



## A multi-disciplinary management of childhood neurotoxicity (from lead exposure & poisoning): Why educational therapy should be included

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### Abstract

Lead exposure and poisoning (PbEP) as an entity remains one of the most preventable environmental health hazards today. The ongoing dangers of PbEP continue to affect millions of people worldwide. Often the PbEP treatment involves only medical intervention. This paper emphasizes the need to include Educational Therapy (EdTx) as one crucial aspect in the multi-disciplinary management of childhood neurotoxicity from PbEP. While medical interventions such as chelation therapy are essential to removing lead (Pb) from the body, Educational Therapy (EdTx) also plays a vital, yet often neglected, component of long-term healthcare management program. EdTx directly addresses the persistent neurodevelopmental, behavioral, and academic impairments caused by PbEP in the early childhood. Drawing parallels to several global cases, the author argues for a sustained, multi-disciplinary approach, involving key professionals from both medical and allied fields, not only just to treat the immediate toxicological effects, but also to support the lifelong learning and cognitive rehabilitation needs of children affected by PbEP.

**Keywords:** Educational therapy (edtx), individualized intervention plan/program (iip), lead exposure and lead poisoning (pbep), multi-disciplinary management

### Introduction

According to the World Health organization (WHO, 2022) [48], lead exposure (PbE for short) and lead poisoning (PbP for short) are considered a dual environmental hazard (PbE + PbP = PbEP, which represents the dual environmental hazard) that remains to one of the most preventable environmental health hazards. On the one hand, PbE refers to coming into contact with lead (Pb for its chemical symbol), which itself is a contaminant, in the environment (e.g., through contaminated air, water, soil, paint, or household dust) (Roberts *et al.*, 2022) [37]. This constitutes the first environmental hazard, i.e., the presence of Pb in the environment, e.g., Pb-based paints, especially in older homes, plumbing systems that use Pb pipes, and contaminated soil near industrial sites. This first hazard concerns the risk of exposure. On the other hand, PbP is the health effect or condition resulting from excessive lead exposure (Lanphear, Navas-Acien, & Bellinger, 2024) [26]. This constitutes the second environmental hazard, which concerns the health outcomes as a result of PbP. It is a known fact that PbP is the toxicological hazard, with effects including cognitive impairments in children, damage to kidneys, severe cardiovascular and neurological problems. Even today, in the 21<sup>st</sup> century, PbEP continues to affect millions of people worldwide, especially children (Ritchie & Roser, 2022; WHO, 2022) [36]. It occurs when Pb, being a toxic heavy metal element, builds up in the body, often through PbE. Even small amounts of Pb can result in serious harm, such as severe developmental delays, challenging learning problems, and also with grave damage to vital organs (e.g., brain, heart, liver and kidneys). Understanding the causes, effects, and prevention of PbP is vital for protecting vulnerable populations and promoting healthier communities.

The aim of this paper is to examine the developmental, cognitive, behavioral, and socio-emotional consequences of PbEP in the early childhood stage, and to highlight how educational therapy (EdTx) can serve as a remedial and supportive intervention, working alongside medical care, to reduce learning difficulties, support adaptive functioning, and empower families through psychoeducation as well as therapeutic alliance between the parents and the educational therapists based on mutual trust and collaboration.

### Lead Exposure & Poisoning (PbEP) Cases Reported Elsewhere

According to Hernberg (2000) [20], PbEP was already known in antiquity. However, the issue of PbEP gradually faded from medical literature. It was not until the late Middle Ages that the PbEP matter resurfaced sporadically. Much later, Hernberg (2000) [20] explained “[I]n the 19th century this disease, *PbEP*, which reached epidemic dimensions during the period of industrialization, was ‘rediscovered’” (p. 244; the term *PbEP* in italic is added by the author). As a result, it prompted a number of detailed Pb-related clinical studies (Lanphear, Navas-Acien, & Bellinger, 2024) [26]. By the 20th century, growing awareness of subclinical and early effects, especially in children, transformed PbEP from a purely clinical issue into a major public health concern, leading to stricter hygienic standards and the rise of preventive efforts today (Hernberg, 2000) [20]. Ritchie and Roser (2022) [36] raised a serious issue of concern that Pb pollution or PbEP remains a widespread problem, but it receives little attention. They quoted from the Institute for Health Metrics’ (2017) [23] Global Burden of Disease study which estimated that in 2019, lead exposure (PbE) was responsible for just over 0.9% of global disability-adjusted life years (DALYs): “[L]ead poisoning is estimated to account for about 1% of the global disease

burden” (Ritchie & Roser, 2022, para. 1) [36]. According to the World Health Organization (WHO, 2022) [48], “[A]lmost 1 million people die every year due to lead poisoning, with more children suffering long-term health effects” (WHO, 2022, para. 1). This is indeed an issue that requires an international attention to address the challenging problem. Between 2010 and 2025, there are 10 widely-reported PbEP

incidents worldwide, ranging from serious outbreaks, water crises, food contamination events, and institutional scandals (see Table 1 below). Naranjo, Hendricks, and Jones (2020) [31] argued that the neurotoxicity of PbEP in children remains an unremitting public health problem today. Table 1 provides a summary of the 10 notable PbEP incidents reported in the past right to the recent Gansu incident.

**Table 1:** A Summary of 10 Worldwide PbEP Incidents

When	Where & Source	What happened
2010	Zamfara State, Nigeria Source: Blacksmith Institute (2011) [5]	A major mining-related PbP outbreak in Zamfara State killed over 163 children and affected hundreds. Although it predated the last decade, cleanup and long-term health impacts persisted into subsequent years.
2015	Bangladesh & South Asia Source: Mickle & Forsyth (2024)	Lead chromate (PbCrO <sub>4</sub> ) was added to turmeric and it was found to link to pregnant women having extremely high Pb levels (PbLs), with up to six times those seen in Flint, Michigan, USA. The contamination work by Jenna Forsyth led to bans and public health reforms across Bangladesh.
2016 to Present	Newark, New Jersey, USA Source: Mickle & Forsyth (2024)	Elevated PbLs were observed in multiple schools beginning in 2016, and affected over 200,000 residents by 2020. In October 2024, a contractor was found to have falsified replacement reports while not completing work.
2016 to Present	Pittsburgh, Pennsylvania, USA Source: Glenza (2017) [16]	Since 2016, PbLs in water has exceeded the U.S. safety standards. The corrosion control issues can be traced back to cost-saving measures. The local authority went on to launch remediation, including orthophosphate corrosion control and replacing ~13,000 lead service lines.
2019	Republic of Georgia Source: Georgian National Center for Disease Control and Public Health (2020) [15]	National study found that 41% of Georgian children aged 2-7 to have elevated PbLs (≥ 5 µg/dL). This was largely linked to leaded spices, paint, toys, and soil, but without an acute outbreak context.
2021 February	East Otago, New Zealand Source: Elder (2021) [14]	An incident on Lead Water Scare was reported to take place in two towns in New Zealand was found to contain PbLs ~40× acceptable limits. 1,512 residents were tested with no hospitalizations required, and long-term risk deemed minimal.
2023 October to 2024 January	St Croix, Virgin Islands, USA Source: Simon (2023) [40]	A state of emergency was declared after Pb and copper (Cu) contamination impacted ~3,800-4,000 homes. The local authorities identified the root causes due were aging infrastructure and brass pipe components.
2023-2025	USA (nationwide) Source: Columbia Broadcasting System (2025) [11]	In 2023, over 500 U.S. children fell ill by Pb-contaminated applesauce pouches that were sold nationwide. Then in May 2025, Publix issued a voluntary recall of baby food pouches that found to exceed the Pb limit permitted by the US Food and Drug Administration. Despite elevated PbLs, no illnesses were reported.
2024	United Kingdom Source: Hughes (2024) [22]	Legacy Pb paint in older homes caused serious concern after a 6-year-old was found to have Blood Lead Levels (BLLs) nearly twice the UK intervention threshold. These estimates suggest hundreds of thousands of children in the UK may have elevated PbLs undetected.
2025 July	Tianshui City, Gansu province, China Source: China Digital Times (2025) [9]	At least 233 of 251 preschoolers were found to have elevated BLLs with several severe cases confirmed. The source was traced to industrial pigment added to food, masqueraded as food dye. Multiple officials suspended or arrested due to data falsification and regulatory failures.

**Keys:** dL=deciliter; µg=Micrograms

**What is Lead Poisoning (PbP)?**

“Lead poisoning (including lead exposure) is a serious problem for children - the younger the child, the greater the risk” (Office of Pollution Prevention & Toxics, 2024, p. 8) [32]. This is because “[L]ead can be absorbed after inhalation or ingestion and is toxic to most organ systems” (Elamin, Bradberry, & Dear, 2024, p. 380) [13]. Recently, the China Digital Times (2025) [9] reported a PbP incident in Gansu province of China, highlighting a serious need for both the general public and the professionals to know and understand what PbP, also previously known as plumbism (Smith, Rathmell, & Marcil, 1938) [42] or saturnism (Haley, 1971; Lelievre *et al.*, 2020) [18, 27], is and the harm it can cause and the effects from the exposure and poisoning. According to the Mayo Foundation for Medical Education and Research (MFMER, 2025) [29], “Lead poisoning occurs when lead builds up in the body, often over months or years.

Even small amounts of lead can cause serious health problems. Children younger than 6 years are especially vulnerable to lead poisoning that can severely affect mental and physical development. At very high levels, lead poisoning can be fatal” (para. 1). It is for this reason that the Gansu PbP incident becomes a big news, not only within the province, but throughout the mainland China, and it also warrants a closer investigation to uncover the root cause (see China Digital Times, 2025, for details) [9]. However, it is not the main focus of this paper. According to the Educator’s Diagnostic Manual (EDM; Pierangelo & Giuliani, 2007) [34] used by the professionals in the field of educational therapy (EdTx), PbP is nosologically categorized in the EDM’s multilevel coding system, under the Level 1 Other Health Impairments (OHI) (based on the specific IDEA 2004 classification) as a specific disorder at Level 2 OHI18.00-Lead Poisoning. The

EDM follows the 13 disability categories listed in the IDEA 2004 (PL No. 108-446). The EDM Level 2 OHI18.00-Lead Poisoning provides the following definition of PbP: “Lead is a metal that can make infants and young children ill, though many of those affected never look sick. Sometimes children with lead poisoning can have learning disabilities and other health problems. Lead poisoning can be detected and it can be prevented” (Pieragelo & Giuliani, 2007, p. 225).

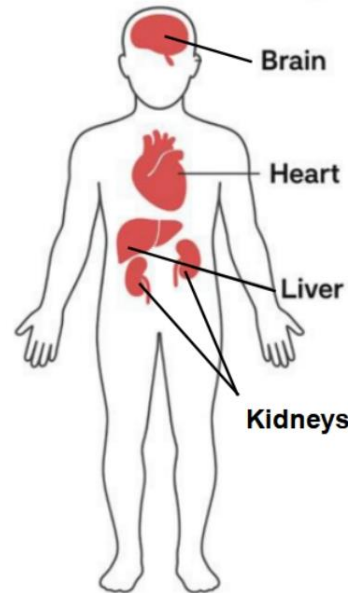
There are eight common non-specific symptoms related to PbEP found under the EDM’s diagnostic code, OHI18.00-Lead Poisoning, that include the following: “irritability, loss of appetite, weight loss, sluggishness, abdominal pain, vomiting, constipation, and pallor from anemia” (Pierangelo & Giuliani, 2007, p. 225) [34]. Moreover, the Mayo Foundation for Medical Education and Research (MFMER, 2025) [29] has also included the following additional PbP symptoms: “developmental delay, learning difficulties ... sluggishness and fatigue ... hearing loss, seizures, eating things, such as paint chips, that are not food (pica)” (para. 5). According to MFMER (2025), “[I]nitially, lead poisoning can be hard to detect - even people who seem healthy can have high blood levels of lead. Signs and symptoms usually don't appear until dangerous amounts have accumulated” (para. 4). Other symptoms of PbP also include “stomach pain, nausea, fatigue, and blackened teeth” (Davidson, 2025, para. 5) [12].

**How Lead Exposure & Poisoning (PbEP) impacts on the Human Body and Its Systems**

In a quick online survey of several comprehensive research studies (e.g., Huang, Shi, & Wu, 2021; Mandal, Mandal, & Chakraborty, 2022; Zhang *et al.*, 2025) [21, 28, 50] on the impact of PbEP on human body, findings show that PbEP is a multi-system toxic threat, affecting everything from the blood vascular or hematologic system (Aktepe, Baran, & Baran, 2022) [11] and the cardiovascular system (Wang *et al.*, 2022a) [45] to the brain and nervous function (Wang *et al.*, 2022b) [46], the kidneys and renal system (Kuracaiad & Kotepui, 2021) [24], the reproductive system (Qu *et al.*, 2021) [35], the liver and hepatic system (Yu *et al.*, 2024) [49], bones and teeth (Boskabady *et al.*, 2022) [7], the

gastrointestinal tract (Safae *et al.*, 2023) [38], and the immune system (Harshitha, Bose, & Dsouza, 2024) [19]. It is crucial that prompt detection, prevention, and minimizing exposure are critical, and no level of PbEP is truly safe.

Figure 1 below highlights the key organ systems in the human body affected by PbEP.



**Brain:** PbEP causes neurological impairment to the brain development & function, resulting in cognitive deficits, learning disabilities as well as behavioral problems.

**Heart:** PbEP can increase blood pressure & also contribute to cardiovascular diseases.

**Liver:** PbEP disrupts liver enzyme function & can also cause oxidative stress as well as liver damage.

**Kidneys:** PbEP accumulates in the kidneys, impairing their function & potentially leading to chronic kidney disease.

**Fig 1:** Key Organs affected by Lead Exposure & Poisoning (PbEP)

In other words, PbEP impacts nearly every major system in the body. Table 2 below provides a summary (with evidence-backed explanations and relevant citations) of key systems and organs that can be affected by PbEP.

**Table 2:** A Summary of Key Systems affected by Lead Exposure & Poisoning (PbEP)

Affected Key Systems	How
1. Hematologic System (including the blood) Source: Aktepe, Baran, & Baran (2022) [11]	Lead inhibits key enzymes in heme synthesis (e.g., ferrochelatase & ALAD), causing anemia, reduced red blood cell production, & fragile blood cells.
2. Cardiovascular System (including the heart) Source: Wang <i>et al.</i> (2022a) [45]	Chronic PbE raises blood pressure, contributes to heart disease, stroke risk, vascular damage, & can also impair cardiac conduction.
3. Nervous System (including the brain) Source: Wang <i>et al.</i> (2022b) [46]	Central Nervous System (especially in children): Pb disrupts neurotransmitter function, impairs synapse formation, myelination, & neuron growth, leading to cognitive deficits, developmental delays, reduced IQ, behavioral problems, & even encephalopathy in cases of high exposure.
	Peripheral Nervous System (more in adults): Pb leads to degeneration of nerve axons and myelin, resulting in weakness, sensory loss, & coordination issues.
4. Renal System (involving the kidneys) Source: Kuracaiad & Kotepui (2021) [24]	Leads to both acute and chronic kidney damage. In acute cases, proximal tubular dysfunction (e.g., glycosuria, aminoaciduria) may occur. Chronic PbE may result in irreversible nephropathy & hypertension.
5. Reproductive System Source: Qu <i>et al.</i> (2021) [35]	Male (Man): Reduced sperm count, motility issues, abnormal morphology, chromosomal damage, & lowered testosterone.
	Female (Women): Increased risk of miscarriage, low birth weight, preterm birth, menstrual irregularities, & fetal developmental harm. Pb crosses the placenta & stored bone lead can affect fetuses.

8. Hepatic System (involving the liver) Source: Yu <i>et al.</i> (2024) <sup>[49]</sup>	Pb has been linked to liver toxicity, causing structural damage, enzyme elevation, steatosis, & impaired liver function.
4. Skeletal System (involving bones & teeth) Source: Boskabady <i>et al.</i> (2022) <sup>[7]</sup>	Primary storage sites for lead. In adults, about 85–95% of body lead is stored in bones; in children, around 70%. Lead accumulates over time & can be released into the blood, especially during pregnancy or bone remodeling.
6. Gastrointestinal Tract Source: Safae <i>et al.</i> (2023) <sup>[38]</sup>	Direct irritation & disruption of digestive function lead to symptoms such as abdominal pain, nausea, constipation, cramping, & appetite loss.
9. Immune System Source: Harshitha, Bose, & Dsouza (2024) <sup>[19]</sup>	Pb can suppress immune function, altering production of inflammatory cytokines & impairing both innate & adaptive immune responses.
10. General & Miscellaneous Effects Source: Huang, Shi, & Wu (2021) <sup>[21]</sup>	Symptoms like fatigue, malaise, weight loss, metallic taste, joint & muscle pain, tremors, & even neurological symptoms (e.g., seizures or convulsions) in severe cases, are also reported.

### Is Educational Therapy (EdTx) an Appropriate PbEP Intervention?

Within the context of medical practice, management of individuals with PbEP involves removal the source of Pb or avoidance of PbE. However, in more severe cases, chelation therapy (Borough & Pomerleau, 2025; Specht *et al.*, 2024) <sup>[6, 43]</sup> with either sodium calcium edetate ( $C_{10}H_{12}CaN_2Na_2O_8$  or EDTA) (Ogar & Okafor, 2024; Specht *et al.*, 2024) <sup>[33, 43]</sup> or dimercaptosuccinic acid (DMSA) (Elamin, Bradberry, & Dear, 2024; Singh *et al.*, 2025) <sup>[13, 41]</sup>, a succimer, which has been prescribed as a safe oral chelator in PbP (Balali-Mood *et al.*, 2025) <sup>[2]</sup>, is used to treat PbEP. The chelator binds to the Pb is excreted from the body. In addition, supportive care service may include monitoring for and managing complications affecting the nervous system, kidneys, and other organs (Elamin, Bradberry, & Dear, 2024) <sup>[13]</sup>.

In addition to the medical treatment for PbEP, there is a neuroscience-informed, non-pharmacological intervention known as Educational Therapy (EdTx) that can serve as a complementary approach alongside chelation therapy. EdTx is an allied field to medical science that “has been officially recognized by the World Health Organization (WHO) and classified under the procedural code 93.82 since 1986 in the WHO’s International Classification of Diseases-9th Edition-Clinical Modifications, Volume 3 (ICD-9-CM, Version 3) (WHO, 1986)” (cited in Chua & Chia, 2023, p. 5) <sup>[10]</sup>. Relevant healthcare authorities should seriously consider including EdTx in a multidisciplinary approach to managing PbEP by addressing the cognitive, behavioral, and academic impairments, which often persist even after a reduction in BLLs through medical treatment. While medical treatments (e.g., chelation therapy) aim to remove Pb from the body, they do not reverse the neurodevelopmental damage already caused by PbEP (e.g., attention deficits, executive functioning impairments, poor language processing, and low academic achievement) (Bellinger, 2008) <sup>[4]</sup>. Educational therapists can play a critical role in managing or remediating these effects through individualized intervention programs to support learning and behavior, particularly in children from high-risk environments. By providing cognitive remediation, environmental modifications, and emotional support, EdTx helps to complement medical treatment and also contribute to long-term functional outcomes in children with PbEP (CDC Advisory Committee on Childhood Lead Poisoning Prevention, 2012; Lanphear *et al.*, 2025) <sup>[8, 25]</sup>.

### What Educational Therapists need to know and do about the PbEP Incident

The recent Gansu incident offers a grim reminder for all educational therapists to take note because PbEP has serious, often irreversible repercussions on cognitive, behavioral, and academic development in young children (Guo, Najafi, & Zhang, 2025) <sup>[17, 50]</sup>. These effects directly inform the EdTx interventions and crucial supports required. Therefore, educational therapists can play a vital role in supporting young children with PbEP by addressing the triad of challenges, i.e., cognitive, behavioral, and emotional problems that can arise due to the neurotoxic effects of Pb. This condition disproportionately affects young children under 6 years of age due to their developing brains and hand-to-mouth behavior (Lanphear *et al.*, 2025) <sup>[25]</sup>. EdTx integrates specialized instructional techniques, cognitive rehabilitation, behavioral supports, and emotional scaffolding to mitigate the developmental impacts of PbEP. The author of this paper delineates four underlying reasons to advocate for the application of EdTx in the management of children with PbEP: Firstly, EdTx can be applied to address the neurocognitive and behavioral deficits seen in children with PbEP. These are the neurotoxic effects caused by PbEP (Guo, Najafi, Zhang, 2025) <sup>[17, 50]</sup> disrupting the synapse formation, neurotransmitter systems, and brain structure, particularly in the prefrontal cortex (PFC), leading to impaired executive functioning, working memory, attention, language, problem-solving, and motor skills in children (MFMER, 2025). In addition to the elevated BLLs, children with PbEP also display lower IQ, slower language development, and more learning disabilities compared to their non-PbEP peers.

Secondly, children with PbEP show academic underachievement and learning gap which can be best addressed by the EdTx-based intervention program. Even moderate PbEP (ranging between 5  $\mu\text{g}/\text{dL}$  and 20  $\mu\text{g}/\text{dL}$ ) before age 3 is associated to significantly lower test scores, i.e., up to a 22 % reduction in reading and a 42 % gap in math proficiency by 4th grade (Trejo, Yeomans-Maldonado, & Jacob, 2024) <sup>[44]</sup>. Children with PbEP who have BLLs above 5  $\mu\text{g}/\text{dL}$  often score lower IQ points (~3 to 5 IQ points lower), negatively affecting their school success and long-term life outcomes (Lanphear, Navas-Acien, & Bellinger, 2024) <sup>[26]</sup>.

Thirdly, behavioral and emotional challenges are seen in children with PbEP, especially self-regulation difficulties (e.g., hyperactivity, impulsivity, aggression, and attention

deficit behaviors) and higher risk of mental health issues (e.g., ADHD, anxiety and antisocial behaviors later in life), impacting classroom behavior and peer relationships (Shaffer *et al.*, 2022) [39]. EdTx can offer a plausible long-term solution to address these socio-emotional behavioral issues through, e.g., behavioral therapy and socio-emotional learning.

Lastly, any PbEP incident that happens anywhere in the world should remind educational therapists that they need to tailor neuropsychological assessment (NPA) for children with PbEP by collaborating with medical teams, educators and other allied professionals (e.g., psychologists, occupational therapists, and speech-language therapists) as well as families because Pb-induced brain injury affects discrete domains. The administration of comprehensive evaluations within the context of EdTx should go beyond just IQ assessment in order to implement individualized intervention programs or plans (IIPs) targeting both learning and behavior (e.g., attention, emotional adjustment, executive functioning skills, language development, motor skills, processing speed, and working memory). Results obtained from the administration of a comprehensive NPA enable educational therapists to better identify the deficits that impact on children with PbEP in order to design appropriate IIPs. Each IIP should include the following essential activities: (i) core academic support, (ii) behavioral regulation strategies, (iii) fine motor training, (iv) social-emotional skills, and (v) speech-language therapy. The design of an IIP often involves school-based plans, i.e., Section 504 plans or Individualized Education Programs (IEPs) in the United States. For children with PbEP, whose BLLs are above 5 µg/dL, early support (e.g., continuous or ongoing monitoring by educational therapists, enrichment programs, and parental involvement interventions), particularly during the preschool years, is warranted to help mitigate some of the developmental harm caused by PbEP (Balza, Bikomeye, & Flynn, 2024) [3].

Moreover, the PbEP in young children (especially in the early childhood phase) has measurable, lasting impacts on brain development and function, intellectual capacity, academic achievement, and socio-emotional behavioral regulation. These eventual outcomes necessitate robust assessment, individualized intervention strategies, and cross-disciplinary coordination among different professionals involved in PbEP management or treatment. Educational therapists play a pivotal role in identifying and addressing the unique learning and behavioral needs arising from PbEP so that affected children receive the support essential for their long-term development and well-being.

## Conclusion

Although medical treatment for PbEP through chelation therapy (e.g., using either EDTA or DMSA) can help to address the physiological removal of Pb, the cognitive and behavioral deficits resulting from early PbEP often persist. This is where EdTx plays a pivotal role in the PbEP management program. As a neuroscience-informed and child-centered practice, EdTx complements medical treatment by directly targeting the developmental, academic, and socio-emotional impairments caused by PbE.

The recent Gansu PbEP incident in China should serve as a sobering reminder for more global education to be done and health systems to improve. It highlights the need for cross-sectoral and multi-disciplinary collaboration among

educators, medical and healthcare professionals, and policymakers. Looking ahead, comprehensive public healthcare and wellness strategies should integrate environmental and regulatory reforms as well as educational and therapeutic interventions to facilitate full recovery and life-long outcomes of PbEP-affected children. Only with this multi-pronged approach can the long-term damage or harm caused by PbEP be truly mitigated.

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**Data Availability Statement:** Not applicable

**Ethics approval:** Not applicable

## Disclaimer

The author hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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