MANTECH Publications

Journal of Rog Nidaan, Vikrutividnyan & Shalya Tantra
Volume 3, Issue 2, July-December 2025

Predictive Analytics for Progression of Vikriti to Vyadhi: A Longitudinal Cohort Study Using Clinical and Digital Biomarkers in the Context of Shalya Tantra (Ayurvedic Surgery and Parasurgical Interventions)

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ABSTRACT

Predictive analytics in healthcare has emerged as a transformative tool for early detection, monitoring, and prognosis of disease progression. In the Ayurvedic framework, the transition from ***Vikriti*** *(dosha imbalance or pathological state) to* ***Vyadhi*** *(clinically manifested disease) is a dynamic and complex process influenced by multiple biological, environmental, and psychosocial determinants. This paper examines the role of predictive analytics in capturing longitudinal changes through both* ***clinical biomarkers*** *(traditional assessments, biochemical measures, surgical outcomes) and* ***digital biomarkers*** *(wearable data, imaging, AI-driven health parameters). In particular, this work contextualizes the principles within* ***Shalya Tantra****, a branch of Ayurveda that deals with surgery and parasurgical practices such as Kshara Karma, Agnikarma, and Jalauka application. By bridging predictive models with Ayurvedic pathophysiology, this study explores how modern analytics can forecast disease progression, optimize surgical decision-making, and improve patient outcomes. Five thematic areas are addressed: (1) conceptual grounding in Ayurveda, (2) cohort design and data integration, (3) predictive modeling approaches, (4) clinical implications for Shalya Tantra, and (5) future directions for digital health-Ayurveda convergence.*

KEYWORDS: *Predictive analytics, Vikriti, Vyadhi, longitudinal cohort, digital biomarkers, clinical biomarkers, Shalya Tantra, Ayurvedic surgery, parasurgical procedures, disease progression*

INTRODUCTION

The progression of pathological imbalance from Vikriti to Vyadhi constitutes a central theme in Ayurvedic nosology. Vikriti represents the earliest detectable abnormality at the level of doshas, dhatus, malas, and agni, while Vyadhi denotes a recognizable clinical condition with structural or functional manifestations. The challenge for contemporary healthcare systems is to detect and intervene during the Vikriti stage before irreversible disease processes unfold.

Shalya Tantra, though traditionally associated with surgical and parasurgical methods, requires robust preoperative, intraoperative, and postoperative evaluation. Predictive analytics—integrating longitudinal datasets from clinical and digital biomarkers—offers a unique opportunity to forecast complications, predict healing trajectories, and identify progression patterns in patients undergoing Ayurvedic surgical care. This convergence may modernize surgical Ayurveda by combining ancient diagnostic wisdom with advanced computational insights.

LITERATURE REVIEW

Traditional Understanding of Vikriti to Vyadhi

Ayurveda explains that disease emerges when dosha imbalances exceed the compensatory capacity of the body's homeostatic systems. This transition is described through *Shat Kriya Kala* (six stages of disease evolution), emphasizing early detection and preventive interventions. The Vikriti stage aligns with preclinical abnormalities, while Vyadhi represents the full manifestation of disease.

Modern Predictive Analytics in Healthcare

In biomedicine, predictive models based on longitudinal cohorts are used to assess disease risk, progression, and outcomes. Digital biomarkers from wearables, imaging, and AI-driven platforms supplement traditional clinical assessments. These models have been applied in cardiology, oncology, and neurology, but less frequently in integrative or surgical Ayurveda contexts.

Shalya Tantra and Data Science

Shalya Tantra's focus on procedures such as Kshara Sutra therapy, Agnikarma, and Raktamokshana necessitates outcome prediction and monitoring. Surgical wound healing, recurrence of fistula, or pain response are areas where predictive analytics could be revolutionary. Literature indicates limited systematic application of predictive modeling to Ayurvedic surgical outcomes, signaling an urgent research gap.

Table 2. Applications of Predictive Analytics in Shalya Tantra

Surgical/Parasurgical Domain	Predictive Focus	Clinical Benefit
Kshara Sutra Therapy (fistula)	Predicting recurrence & healing time	Tailored treatment schedules
Agnikarma (therapeutic cautery)	Forecasting pain relief duration & recurrence	Optimal intensity & frequency
Jalauka Avacharana (leech therapy)	Estimating inflammatory marker reduction	Personalized session intervals
Wound management	Healing trajectory prediction	Early identification of non-healing wounds
Shalyaghna interventions (foreign body removal, abscess)	Postoperative infection risk modeling	Targeted prophylaxis

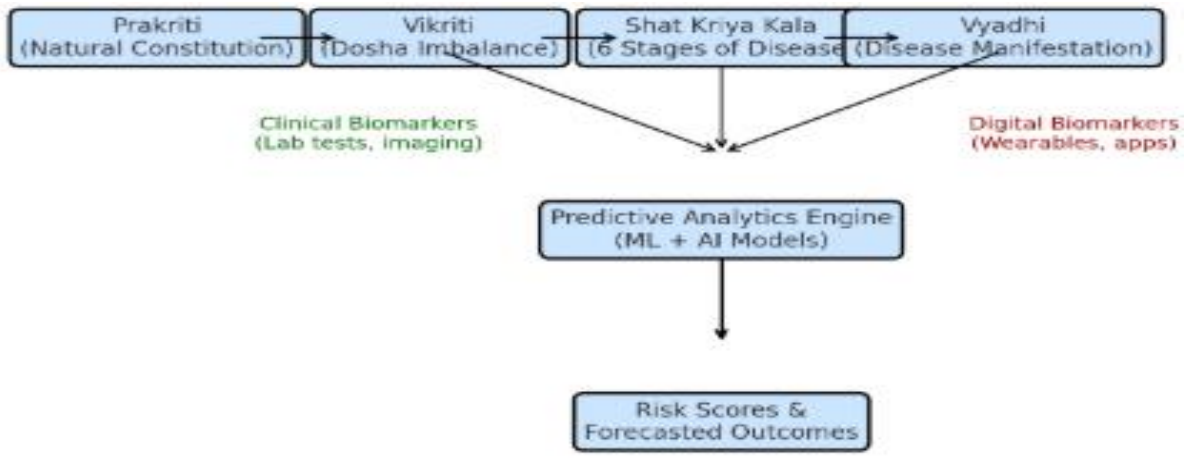

Figure 1. Conceptual Model of Vikriti-to-Vyadhi Progression Using Predictive Analytics

METHODOLOGY AND THEMATIC FRAMEWORK

To structure the exploration, five thematic areas are elaborated:

1. Conceptual Framework: Ayurveda Meets Predictive Analytics

Ayurveda emphasizes individualized diagnosis, considering Prakriti, Vikriti, Agni, Satmya, and Desha. Predictive analytics incorporates statistical and machine learning models that analyze temporal data for prognostic insights. Mapping Ayurvedic variables to quantifiable biomarkers—such as inflammatory markers, thermographic imaging, gait analysis, or heart-rate variability—creates a bridge between traditional and modern systems.

Table 1. Mapping of Ayurvedic Parameters with Modern Biomarkers

Ayurvedic Parameter	Clinical Biomarker Equivalent	Digital Biomarker Equivalent	Predictive Value
Dosha imbalance (Vata, Pitta, Kapha)	Inflammatory markers, metabolic profile	HRV (heart rate variability), sleep quality, stress tracking	Predicts systemic imbalance & disease risk
Agni (digestive/metabolic fire)	Blood glucose, lipid profile, gut microbiome markers	Continuous glucose monitors, food-logging apps	Early predictor of metabolic disorders
Dhatu status	Hematological & tissue-specific tests	Imaging (MRI, thermography)	Tracks degeneration or tissue healing
Mala elimination	Renal & liver function tests	IoT-based excretory monitoring	Detects toxin accumulation
Prakriti & Vikriti profile	Genetic susceptibility	Long-term lifestyle tracking	Risk stratification in cohort studies

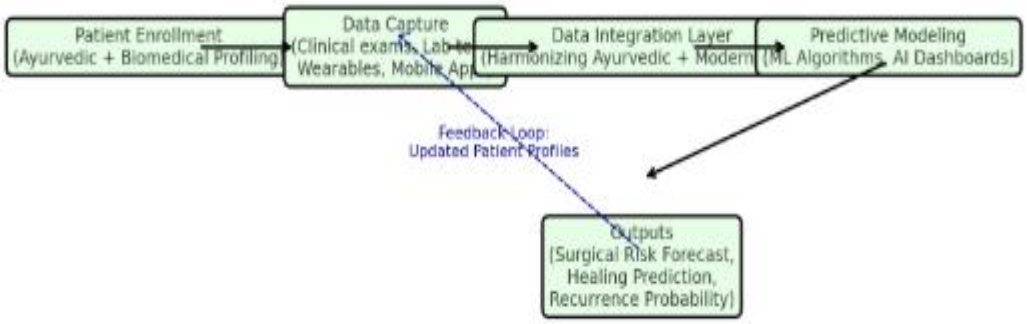

Figure 2. Longitudinal Cohort Data Pipeline for Shalya Tantra Patients

2. Longitudinal Cohort Design

Longitudinal cohort studies are essential for tracing Vikriti-to-Vyadhi progression. Participants are assessed repeatedly over time for:

- **Clinical biomarkers**: blood tests, wound healing parameters, pain scores, recurrence rates.
- **Digital biomarkers**: wearable activity trackers, imaging analytics, mobile health logs, natural language processing of symptom diaries.
  Such cohorts can include patients undergoing Shalya Tantra interventions, ensuring a blend of Ayurvedic and biomedical data streams.

3. Predictive Modeling Approaches

Predictive models may employ:

- **Regression models** to map dosha imbalance trajectories with clinical outcomes.
- **Machine learning classifiers** (random forests, SVMs) to stratify patients at risk of progression.
- **Time-series models** (LSTM, ARIMA) for real-time monitoring of biomarker evolution.
- **Explainable AI (XAI)** to ensure transparency, aligning with Ayurveda's emphasis on individualized reasoning (*Yukti*).

4. Clinical Implications for Shalya Tantra

Predictive analytics can inform Shalya Tantra in multiple dimensions:

- **Preoperative**: forecasting surgical risks based on dosha imbalance and digital biomarkers (e.g., predicting delayed wound healing in patients with Kapha-dominant

Vikriti and sedentary digital profiles).

- **Intraoperative**: real-time biomarker monitoring to adjust surgical decisions.
- **Postoperative**: prediction of recurrence, pain trajectories, or scar outcomes using machine learning models.
- **Parasurgical interventions**: optimizing Jalauka application schedules or Agnikarma intensity through predictive insights.

5. Future Directions and Integrative Scope

he future lies in multi-modal datasets uniting Ayurvedic diagnostic charts, genomic markers, digital health data, and surgical outcomes. Collaborative frameworks between Ayurvedic institutions, biomedical research, and computational sciences will be critical. Potential applications extend beyond Shalya Tantra into preventive medicine, personalized therapy, and global integrative healthcare.

CHALLENGES

Data Standardization

Ayurvedic parameters such as dosha imbalance are qualitative and subjective. Translating them into standardized, quantifiable variables remains a challenge.

Cohort Size and Diversity

Longitudinal cohorts require large, diverse populations to achieve predictive reliability. Ayurvedic surgical cohorts are often small and heterogeneous.

Integration of Digital Tools

Adoption of wearable devices and digital platforms in Ayurvedic settings may face technological and economic barriers.

Ethical Considerations

Predictive analytics must address privacy, consent, and data security, especially when sensitive digital health information is integrated.

SCOPE AND OPPORTUNITIES

Personalized Surgery

Predictive models can guide patient selection, timing of interventions, and tailored post-surgical care in Shalya Tantra.

Preventive Ayurveda

By forecasting Vikriti progression, interventions can be implemented before Vyadhi manifests, aligning with Ayurveda's preventive ethos.

Education and Research

Incorporating predictive analytics into Ayurvedic curricula can foster new generations of integrative practitioners.

Global Healthcare Integration

Showcasing evidence-based predictive frameworks rooted in Ayurveda may expand its credibility and integration into global health systems.

DISCUSSION

The fusion of predictive analytics with Ayurvedic paradigms marks a paradigm shift in understanding health and disease. Unlike conventional models that focus on disease management post-manifestation, this framework emphasizes early detection and dynamic monitoring, resonating deeply with the Ayurvedic focus on preventive care. In Shalya Tantra, this approach could reduce recurrence rates, enhance surgical precision, and improve patient satisfaction.

However, challenges persist in methodological alignment, including quantification of Ayurvedic constructs, designing interoperable digital platforms, and achieving multidisciplinary collaboration. Despite these limitations, the synergy of computational models with holistic Ayurvedic principles promises to yield transformative healthcare innovations.

CONCLUSION

Predictive analytics provides a powerful framework to forecast the transition of Vikriti into Vyadhi, especially when enriched by longitudinal data from clinical and digital biomarkers. In

the context of Shalya Tantra, such predictive approaches can revolutionize surgical and parasurgical care—enabling proactive, personalized, and evidence-driven interventions. While challenges in data standardization and technological adoption remain, the integrative potential is immense. The pathway ahead requires collaborative research, innovative methodologies, and ethical vigilance. Ultimately, the confluence of Ayurveda and predictive analytics could herald a new era in global health where ancient wisdom meets cutting-edge science for holistic patient care.

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