Kingdom.

The pathogen remains unknown, but the Plague of Athens is a significant part of pandemic history and its effects on human civilization. This review examines the causes and impacts of the Plague from historical and medical viewpoints. The Plague of Athens clearly highlighted the numerous challenges associated with infectious diseases during a crisis.

## The historical context

The Peloponnesian Wars were complex conflicts in the 5th century BCE when Athens and its Delian League allies faced off against Sparta and the Peloponnesian League (Fig. 2) [1,2]. The period leading up to the war was Athens' Golden Age (the *Pentekontaetia*, 479–431 BCE), with political, cultural, philosophical, and artistic accomplishments at their apex [3]. For instance, Athens was unique for being one of the first states to practice direct democracy via the *Ekklesia* (ἐκκλησία, Assembly) and the *Boulé* (βουλή, Council of 500), which allowed its citizens to have a say in the decision-making process [3]. Pericles (495–429 BCE) was the capable leader of the city-state during the *Pentekontaetia*. He ensured that the city maintained its democratic values and social cohesion [3].

The war broke out due to increasing hostility between the two factions over commerce, league, and land. Sparta and its allies considered Athens' dominance over Greek city-states a threat to their existence, ultimately leading to the outbreak of the war. Pericles' plan was defensive, meaning Athens would rely on its naval power and avoid direct land confrontation with the Spartans. Athens also strengthened the city fortifications, built the Long Walls from the urban area to Piraeus, and called the population to defence [1,3–9].

Although the policy was successful, it also had drawbacks. The refugees from the surrounding countryside escaped into the walled city, which had to accommodate between 300 000 and 400 000 inhabitants within approximately 5.2 square kilometres, eventually straining the city's resources and infrastructure to a breaking point [1,3]. The Long Walls protected the town and its people from Spartan forces but also made the city and its inhabitants vulnerable to epidemics, which would prove deadly with the forthcoming Plague.

## The plague as described by Thucydides: a firsthand account

In his history of the Peloponnesian War (Fig. 3), Thucydides provides the earliest and most detailed account of an epidemic in antiquity, tracing its origins to Ethiopia (south of Egypt) before it spread to Greece via Lemnos during the second year of the Peloponnesian War [1].

The outbreak coincided with Pericles' defensive strategy, which forced many to seek shelter within the city's overcrowded walls. The city's infrastructure could not handle the sudden arrival of the refugees, creating unsanitary conditions, including a poor-quality water supply and inadequate waste disposal systems. These conditions made Athens a perfect breeding ground for the outbreak and spread of a contagious disease [1].

The plague began in the port of Piraeus and was likely introduced through shipping [1]. There were two major waves: the first from 430 to 429 BCE, which resulted in many deaths, including Pericles, and the second in 427 BCE. The disease continued sporadically in the following years, but Thucydides did not provide further details [1].

Thucydides described the symptoms of the plague in various stages. The illness began suddenly, presenting with excruciatingly severe headaches, a high fever, conjunctivitis, and a sore throat accompanied by foul breath (days 1–2). This was followed by a respiratory phase (days 2–4), characterized by hoarseness, a productive cough with blood-stained sputum, chest pain, and worsening shortness of breath. Neurological symptoms, including



Fig. 2. A map of the Greek city states and their alliances at the onset of the Peloponnesian War around 431 BCE. Author: Marsyas Attribution-Share Alike 3.0 Unported.

delirium and confusion, were common [1,10,11]. From days 4 to 6, there was a gastrointestinal phase characterized by severe abdominal pain, diarrhoea, vomiting blood, and extreme dehydration. Sufferers experienced insatiable thirst, and in their attempts to quench it, they ended up drowning in wells while searching for water [1,10,11]. The cutaneous phase often occurred, presenting as red (erythematous) macules and papules on the chest, face, and extremities. These lesions typically progressed into pustules or ulcers, which Thucydides described as sores with crusts. Patients reported feeling as if on fire and experiencing burning sensations in various parts of their bodies; they tried to cool down with water or ice [1,12].

The mortality rate was high, with estimates indicating that 75 000 to 100 000 people died (25–33% case-fatality ratio), primarily from complications such as dehydration and secondary infections [1,12]. Most deaths occurred between the seventh and ninth days in severe cases [1]. The disease affected everyone, and healthcare providers were more impacted due to their repeated exposure to the source of the disease [1,12]. Factors contributing to the high mortality rate may have included overcrowding, poor environmental conditions, lack of immunity, and inadequate treatment [1]. Secondary bacterial infections, traumatic ulcerations, sepsis, and systemic shock likely contributed to these deaths. Survivors faced lasting health issues, including amputations, gangrene, blindness, and neurological deficits, along with cognitive and sensory impairments. Thucydides noted that they seemed to develop immunity, marking an early reference to innate immunity [1].

Thucydides did not reference public health measures, such as quarantines or evacuations. This omission reflects the limited understanding of disease transmission in classical Greek medicine, which attributed illnesses to religious or humoral theories [13,14]. His narrative focuses on the political and social implications of the epidemic rather than biomedical responses [13,14]. His training as a historian, political philosopher, and military leader—not a physician—may explain his narrative [1,10,13]. Although public health measures might not have captured the interest of the chronicler, they may have been in place, nonetheless.

The Plague of Athens decimated a large segment of Athens' population and impacted its social and political framework for the forthcoming years.

### Beyond mortality: the ripple effects of the Athenian Plague

The Athenian Plague, as recounted by Thucydides, was not merely a biological disaster but also a catalyst for significant changes in Athens, affecting democracy, military strategy, and imperialism (Fig. 4) [1].

The epidemic severely weakened Athens' military capabilities, killing at least 4000 Athenian hoplites and 400 cavalymen, and diminishing the city's ability to defend itself against Sparta [1]. Under Pericles, Athens maintained its supremacy by avoiding land battles. However, his successors did not follow Pericles' military strategies after his death, further complicating the situation [1].



**Fig. 3.** Fragment from the fourth book of Thucydides' History of the Peloponnesian War (P. Oxy. 16). Discovered by Grenfell and Hunt in 1897 in Oxyrrhynchus, this fragment is dated to the first century. It is housed at the University of Pennsylvania Museum of Archaeology and Anthropology. It remains in the public domain.

Demographically, the plague caused a loss of 25–33% of Athens' population, particularly affecting economically active and child-bearing groups [12]. This decline impacted both urban and rural economies, resulting in famine and deepening the city's vulnerability, which was exacerbated by the ongoing war [1]. Politically, Pericles' death created a power vacuum that allowed demagogues to rise and undermined public confidence in the government [13]. These crises led to political instability, as did Athens's multifaceted internal and external threats [1].

Although the plague was not, in and of itself, the cause of Athens' defeat in the Peloponnesian War, it significantly weakened the city's demographic and economic resilience, shaping its military strategies, foreign policy, and social organization for generations to come.

### A diagnostic challenge across millennia

The Plague of Athens poses a historical diagnostic challenge due to limited sources and ambiguous descriptions, making it difficult to identify the pathogen [1]. Thucydides, a soldier and historian rather than a physician, provided observations within the context of his time, lacking vital epidemiological details such as incubation periods, modes of transmission, and specific symptom details [1].

Additionally, the possibility that the plague resulted from an extinct pathogen or a syndemic complicates the diagnosis [14].

A notable episode of the epidemic occurred in June 430 BCE, when the Athenian general Hagnon led 4000 soldiers by sea to Thrace, resulting in the death of 1050 men within 5 days, reflecting an attack and case fatality rate of over 25% [1,12]. This pattern aligns with an infectious disease transmitted through respiratory or aerosol methods. Epidemiological models suggest zoonotic or vector-borne diseases, alongside respiratory infections, as potential causes [12,15]. However, most respiratory pathogens quickly burn out in overcrowded locations, while Thucydides indicates an over 2-year duration, suggesting a more complex transmission dynamic [1,12,15].

Notwithstanding this, Thucydides' description underscores a high infection risk for caregivers and the development of immunity in survivors, indicative of directly transmissible diseases through human-to-human contact, features consistent with aerosol- or droplet-spread diseases such as pneumonic plague, epidemic typhus, or viral haemorrhagic fevers [12,14,15]. Given the influx of refugees and overcrowded conditions in wartime Athens, airborne transmission was highly likely. Recent paleogenomics evidence suggests that ancestral strains of *Yersinia pestis* have been capable of respiratory spread, supporting the hypothesis that an early pneumonic form of *Y. pestis* could have driven the Plague of Athens [16–21].

The clinical features of the Athens Plague can suggest a specific diagnosis, particularly signs of infection such as person-to-person transmission, skin eruptions, gastrointestinal symptoms, and neurological issues [11–15]. Modern analyses propose four potential infectious origins: first, an infectious agent unique to ancient Athens that is now extinct [11]; second, a known contagious disease introduced to a naïve population, similar to syphilis in Naples (1494), smallpox in Mexico (1530), measles in Fiji (1875), and COVID-19, where a lack of immunity led to increased severity [22,23]; third, a known infectious disease like typhoid fever or epidemic typhus [11,12,15]; and fourth, an evolved pathogen, adapting to new hosts and becoming less virulent, exemplified by COVID-19 and the myxomatosis epidemic in Australian rabbits [23,24].

Identifying the cause of the Athens Plague through symptom analysis and historical records has proven challenging. Carl Witt first suggested that Thucydides' account might refer to smallpox [25]. Over 30 potential diagnoses, including bubonic plague, epidemic typhus, measles, typhoid fever, and smallpox, have been proposed, emphasizing the case's complexity [11,12,15]. Table 1 [14] compares the clinical picture of the Athens Plague with the features of the five most commonly entertained diagnoses.

The rash, a critical diagnostic sign, Thucydides described as livid red and spreading from the head down, aligns with measles but not with typhoid fever's typical faint rose spots or the characteristics of smallpox or bubonic plague, including disfiguring scars and buboes [1,26–31]. The exanthem has the same descending pattern as smallpox but is not livid [29]. The rash of epidemic typhus is mainly truncal, does not spread from the head to the lower limbs, and is not intensely livid [28,32].

Thucydides' account of the plague in Athens does not mention rats, which some argue weakens the case for *Y. pestis* as the causative agent [26,33]. This omission aligns with the classical Athenian understanding of disease, as fifth-century BCE medicine lacked the concept of vector-borne transmission, and small animals like rats were not recognized as relevant to illness [14]. Thucydides focused more on moral and civic outcomes than on zoological details, and Greek medical texts of the time rarely referred to rats, instead noting lice, which are visibly associated with humans [1,13,34]. The absence of buboes and any recorded rat die-off, while weakening the



**Fig. 4.** Plague in an Ancient City (c. 1652) by Michiel Sweerts (1618–1664). This painting is thought to illustrate the Plague of Athens and vividly captures the suffering and despair of Athenians during the Plague. It is currently housed in the Los Angeles County Museum of Art. It remains in the public domain.

argument for bubonic plague, does not deny the plausibility of a *Y. pestis* pneumonic form spreading independently of rodents [16–21,35].

Challenges arise from the chronological and linguistic analysis of Thucydides' description, which is more descriptive than analytical [1]. Issues include the timing and duration of the outbreak and the precise terms he used [1]. The philological analysis of the terms used by Thucydides presents another drawback. His choices of words like *loimós* (λοιμός, suffering), *rónos* (πόνος, fatigue), and *nósos* (νόσος, illness), instead of epidemic (πλῆγá) or epidemics (πληγή), limit modern interpretations [1]. He described the rash as *fluctaínais mikraís kai hélkesin exeenteekós* (φλυκταίναις μικραῖς καὶ ἑλκοσιν ἐξηντηκός), which has been translated as blisters or pustules (φλυκταίνεις) and ulcers (ἑλκος), but also as blains, blebs, blisters, bullae, eruptions, pimples, blemishes, vesicles, and whelks, further complicating the matter [36]. Sometimes, *ἑλκος* is translated as buboes, whereas the term *βουβών* (bubo) was in use in 5th-century Greece [26,36,37].

Recent archaeological findings at the Kerameikos cemetery in 2001 revealed a mass grave from the time of Athens' Plague, and microbial DNA analysis indicated the presence of *Salmonella enterica* serovar *Typhi*, suggesting typhoid fever as a possible cause of the outbreak [38,39]. However, the evidence remains inconclusive due to the sample size, potential contamination, and the possibility of endemic typhoid fever in ancient Greece [12,27]. The DNA matched that of the modern *S. enterica* serovar *Typhi* with 7% sequence divergence, which could place this ancient sequence outside of *S. enterica* and *S. typhimurium*, complicating the determination of its role in the Athens Plague [40].

The knowledge of evolutionary biology aids in understanding ancient epidemics. The Plague of Justinian was the first documented bubonic plague pandemic from 541 to 544 CE [35,41]. Although *Y. pestis* has been infecting humans for at least 5000 years [16,17], ancestral strains lacked key virulence factors, such as the

*Yersinia murine toxin* (*ymt*), acquired around 3700 BCE, which enabled modern strains to be transmitted by fleas [17,18]. Additionally, the plasminogen activator gene (*pla*), which mutated around 1000 BCE, is crucial for causing bubonic plague [17,19]. Ancestral strains could only cause pneumonic and septicemic plague [16,18]. They coexisted and evolved in parallel for centuries with modern strains, adapting to different environmental conditions [19]. Their disappearance suggests that they went extinct after the Iron Age [17].

The epidemiological characteristics of the Athens Plague support the idea of an ancestral pneumonic strain of *Y. pestis*, as it features person-to-person transmission and outbreaks in poorly ventilated areas with direct contact with source cases [20,21,42–44]. Several potential animal reservoirs have also been identified, including cattle and domestic animals, which may have sustained the duration of the Plague of Athens [44–46]. Although pneumonic plague is typically lethal without treatment, the lower 25–33% mortality rate of the Athens Plague suggests an evolutionary trend towards increased virulence in modern strains [16,47].

Symptoms of the Athens Plague, particularly respiratory and gastrointestinal, align with pneumonic plague (Table 1), although the generalized rash is inconsistent with typical *Y. pestis* infection [1,20,31,43]. This discrepancy may stem from changes in pathogens or a viral superinfection [14,18]. The ancient *Yersinia* strains may possess different virulence factors than modern strains, resulting in distinct symptomatology [16,18,19,48]. Interestingly, *Yersinia pseudotuberculosis* (the ancestor of *Y. pestis*) causes Far East scarlet-like fever with a rash, among other symptoms that can be macular, erythematous, or scarlatiniform [49]. *Y. pseudotuberculosis* has a sizeable animal reservoir, including healthy pigs, dogs, cats, cattle, horses, rabbits, and birds [49].

Attributing the cause of the Plague of Athens to a specific infectious disease requires paleomicrobiological evidence, which remains lacking [50]. Despite speculation linking ancestral *Y. pestis*

**Table 1**  
Comparative analysis of symptoms: Athens' Plague vs. major historical diseases

| Symptom/sign              | Athens' Plague  | Epidemic typhus   | Smallpox         | Measles       | Typhoid fever | Bubonic plague |
|---------------------------|-----------------|-------------------|------------------|---------------|---------------|----------------|
| Initial presentation      |                 |                   |                  |               |               |                |
| Sudden onset              | +               | +                 | +                | +             | –             | +              |
| High fever                | +               | +                 | +                | +             | +             | +              |
| Severe headache           | +               | +                 | +                | +             | +             | +              |
| Initial chills            | –               | +                 | +                | +             | +             | +              |
| Prodromal period          | –               | +                 | +                | +             | +             | –              |
| Respiratory symptoms      |                 |                   |                  |               |               |                |
| Cough                     | +               | +                 | +                | +             | –             | +              |
| Chest pain                | +               | –                 | –                | –             | –             | +              |
| Bloody sputum             | +               | –                 | –                | –             | –             | +              |
| Pharyngitis               | +               | –                 | +                | +             | –             | –              |
| Gastrointestinal symptoms |                 |                   |                  |               |               |                |
| Nausea/vomiting           | +               | +                 | +                | –             | +             | +              |
| Diarrhoea                 | +               | –                 | +                | –             | +             | –              |
| Abdominal pain            | +               | –                 | –                | –             | +             | –              |
| Bloody stools             | +               | –                 | –                | –             | +             | +              |
| Cutaneous manifestations  |                 |                   |                  |               |               |                |
| Initial rash              | Whole body      | Trunk→extremities | Face→body        | Face→body     | Rose spots    | –              |
| Rash progression          | Vesicles→ulcers | Macular→petechial | Macules→pustules | Maculopapular | Macular       | –              |
| Gangrene of extremities   | +               | +                 | –                | –             | –             | –              |
| Rash timing (d)           | 5–8             | 4–7               | 3–4              | 3–5           | Week 2        | –              |
| Neurological symptoms     |                 |                   |                  |               |               |                |
| Delirium                  | +               | +                 | +                | –             | +             | +              |
| Restlessness              | +               | +                 | +                | –             | +             | +              |
| Memory loss               | +               | +                 | –                | –             | –             | –              |
| Insomnia                  | +               | +                 | –                | –             | +             | –              |
| Other features            |                 |                   |                  |               |               |                |
| Conjunctivitis            | +               | +                 | –                | +             | –             | –              |
| Lymphadenopathy           | –               | –                 | –                | +             | –             | +              |
| Buboes                    | –               | –                 | –                | –             | –             | +              |
| Extreme thirst            | +               | +                 | +                | –             | +             | +              |
| Survival immunity         | +               | +                 | +                | +             | –             | +              |
| Epidemiology              |                 |                   |                  |               |               |                |
| Case fatality rate (%)    | 25–33           | 10–60             | 20–60            | 5–15          | 10–20         | 40–60          |
| Seasonal pattern          | None            | Winter-spring     | None             | Winter-spring | None          | Variable       |
| Vector required           | Unknown         | Lice              | No               | No            | No            | Fleas          |

+ = **present**, – = **absent or not reported**. Adapted from Cunha [14].

strains to the epidemic, the true nature of the Plague of Athens remains elusive.

The Plague of Athens remains a mystery due to the limitations of historical accounts, vague clinical descriptions, and inconclusive archaeological evidence, which leave us guessing about the identity of the plague. Whether it was an extinct pathogen or a common disease like typhoid fever, smallpox, plague, or measles, none of the diseases considered fit the epidemic perfectly. The Plague of Athens demonstrates that diagnosing historical medical illnesses based solely on their clinical presentation is nearly impossible. It illustrates that only a combination of historical, linguistic, paleopathological, and paleomicrobiological approaches can solve the enigma of such complex medical mysteries.

### Legacy of mystery and wisdom: insights from the Athenian Plague

In his historical narrative of the Peloponnesian War, Thucydides provides a poignant account of the Plague of Athens and offers insights into the conflict. The Plague presents an intense drama about how the epidemic exposes the weaknesses of human society and its inhabitants, who were helpless against the scourge, regardless of rank or wealth. Thucydides' observations are profoundly distressing regarding human life's fragility while highlighting human nature's resilience and resourcefulness when confronted with a new situation.

The Plague spread quickly in Athens, a highly populated city, exemplifying the importance of understanding the disease's mechanism and how it could have been prevented. Thucydides

remarks on the limitations of medicine in his time in coping with the plague. He also indicates the significance of environmental factors such as overcrowding, unsanitary conditions, and inadequate infrastructure in facilitating the epidemic. These reflections underscore the need for robust public health systems, enhanced disease surveillance, and effective outbreak mitigation strategies.

Although the specific pathogen responsible for the Plague of Athens remains unidentified, scholars continue to debate whether it is a bacterial disease, such as typhus, plague, or typhoid fever, or a viral disease, like smallpox or measles. Nonetheless, this epidemic is one of the earliest documented instances of innate immunity.

In Thucydides' account, social cohesion deteriorates, conventional political institutions erode, and pronounced psychological distress, pervasive in Athens, is characterized by the afflictive emotions of fear, anxiety, and uncertainty. The powerful effects of epidemic disease on Athenian society—politically, socially, and psychologically—serve as a reminder of how epidemic disease can affect society. He suggests that epidemics are not only a threat to the physical health of populations; they erode societal morale, destabilize governance, and revise the course of history. The Athenian Plague is a lesson on how countries should focus not only on the medical and biological aspects of infectious diseases but also on the social and psychological effects.

Two and a half millennia later, Thucydides' account of the Plague of Athens remains one of the most relevant historical parallels to modern global events. The effects of infectious diseases, social unrest, and political instability continue to shape our world. This highlights that the historian's analysis of pandemics and large-scale conflicts is still pertinent and can provide valuable

insights. We need Thucydides more than ever, as he helps us understand what pandemics can do, reshaping the world like wars. The Plague of Athens, along with the Peloponnesian War itself, serves as evidence of the enduring impacts of disease on society and urges us to confront the challenges of our time to prevent what Thucydides himself described as “no other (war) was like it” (οὐχ ὁμοία ἄλλη) [1].

### Author contributions

P.D. and L.P. designed the review, while all authors conducted the literature search. P.D. drafted the manuscript. All authors contributed to the report and approved the final version.

### Transparency declaration

#### Potential conflict of interest

The authors declare that they have no conflicts of interest.

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### Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly Editor Version 1.5.81 to enhance the clarity and language of the work, as well as to fix spelling and punctuation errors throughout the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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