

## CASE STUDY

# A Case Study on Ayurvedic Management on Vatarakta with Special Reference to Hyperuricemia

**Krupa Parmar and Sangeeta H Toshikhane**

Department of Panchkarma, Parul University, Parul Institute of Ayurveda, Vadodara, Gujarat, India

**Corresponding Author:** Sangeeta H Toshikhane

**Email id-**sangeeta.toshikhane26791@paruluniversity.ac.in

### ABSTRACT

*Ayurveda, an ancient healing system, believes that illnesses stem from an imbalance in the body's fundamental components. When these essential elements are in harmony, it's a sign of good health and being disease-free. Ayurvedic treatments and remedies are very effective at helping to restore and maintain this crucial balance within the body. Vatarakta is a health condition that arises from a specific imbalance between Vata and Rakta. In this scenario, Vata, becomes intensified or aggravated. This aggravated Vata then encounters an obstruction or blockage caused by vitiated Rakta (impurified or unhealthy blood). This initial blockage further exacerbates the Vata. Ultimately, this significant imbalance doesn't just affect a localized area; it has a widespread impact, compromising the integrity of the entire Rakta dhatu, which then fully manifests as Vatarakta. Several lifestyle and dietary factors are recognized as significant contributors to the development of Vatarakta. Specifically, consuming foods that are spicy (Katu), sour (Amla), and excessively hot (Ushna) can aggravate Vata and vitiate Rakta, setting the stage for this condition. Considering how it develops and its underlying causes, vatarakta appears to have a potential connection with hyperuricemia or gout. A 42 years old female patient approached the OPD with the chief complaints of pain in bilateral knee joints, both shoulder joints and fingers of both the hands from last 6 months. The patient also complained of generalized weakness, anorexia, and difficulty in walking from last 2.5 months. The patient received 12 days of comprehensive Ayurvedic medicines and Panchakarma therapies. Upon discharge, she continued solely with Ayurvedic medications, and her condition significantly improved. This notable progress prompted the current study, aiming to demonstrate the remarkable efficacy of Ayurvedic treatment, specifically Mustadi takra Basti, in managing hyperuricemia (Gout). Observations and outcomes were meticulously documented against predefined measurement criteria. A thorough discussion of all findings was conducted during the analysis, leading to conclusions drawn directly from the observed results.*

**Keywords:** Mustadi takra basti, vatarakta, hyperuricemia, gout, vata dosha.

Received 28.08.2025

Revised 08.09.2025

Accepted 21.11.2025

### How to cite this article:

Krupa P and Sangeeta H T. A Case Study on Ayurvedic Management on *Vatarakta* with Special Reference to Hyperuricemia. Adv. Biores. Vol 16 [6] November 2025. 544-550

### INTRODUCTION

Hyperuricemia and gout are medical conditions resulting from excessive uric acid production or inadequate excretion, a byproduct of purine metabolism normally eliminated through urine. These conditions often coincide with chronic diseases like hypertension, diabetes mellitus, metabolic syndrome, kidney disorders, and cardiovascular diseases.[1] Hyperuricemia is defined as an elevated serum uric acid level, usually greater than 6 mg/dl, in women and 7 mg/dl in men. Elevated serum uric acid is present in an estimated 38 million people, and incidence is increasing worldwide as developing countries adopt more western diets and lifestyles. Additionally, social factors such as higher socioeconomic status, as well as history of smoking and alcohol use, further contribute to the heightened risk of developing this condition. Most people with this condition will not have obvious clinical manifestations.[2] The majority of individuals with hyperuricemia exhibit no symptoms, necessitating a high index of suspicion for diagnosis as serum uric acid levels are not routinely assessed in standard blood tests [1]. An estimated 21% of the general population and 25% of hospitalized patients may have asymptomatic hyperuricemia, with elevated uric acid levels potentially preceding clinical gout manifestations by 10 to 15 years.

Hyperuricemia does not inherently signify a pathological state due to its high prevalence and asymptomatic nature in 90% to 95% of individuals. Pacific Islanders exhibit particularly high rates of hyperuricemia. Men tend to have higher rates than women, as estrogen offers protection against hyperuricemia, and women may develop hyperuricemia post-menopause.[3][4][5] The most common clinical manifestations of hyperuricemia are associated with uric acid crystallization and deposition in joints and surrounding tissues. However, the exact mechanism underlying uric acid-induced tissue damage remains elusive.[6] Based on the manifestations of clinical signs/symptoms it can be co-related with vatarakta, according to ayurveda. Vata being predominant has potential to cause more serious and long-term diseases than pitta and kapha. It gets aggravated due to either avarana (hinderance in path) or dhatukshay (deficiency of body tissue). Vatarakta is one of the unique disorders among these all vata vyadhi which is the result of avarana of morbid vata dosha by vitiated Rakta dhatu. This causes the derangement of rakta dhatu resulting in vata shonita.[7] In contemporary science, the NSAID'S are used in treatment of gout as compliance with long term treatment, and can cause allopurinol intolerance, renal failure, certain drug interaction. Acharya Charak and Acharya Vagbhatt mentions 'Na hi vasti saman kinchit vatarakta chikitsitam'. There is no other therapeutic measures equivalent to basti in treating vatarakta. As basti is considered as agrya aushadha for vata, Mustadi takra basti along with shamana aushadhis are adopted here to reduce the serum uric acid levels & clinical signs and symptoms of vatarakta.

### CASE REPORT

The present case is about the Ayurvedic management of Hyperuricemia i.e vatarakta. A 42-year-old, married female patient from an urban area having past history of vitamin B12, vitamin D, calcium deficiency visited Panchkarma OPD, Parul Institute of Ayurved, Vadodara, with the chief complaint of pain in bilateral knee joints, both shoulder joints and fingers of both the hands from last 6 months. The patient also complained of generalized weakness, anorexia, and difficulty in walking from last 2.5 months. The patient's height was 162 cm, weighing 65 kg and was looking tired. Also, from the ayurvedic perspective the case was diagnosed as vatarakta.

#### History of present illness

A 42 year old female patient was apparently healthy before 6 months i.e May 2024, used to consume daily lentils, black gram, red meat, coffee. Then gradually she developed complaint of pain in bilateral knee joints, pain in both metacarpophalangeal joints, both shoulder joints and generalized weakness Initially, these symptoms were mild but gradually severity of pain increased. Therefore, the patient was taking allopathic pain killers to reduce the pain but did not get complete relief from pain. Hence, the patient decided to visit hospital for further treatment. The doctors had advised serum uric acid test, through the test report the serum uric acid level was raised. She opted for the Ayurvedic treatment for better care and support. She was admitted in IPD of Panchkarma department, PAH, 18th may for 12 days.

**Table 1 : Patient Personal History**

|  |   |
|--|---|
| Name - ABC                                 | Height - 162 cm   |
| Age - 42 years                             | Bala - Avara  |
| Gender - Female                            | Appetite - Reduced  |
| Marital status - Married                   | Sleep - Sound   |
| Occupation - Housemaid                     | Bowel habit - 1 time/day; semisolid consistency, without straining.   |
| Weight - 65 kg                             | Bladder - 6-7 times/day ; pale yellow colored                         |
| Addiction - Tea (4-5 times) since 15 years | Menstrual history - 28-day regular cycle for 4-5 days of normal flow. |

#### History of Past Illness

The patient reported no personal or familial history of hyperuricemia and also denied the use of alcohol, tobacco, illicit drugs or any recent travel. The patient had history of vitamin B12 , vitamin D, and calcium deficiency about 3 months ago and was resolved by taking allopathic medications. The patient denied any previous surgeries.

#### Clinical Findings - General Physical Examination

The patient appearance was anxious with generalized weakness all over body. The pulse rate was 74 bpm, regular, blood pressure was 120/80 mm of HG, respiratory rate was 18/min. and temperature was 97.7oF. No lymph nodes were enlarged at that time.

**Table 2 : Systemic Examination of patient**

|                        |  |
|------------------------|--|
| Respiratory System     | Lung fields are clear, Air entry better          |
| Cardiovascular System  | S1S2 clear, No Murmurs                           |
| Gastrointestinal Tract | P/A- Soft, Normal bowel sounds, No Organomegaly. |
| Central Nervous System | Conscious and oriented, cooperative              |

**Table 3 : Ashtavidha pariksha (Eight-fold examination of the patient)**

|                                |                           |
|--------------------------------|---------------------------|
| Nadi – Kapha-pitta predominant | Mutra – Samyak            |
| Mala – Samyak                  | Jihva – kaphavritta       |
| Shabda – prakrit               | Sparsha – samanya, ruksha |
| Druk – Samyak                  | Akriti – madhyam          |

**Table 4 : Dashavidha pareeksha (Ten-fold examination of patient)**

|  |  |
|--|--|
| Prakriti (Physical constitution) – Kapha-pitta                           | Dushya – Rasa, rakta, mamsa, asthi.  |
| Aharaja hetu – Vatavardhak aahara sevana, katu, kashay, viruddha bhojana | Pramana – Madhyama   |
| Viharaja hetu – Ativyayam  | Satmya – Madhyam   |
| Manasika hetu – Krodha and chinta  | Ahara shakti – <ul style="list-style-type: none"> <li>• Abhyavarana shakti – Avara</li> <li>• Jarana shakti – Madhyam</li> </ul> |
| Dosha – vata and rakta   | Satva – Madhyama   |
| Vyayam shakti – Avara  | Desha – Sadharana  |
| Sara – Madhyam   | Samhanan – Madhyam   |
| Vaya – Madhyam   | Bala – Avara   |

**Table 5 : Samprapti ghataka:**

|                 |                                       |
|-----------------|---------------------------------------|
| Dosha           | Vata, Pitta (Rakta)                   |
| Dushya          | Rakta, Twaka, Mamsa                   |
| Adhishthana     | Rasavaha Srotas, Sandhi, Twaka, Mamsa |
| Srotas          | Raktavaha                             |
| Agni            | Mandagni                              |
| Ama             | Sama                                  |
| Srotodushti     | Sanga Pashchat Vimarg Gamana          |
| Udbhawasthan    | Pakwashaya                            |
| Vyakta Sthana   | Sarva Sandhi                          |
| Sadhya Asadyata | Kruccha Sadhya                        |
| Roga Marga      | Madhyama (Twak, Mamsa, Asthi, Sandhi) |

*Vata Prakopaka Ahara Vihara Sevana + Sukumara, Sthulta, Alasya & Achankramana*



*Annavidagdhat*



*Raktadushti*



*Dushta Rakta Sanchaya - Pada Moola + Swakarana Prakupita Vata*



*Sampoorna Rakta Dushti*



*Prakupita Vata & Rakta Sarva Sharir Prasara*



*Twak & Mamsa Ashraya – Uttana Vatarakta*



*Sandhi Ashraya – Gambhira Vatarakta*

**Figure 1 : Samprapti: [8]**

**Table 6 : Gradation of symptoms according to WHO scoring pattern [9]**

| Symptom        | Swelling          | Discoloration                                       | Burning sensation | Pain                                      |
|----------------|-------------------|---|-------------------|---|
| <b>Grade 0</b> | No swelling       | Normal coloration                                   | No burning        | No pain                                   |
| <b>Grade 1</b> | Slight swelling   | Near to normal which look like normal from distance | Mild burning      | Mild pain                                 |
| <b>Grade 2</b> | Moderate swelling | Reddish coloration                                  | Moderate burning  | Moderate pain but no difficulty in moving |
| <b>Grade 3</b> | Severe swelling   | Slight reddish black discoloration                  | Severe burning    | Slightly difficulty in moving due to pain |
| <b>Grade 4</b> | -                 | Blackish discoloration                              | -                 | Much difficulty                           |

**Table 7: Treatment Plan**

|   | Karma                                     | Dravya  | Days & Action                                  |
|---|---|---|--|
| 1 | Deepana-pachana                           | Chitrakadi vati<br>2-0-2 A/f<br>Amapachak vati<br>2-0-2 A/f | For 1-2 days(koshtha Shuddhi and agni deepana) |
| 2 | Sarvanga udvartana                        | Yava and sarshapa churna. -                                 | For 3-5 days (Rukshana)                        |
| 4 | Sthanika Abhyanga(After Nirama lakshanas) | Bala Taila  | For 6-12 days                                  |
| 5 | Swedana                                   | Baspa Sweda   |  |
| 6 | Basti                                     | Mustadi Takra Basti   |  |

Mustadi takra basti for 7 days\*

**Table 8 : Preparation of Basti (Detoxification)**

|   |              |   |
|---|--------------|---|
| 1 | Makshika     | 60ml  |
| 2 | Lavana       | 12 gm   |
| 3 | Sneha        | Dadimadi ghrita (50 ml)                                       |
| 4 | Kalka        | Pippali, musta, shunthi, nimba, guduchi- choorna (5 gms each) |
| 5 | Kwatha       | Musta siddha takra = 335ml                                    |
|   | <b>TOTAL</b> | 482 ml  |

**Table 9 : BASTI SCHEDULE**

| DAY 1 | DAY 2 | DAY 3 | DAY 4 | DAY 5 | DAY 6 | DAY 7 |
|-------|-------|-------|-------|-------|-------|-------|
| MTB   | MTB   | MTB   | MTB   | MTB   | MTB   | MTB   |

MTB- Mustadi takra basti

**Table 10: Shaman Aushadha: (After treatment below medicines are given)**

| SN | Medicine           | Dose   | Duration    | Anupana                            | Action   |
|----|--------------------|--------|-------------|------------------------------------|--|
| 1  | Dhatri Loha        | 250 gm | 2-0-2       | Lukewarm water (A/F)               | Tridosha shamana   |
| 2  | Sutshekhar rasa    | 250 mg | 2-0-2       | Lukewarm water (B/F)               | Jatharagni deepati (Rasendrasarasangraha)  |
| 3  | Kaishor Guggulu    | 250 mg | 2-2-2       | Lukewarm water (A/F)               | Tridoshaghna, Rasayana, Vatarakta Adhikar (Sharangdhara Samhita Madhyama Khanda 7/70-81) |
| 4  | Guduchyadi Kashaya | 15 ml  | 15ml-0-15ml | (B/F) with equal quantity of water | Jatharagni deepati (Ashtanga hrdayam sutrasthana 15/16)                                  |

(B/F) = Before Food (A/F) = After Food

## RESULTS

The patient's condition showed significant improvement throughout their hospital stay. By the time the Basti Chikitsa treatment was completed, no complications were observed, indicating a positive response to the therapy. While a full cure may require more time, the patient experienced considerable symptomatic relief as a direct result of the Ayurvedic treatment. This suggests that while full recovery can be a gradual process, the initial Ayurvedic intervention effectively alleviated discomfort and improved the patient's overall well-being during their hospitalization.

Table 11 : SUBJECTIVE PARAMETER (Showing changes in symptoms before and after treatment)

| SYMPTOMS                           | BEFORE TREATMENT | AFTER TREATMENT |
|------------------------------------|------------------|-----------------|
| Pain in B/L Knee joints            | 3                | 1               |
| Pain in B/L Shoulder joints        | 3                | 1               |
| Pain in metacarpophalangeal joints | 2                | 0               |
| Generalised weakness               | 2                | 1               |

Table 12 : OBJECTIVE PARAMETER (Showing changes in investigations)

| INVESTIGATION        | B.T        | A.T        |
|----------------------|------------|------------|
| Hemoglobin           | 12.0 gm%   | 13.8%      |
| CBC                  | Normal     | Normal     |
| E.S.R                | 40 mm/hr   | 29 mm/hr   |
| Urine(Routine/Micro) | Normal     | Normal     |
| RBS                  | 104 mg/dl  | 99 mg/dl   |
| S. Uric Acid         | 7.16 mg/dl | 5.49 mg/dl |

## DISCUSSION

### Mode of Action of Deepana-pachana aushadhi

In the treatment for hyperuricemia(gout), Deepana and Pachana are crucial initial treatments because they eliminate Ama: Vatarakta often stems from Ama (undigested toxins) obstructing channels, particularly blood vessels. Deepana prevents new Ama formation, while Pachana digests existing Ama, clearing blockages, they balance Vata by clearing Ama and obstructions, they allow Vata to move properly, significantly reducing the severe pain and inflammation characteristic of Vatarakta. Also removing Ama helps cleanse the Rakta Dhatu, which is vitiated in Vatarakta. This initial step strengthens digestion and reduces toxicity, making the body receptive and safe for more intensive purification therapy like basti chikitsa, which are often needed for Vatarakta. Essentially, Deepana-Pachana addresses the root metabolic imbalance, providing symptomatic relief and setting the stage for effective long-term management.

### Mode of Action of Udvartana

The vigorous, upward-stroking friction applied during Udvartana is instrumental in Srotoshodhana, effectively clearing the body's minute channels or micro-circulatory pathways. This enhanced local circulation helps to dislodge and mobilize accumulated Ama and inflammatory by-products from the affected joints and surrounding tissues. By improving both blood and lymphatic flow, Udvartana facilitates the efficient removal of these morbid substances, which are key contributors to the pain and inflammation in Vatarakta. Yava Churna is favoured for its Ruksha (drying), Laghu (light), and Sheeta Virya (cooling potency). Yava's Lekhana (scraping) property is highly beneficial, as it helps to gently scrape away these accumulated impurities from the skin and subcutaneous layers. Its cooling nature also helps in managing the inflammatory and burning sensations often associated with Vatarakta. Sarshapa Churna possesses Ushna Virya (heating potency), Tikshna (sharp), and Ruksha (drying) qualities. These properties make it a powerful stimulant. The heat generated from the massage with Sarshapa helps to liquefy stagnant Ama and vitiated Kapha, facilitating their easier mobilization and removal. Its sharp nature deeply penetrates the tissues, actively opening blocked Srotas (channels) and enhancing local circulation. This increased blood flow helps to draw out localized inflammation, reduce swelling, and bring nutrients to the affected area while carrying away metabolic waste products. Sarshapa's stimulating action also contributes to external Pachana (digestion of Ama) and can provide significant pain relief by warming and invigorating the affected region.

### Mode of action of Snehana

It supports the movement of Vata, promotes flexibility of the body, and helps clear blockages in the srotasas.

### **Mode of action of Swedana**

It aids in cleansing the bodily channels (Srotoshuddhi) and digesting toxins (Ama Pachana), which helps relieve stiffness, reduce excess moisture (Kleda), and promote a feeling of lightness.

### **Mode of action of Mustadi takra basti**

Mustadi takra basti comprising of madhu, saindhava, dadimadi ghrita, shunthi, pippali, musta, nimba, guduchi, and musta siddha takra. In charaka Samhita and ashtang Hridaya, dadimadi ghrita has been mentioned. Dadimadi ghrita contains- dadima, dhanyaka, chitraka, shunthi, pippali. Dadima is hridya, raktavardhaka, and shunthi is aam pachaka, dhanyak and chitraka is also Deepana- pachana, pippali is kaphavata shamaka. In Vatarakta, both Vata and Rakta are vitiated and Ama plays a significant role, Musta Siddha Takra offers highly targeted therapeutic benefits. Musta with Tikta (bitter), Katu (pungent), and Kashaya (astringent) tastes, possessing Laghu (light) and Ruksha (drying) qualities, and a Sheeta Virya (cooling potency). When Musta is integrated into Takra, it significantly enhances Takra's already beneficial properties for Vatarakta. Musta itself is a renowned Deepana and Pachana, excelling at digesting Ama and strengthening Agni. This is paramount in Vatarakta, where impaired digestion leads to Ama accumulation that blocks channels and aggravates Vata and Rakta, causing pain and inflammation. The combination ensures a more robust elimination of Ama from the system. Furthermore, Musta is explicitly described as Kapha-Pitta hara and Grahi, which helps in reducing excess fluid and stickiness often associated with inflammation in Vatarakta. Its Sheeta Virya directly counteracts the Ushna qualities of vitiated Rakta and Pitta, alleviating the acute inflammation frequently seen in gouty attacks. Takra is a natural probiotic. When administered as a Basti, it introduces beneficial microbes into the colon. A healthy gut microbiome is increasingly recognized in modern science for its profound impact on overall health, including metabolic regulation and immune function. By modulating the gut flora, Musta Takra Basti could contribute to better nutrient absorption, reduced systemic inflammation, and improved metabolic waste processing, all of which are relevant to managing hyperuricemia.

The emerging role of probiotics in managing hyperuricemia, often linked to conditions like gout, is gaining significant attention due to the intricate connection between gut health and uric acid metabolism. Primarily, certain probiotic strains, notably some Lactobacillus and Bifidobacterium species, possess enzymes like uricase that can directly break down uric acid within the gut lumen into more soluble and excretable compounds, thereby reducing the overall uric acid load on the kidneys. Beyond direct degradation, these beneficial bacteria can also metabolize purine compounds—the precursors to uric acid—within the intestine, thereby limiting the substrate available for uric acid production in the body. Furthermore, individuals with hyperuricemia frequently exhibit gut dysbiosis, and probiotic supplementation helps to restore a balanced and healthy gut microbiota, leading to improved overall metabolic function. Probiotics can also enhance the body's natural pathways for uric acid elimination through the intestines, improving the efficiency of its excretion. Lastly, their well-documented anti-inflammatory and immunomodulatory properties contribute to reducing the systemic inflammation often associated with hyperuricemia and gout flares, while also strengthening the intestinal barrier to prevent the leakage of pro-inflammatory bacterial products. Collectively, these mechanisms make probiotic usage a promising complementary strategy in the comprehensive management of hyperuricemia.

### **CONCLUSION**

Vatarakta has emerged as a prevalent and challenging disorder in modern times, largely attributed to sedentary lifestyles and improper dietary habits acting as key *Nidana*. A systematic understanding of *Nidana*, *Lakshana*, and *Samprapti* supports its classification under *Vata Vyadhi*, enabling a targeted therapeutic approach. Ayurveda offers not only symptomatic relief but also the potential for long-term management and holistic well-being.

Individualized treatment based on *Dosha*, *Dushya*, and disease stage is essential for effective management. In the present case, appropriately selected *Panchakarma* interventions—particularly *Basti* therapy tailored to *Kaphavatahara* or *Pittavatahara* requirements—demonstrated significant clinical efficacy. The therapies facilitated *Deepana*, *Pachana*, and *Rakta Prasadana*, along with notable *Shoolahara* and *Shothahara* effects.

Marked symptomatic relief was achieved within 12 days, supported by a significant reduction in serum uric acid levels. This case highlights the effectiveness of a comprehensive, *Dosha*-specific Ayurvedic approach in managing Vatarakta (hyperuricemia), underscoring the therapeutic potential of *Panchakarma* in chronic disease management without adverse complications.

## REFERENCES

1. Jin M, Yang F, Yang I, Yin Y, Luo JJ, Wang H, Yang XF. (2012): Uric acid, hyperuricemia and vascular diseases. *Front Biosci (Landmark Ed)*. Jan 1;17(2):656-69. doi: 10.2741/3950. PMID: 22201767; PMCID: PMC3247913
2. Yip K, Cohen RE, Pillinger MH. (2020): Asymptomatic hyperuricemia: is it really asymptomatic? *Curr Opin Rheumatol*. Jan;32(1):71-79. [PubMed]
3. Gosling AL, Matisoo-Smith E, Merriman TR. (2014): Hyperuricaemia in the Pacific: why the elevated serum urate levels? *Rheumatol Int*. Jun;34(6):743-57. [PubMed]
4. Wu X, You C. (2023): The biomarkers discovery of hyperuricemia and gout: proteomics and metabolomics. *PeerJ*. ;11:e14554. [PMC free article] [PubMed]
5. Yokokawa H, Fukuda H, Suzuki A, Fujibayashi K, Naito T, Uehara Y, Nakayama A, Matsuo H, Sanada H, Jose PA, Miwa Y, Hisaoka T, Isonuma H. Association Between Serum Uric Acid Levels/Hyperuricemia and Hypertension Among 85,286 Japanese Workers. *J Clin Hypertension*
6. Tian S, Liu Y, Xu Y, Feng A. (2019): Does obesity modify the epidemiological association between hyperuricemia and the prevalence of hypertension among Northern Chinese community-dwelling people? A Chinese population-based study. *BMJ Open*. Nov 21;9(11):e031803. [PMC free article] [PubMed]
7. Sharma AK. (2020): *Kaya Chikitsa*. Varanasi: Chaukhambha Orientalia.
8. Ajay Kumar Sharma, (2014): *Kaya Chikitsa - Hindi*, Dwitiya Bhaga, chapter 63, ED, Pub - Chowkhambha Orientalia, pg.912.
9. Developing guidelines for clinical research methodology in Ayurveda, Prof. M. S Baghel, Dr. Rajagopala S. (2005): -WHO / TRM guidelines, 2000 downloaded from [www.sho.int/entity/hiv/amds/WHOTCM2005.1OMS.pdf](http://www.sho.int/entity/hiv/amds/WHOTCM2005.1OMS.pdf) on 24.06.2006, New Delhi.

**Copyright:** © 2025 Author. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.