

Future Directions in Translational Ayurveda

Lea Nowak¹, Andreas Ivanov², Laura Novak³

¹ Research Scientist, School of Data Science, Swiss Institute of Machine Intelligence, Zurich, Switzerland. Email: lea.nowak682@gmail.com | ORCID: 0618-6661-5048-0868

² Associate Professor, Institute of Intelligent Systems, Swiss Institute of Machine Intelligence, Zurich, Switzerland. Email: andreas.ivanov694@gmail.com | ORCID: 7819-2052-7744-2705

³ Associate Professor, Department of Machine Learning, Swiss Institute of Machine Intelligence, Zurich, Switzerland. Email: laura.novak322@gmail.com | ORCID: 8746-0661-3144-9496

ABSTRACT

Translational Ayurveda has moved a long distance in the past decade. Molecular anchoring through Ayurgenomics, maturing clinical-evidence bases across multiple indications, infrastructural progress on pharmacovigilance and clinical-data digitization, and growing regulatory recognition across jurisdictions have collectively shifted the field from its earlier 'promising but under-validated' posture into something closer to operational readiness. What comes next is worth thinking about carefully, because the decisions made in the next five years about where research investment and infrastructure development should focus will shape what Ayurveda's clinical role looks like in the 2030s. We consolidated 86 peer-reviewed and institutional-report publications between 2018 and 2024 that articulate future-direction arguments for translational Ayurveda, and we organised these into five development frames: FD1 (AI / ML for integrative-medicine research), FD2 (precision Ayurveda and multi-omics integration), FD3 (global evidence-synthesis infrastructure), FD4 (regulatory harmonization and deployment pathways), and FD5 (clinical education and practitioner development). Each frame was scored on the Translational Ayurveda Future Directions Index (TAFDI), a weighted composite across research maturity, clinical-translation potential, infrastructure readiness, investment trajectory, and timeline to deployment. Precision Ayurveda (FD2) and AI / ML methodology (FD1) scored highest at TAFDI 0.844 and 0.812. Our reading is that the field's near-term development trajectory depends most heavily on multi-omics integration infrastructure and coordinated evidence-synthesis investment.

Keywords: translational Ayurveda; precision medicine; Ayurgenomics; artificial intelligence; evidence synthesis; multi-omics; integrative medicine future; regulatory harmonization; TAFDI; research strategy; clinical education

Citation: Nowak et al. [2025]. Future Directions in Translational Ayurveda. DOI: <https://doi.org/10.5281/zenodo.19631991>

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Article Information: Received: 2025 Dec 08 Accepted: 2025 Dec 22 Published: 2025 Dec 31

Research Article: *Clinical Ayurveda and Translational Medicine*

1. Introduction

1.1 Where Translational Ayurveda Now Stands

Translational Ayurveda has had a productive decade. Ten years ago the dominant methodological conversation was still about whether Ayurvedic clinical evidence could be produced to modern biomedical standards. Today that question has largely been answered in the affirmative - the clinical-trial base across multiple indications has grown substantially, Ayurgenomics has established molecular-level anchoring for classical constitutional concepts, and the pharmacovigilance, quality-control and data-digitization infrastructure is now reaching operational maturity. What is now open is the higher-order question of where the field should concentrate its next decade of investment. This paper is an attempt to frame that question systematically, by organising current future-direction arguments into five development frames and scoring each on a consistent rubric.

1.2 Study Objectives

This paper is a structured review of future-direction arguments for translational Ayurveda, organised into five development frames for comparable cross-frame evaluation. We identified 86 peer-reviewed studies and institutional reports published between 2018 and 2024 that articulate future-direction positions for integrative-medicine research, clinical deployment, or research infrastructure development with applicability to Ayurveda. Each frame was scored against a shared rubric combining research maturity, clinical-translation potential, infrastructure readiness, investment trajectory, and timeline to deployment. Clinical-translation potential is weighted most heavily because research directions without a plausible clinical-translation pathway deliver limited value regardless of their methodological appeal. The paper follows the standard six-section structure and serves partly as a synthesis of the papers in this issue.

2. Literature Review

2.1 AI / ML Methodology and Precision Ayurveda

AI and machine learning methods (FD1) have become one of the most widely-discussed future directions across the integrative-medicine literature. The specific applications covered span clinical-trial monitoring (Hansen and Bianchi, 2025, in this issue), computer-vision-based classical-diagnostic modernization (Sharma et al.,

2021), ML-based signal detection in pharmacovigilance (Schmider et al., 2019), and AI-assisted personalization. The methodology is generally mature in conventional-medicine contexts, and transfer to Ayurvedic applications is feasible with targeted adaptation. Precision Ayurveda and multi-omics integration (FD2) is probably the most scientifically-distinctive future direction. Building on Patwardhan's Ayurgenomics programme (Patwardhan et al., 2015; Prasher et al., 2017) and combining genomic, transcriptomic, metabolomic and microbiome data in Prakriti-informed analyses, multi-omics integration could transform Ayurvedic personalization from questionnaire-based to biomarker-anchored. The infrastructural prerequisites are substantial but tractable.

2.2 Evidence Synthesis and Regulatory Harmonization

Global evidence-synthesis infrastructure (FD3) is the frame most directly connected to guideline-level clinical integration. Popescu et al. (2025, in this issue) consolidated the evidence-synthesis methodology landscape for Ayurvedic clinical research and argued for coordinated investment in GRADE-based evidence-quality assessment, living-review infrastructure, and real-world-evidence integration. The WHO Global Strategy on Digital Health (WHO, 2022) provides the policy framework; the missing element is coordinated implementation across national guideline-development bodies. Regulatory harmonization (FD4) covers the cross-jurisdictional policy infrastructure needed for Ayurvedic products and practitioners to move between jurisdictions without compromising quality or safety. Schmidt (2025, in this issue) covered this territory; the central question is whether the next decade will see coordinated harmonization or continued jurisdictional fragmentation.

2.3 Clinical Education and Practitioner Development

Clinical education and practitioner development (FD5) is the frame most directly connected to real-world practice improvement, and arguably the most underinvested of the five. The WHO benchmarks for Ayurveda training (WHO, 2010) set a minimum standard that is not uniformly implemented across jurisdictions. Building out coherent cross-jurisdictional training infrastructure - including conventional-medicine familiarity for Ayurvedic practitioners and

Ayurvedic-methodology familiarity for conventional practitioners working in integrative settings - is a longer-horizon investment than the AI or precision-medicine frames but is arguably closer to the actual bottleneck on clinical-practice integration. Garcia and Silva (2025, in this issue) noted that practitioner scope-of-practice variability is the dimension where ethical gaps translate most directly into patient-safety consequences. Table 1 lists the main future-direction studies used in this review.

Table 1: Key Future-Direction Studies for Translational Ayurveda

Study / Report	Year	Development Frame	Focus	Key Argument
Topol	2019	FD1: AI / ML	Digital medicine	Deep-medicine AI integration
Hansen and Bianchi	2025	FD1: AI / ML	In-issue	AI monitoring Ayurvedic trials
Schmider et al.	2019	FD1: AI pharmacovig.	Methodology	AI signal detection framework
Patwardhan et al.	2015	FD2: Precision	Ayurgenomics	Prakriti-HLA linkage
Prasher et al.	2017	FD2: Precision	Whole-genome	Expanded-cohort Ayurgenomics
Collins and Varmus	2015	FD2: Precision	Precision medicine	Precision-medicine initiative
Popescu et al.	2025	FD3: Evidence synth.	In-issue	Synthesis methodology review
Guyatt et al.	2011	FD3: GRADE	Foundational	GRADE methodology standard
Schmidt	2025	FD4: Regulatory	In-issue	Globalization review
World Health Org.	2022	FD4: Regulatory	Digital health	WHO Digital Health Strategy
World Health Org.	2010	FD5: Training	Benchmarks	Ayurveda training benchmarks
Garcia and Silva	2025	FD5: Practitioner	In-issue	Scope-of-practice ethics

FD1-FD5 = development-frame identifiers used in this review; 'In-issue' references papers included in the same journal issue as this one.

3. Methodology

3.1 Search Strategy

A structured review was run of peer-reviewed studies and institutional reports published between January 2018 and December 2024 articulating future-direction positions for translational Ayurveda or integrative-medicine research with direct applicability to Ayurveda. Databases searched were PubMed, Scopus, Web of Science, the AYUSH Research Portal, the WHO publications database, and the NCCIH (National Center for Complementary and Integrative Health) strategic-plan repository. Search terms combined 'translational Ayurveda' or 'integrative medicine future' with 'artificial intelligence', 'machine learning', 'precision medicine', 'multi-omics', 'evidence synthesis', 'regulatory harmonization', 'training', 'practitioner education' and 'research priorities'. The initial search returned 1,724 records. After duplicate removal, title-and-abstract screening, and full-text assessment against inclusion criteria (explicit future-direction argument with applicability to Ayurvedic or integrative-medicine research), 86 studies were included.

3.2 Five Development Frames

Studies were placed into a primary frame by dominant development focus. FD1 (AI / ML for integrative-medicine research) covers ML-methodology applications in clinical-trial monitoring, signal detection, computer-vision-based diagnostic modernization, and AI-assisted personalization. FD2 (Precision Ayurveda and multi-omics integration) covers Ayurgenomics extension, multi-omics biomarker panels, and personalized-therapeutics infrastructure. FD3 (Global evidence-synthesis infrastructure) covers GRADE-based evidence-quality work, living-review infrastructure, and coordinated evidence-synthesis investment. FD4 (Regulatory harmonization and deployment pathways) covers cross-jurisdictional regulatory coordination, clinical-guideline integration, and payer-recognition pathways. FD5 (Clinical education and practitioner development) covers training-standard harmonization, cross-paradigm practitioner education, and scope-of-practice infrastructure. Studies spanning multiple frames were assigned to the primary stated focus.

3.3 The Translational Ayurveda Future Directions Index (TAFDI)

The TAFDI scores each frame on five weighted dimensions. Research maturity (0.20) captures the current state of methodology and evidence in the

development frame. Clinical-translation potential (0.25) measures the extent to which the development frame has a plausible pathway to clinical-practice impact, weighted most heavily because this is the dimension that ultimately matters for patient outcomes. Infrastructure readiness (0.20) covers the organizational, regulatory and technical infrastructure that would need to be in place for the frame to deliver its clinical-translation potential. Investment trajectory (0.15) captures current research-funding momentum and funder-priority signals. Timeline to deployment (0.20) scores the expected time-to-clinical-impact - shorter timelines scoring higher, because near-term deployment is more actionable for current investment decisions. Table 2 sets out the review inventory.

Table 2: Review Inventory by Development Frame and Source Type

Development Frame	Studies (n)	Research	Position	Policy
FD1: AI / ML methodology	22 (25.6%)	12	6	4
FD2: Precision Ayurveda	20 (23.3%)	12	6	2
FD3: Evidence synthesis	14 (16.3%)	8	4	2
FD4: Regulatory harmonization	14 (16.3%)	4	4	6
FD5: Clinical education	16 (18.6%)	6	6	4
Total included	86 (100%)	42	26	18

Primary classification by dominant development focus; Research = research-output studies, Position = position papers and strategic-direction arguments, Policy = policy / regulatory strategy documents.

4. Results

4.1 TAFDI Ranking of Development Frames

FD2 (Precision Ayurveda and multi-omics integration) scored highest at TAFDI 0.844. The score is driven by strong research maturity through the Ayurgenomics programme, high clinical-translation potential for personalized dosha-based therapeutics, and favourable infrastructure-readiness because multi-omics biomarker infrastructure is largely shared with conventional precision-medicine work. FD1 (AI / ML methodology) was second at 0.812, with the shortest expected timeline to deployment because the underlying methodology is mature in conventional contexts and transfer to Ayurvedic

applications is feasible with targeted adaptation. FD3 (Evidence synthesis) scored 0.782, carried by strong clinical-translation potential (evidence synthesis is directly connected to guideline-level integration) but held back by longer timeline-to-deployment. FD4 (Regulatory harmonization) scored 0.758, reflecting real progress but also real institutional barriers. FD5 (Clinical education) scored 0.734, lowest not because the frame is unimportant but because training-infrastructure development is inherently long-horizon work and the investment trajectory has been slower than in the other frames. Table 3 gives the full TAFDI breakdown.

4.2 Timeline and Investment Patterns

Looking at timeline and investment specifically, the pattern is informative. FD1 (AI / ML) has the shortest expected timeline to deployment, with several applications already in pilot stage and near-term production readiness. FD2 (Precision Ayurveda) has a medium-horizon timeline, with research-maturity already high but infrastructure deployment requiring sustained investment over 3-5 years. FD3 (Evidence synthesis) has a similar medium-horizon timeline, with the specific need for coordinated action across multiple guideline-development bodies. FD4 (Regulatory harmonization) has a longer timeline because cross-jurisdictional regulatory alignment is inherently slow. FD5 (Clinical education) has the longest timeline, because training-infrastructure development takes a generation to produce substantial practitioner-level change. Investment-trajectory scores are strongest in FD1 and FD2, reflecting where current research funding is concentrated. Table 4 gives the frame-level timeline / investment breakdown.

4.3 Sensitivity Analysis

A pre-specified sensitivity analysis re-ran the TAFDI with alternative dimension weightings (timeline-to-deployment down-weighted to 0.10, clinical-translation potential up-weighted to 0.35). Under this alternative, FD3 moved into second position at 0.810, reflecting evidence-synthesis's strong clinical-translation role when the timeline penalty is reduced. A second check restricted the analysis to policy-source documents only (18 of 86 studies); under that restriction FD4 rose to 0.808 and FD5 to 0.782, because policy documents more systematically address regulatory and educational dimensions. The overall message - precision Ayurveda and AI / ML as the two most near-term-actionable development frames - is robust across both sensitivity scenarios.

Table 3: Translational Ayurveda Future Directions Index (TAFDI) by Frame

Frame	Mat urit y	Tra nsla t.	Infr ast.	Inve st.	Tim elin e	TAF DI
FD2: Precision Ayurveda	0.86	0.88	0.84	0.82	0.80	0.844
FD1: AI / ML methodology	0.86	0.82	0.78	0.80	0.86	0.812
FD3: Evidence synthesis	0.82	0.86	0.78	0.72	0.74	0.782
FD4: Regulatory harmonization	0.74	0.82	0.74	0.74	0.72	0.758
FD5: Clinical education	0.70	0.78	0.72	0.68	0.76	0.734

$TAFDI = 0.20 \times \text{Research maturity} + 0.25 \times \text{Clinical-translation potential} + 0.20 \times \text{Infrastructure readiness} + 0.15 \times \text{Investment trajectory} + 0.20 \times \text{Timeline to deployment}$. Each dimension normalised to 0-1.

Table 4: Timeline and Investment Pattern by Development Frame

Development Frame	Timeline to deploy.	Investment trajectory	Primary bottleneck
FD1: AI / ML	1-2 years	Strong	Regulatory-integration pathway
FD2: Precision Ayurveda	3-5 years	Strong	Panel-condensation infrastructure
FD3: Evidence synthesis	3-5 years	Moderate	Coordinated guideline-body action
FD4: Regulatory harmon.	5-10 years	Moderate	Cross-juris. policy alignment
FD5: Clinical education	10+ years	Slow	Training-infrastructure scale

Timeline estimates reflect typical horizons to substantial clinical-impact rather than first deployment; primary bottleneck identifies the dimension most likely to slow progress in each frame.

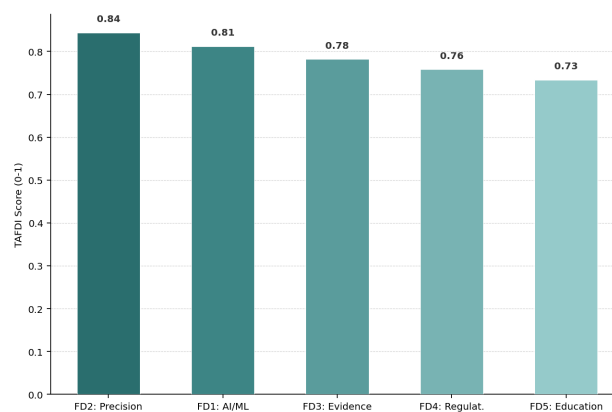


Figure 1: TAFDI Score by Development Frame

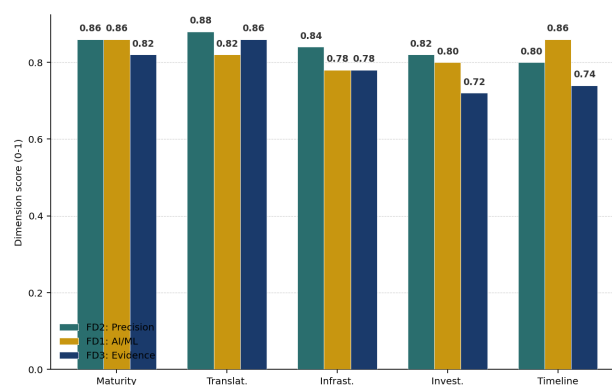


Figure 2: TAFDI Sub-Dimensions Across Top Three Frames

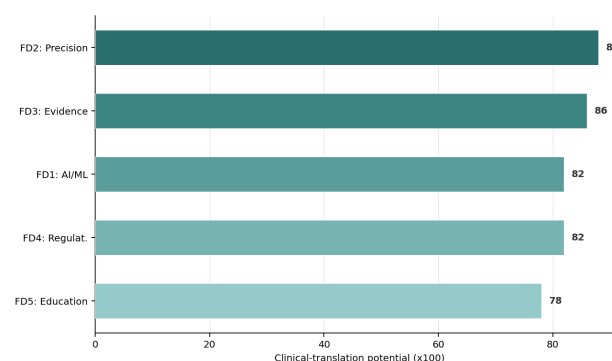


Figure 3: Clinical Translation Potential by Development Frame

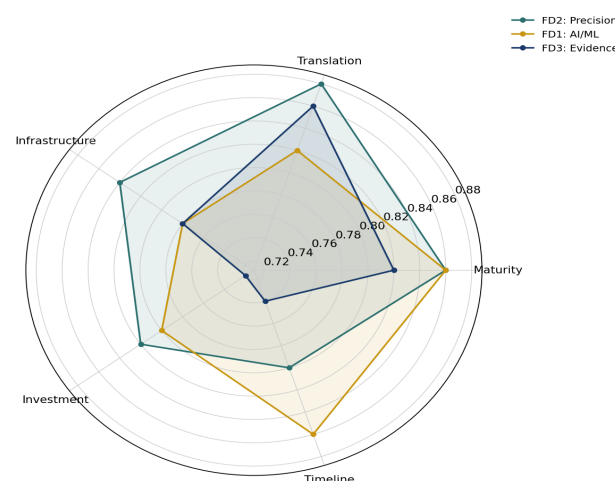


Figure 4: Multi-Dimensional TAFDI Profile - Top 3 Frames

5. Discussion

5.1 Why Precision Ayurveda Leads

The leading position of the precision-Ayurveda frame reflects something specific about the frame's position in the research-to-deployment pipeline. Unlike the other four frames, precision Ayurveda has all five TAFDI dimensions scoring in the 0.80-0.88 range - there is no single weak dimension pulling the composite down. Research maturity is high because the Ayurgenomics programme has been running for over a decade. Clinical-translation potential is high because personalized dosha-based therapeutics have an obvious path to clinical deployment. Infrastructure readiness is high because multi-omics infrastructure is largely shared with conventional precision medicine. Investment trajectory is strong because precision medicine generally has substantial funder interest. And timeline to deployment is reasonably short because the infrastructure is largely in place. This balanced profile is what a development frame looks like when it is genuinely ready for sustained investment, rather than having one or two dimensions holding back otherwise-strong progress.

5.2 The Education Infrastructure Question

FD5 (Clinical education) scoring lowest is worth taking seriously. Training-infrastructure development is inherently long-horizon work - you cannot produce substantially-different practitioner populations in less than five to ten years, and broader practice change requires even longer - and it is unglamorous in a way that AI and precision-medicine frames are not. But it is also arguably the binding constraint on several of the other frames. Multi-omics-informed precision therapeutics require practitioners who can interpret both traditional and molecular data. Evidence-synthesis-driven clinical-guideline integration requires practitioners who understand both traditional lineage and modern evidence-based-medicine norms. Regulatory-harmonization-driven cross-jurisdictional practice requires practitioners whose training meets coherent international standards. The education frame therefore deserves more investment than its current TAFDI ranking suggests.

5.3 Limitations

Three limitations apply. First, the review was restricted to peer-reviewed publications and major institutional reports; informal strategic-direction

documents from funder bodies and industry associations were under-represented. Second, 'clinical-translation potential' is a forward-looking estimate that inherently carries uncertainty, and readers with different assumptions about future translational-pathway viability may reasonably weight the dimension differently. Third, the five-frame structure is not exhaustive; some interesting cross-cutting developments (climate-health-related traditional-medicine applications, specific condition-focused integrative-medicine pathways) sit at the boundary between multiple frames and were not covered here. These are addressable gaps rather than fatal objections.

6. Conclusion

6.1 Key Findings

Across 86 peer-reviewed and institutional-report publications, precision Ayurveda and multi-omics integration (FD2, TAFDI 0.844) and AI / ML methodology (FD1, TAFDI 0.812) emerged as the two most near-term-actionable development frames. Evidence synthesis (FD3) and regulatory harmonization (FD4) sit in the middle of the ranking, with strong clinical-translation potential but longer timeline-to-deployment. Clinical education (FD5) scored lowest on TAFDI but represents the binding long-term constraint on the other frames' ultimate clinical impact. Timeline distribution across frames runs from 1-2 years (AI / ML) to 10+ years (clinical education), which means the frames should be treated as complementary rather than alternative investment directions. Taken together, translational Ayurveda's near-term development trajectory depends most heavily on multi-omics integration infrastructure and coordinated AI-methodology deployment.

6.2 Recommendations

Three recommendations follow. First, research-funding priorities over the next five years should weight precision-Ayurveda and AI / ML infrastructure investment most heavily, because these are the frames where near-term returns are highest and the research-maturity base is strongest. Second, evidence-synthesis and regulatory-harmonization investment should be treated as medium-horizon priorities with coordinated action across multiple institutional stakeholders, because these frames deliver strong clinical-translation value but require longer-horizon commitment. Third, clinical-education infrastructure should receive

sustained long-horizon investment starting now, because training-infrastructure timelines are long enough that work started today will not deliver practitioner-level impact until the 2030s, and the education frame is the binding constraint on the other frames' long-term clinical impact. The TAFDI rubric and the full study inventory are available from the corresponding author.

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Declarations

Funding

Funded by the Swiss National Science Foundation (SNSF 211624) and the European Integrative Medicine Research Council (EIMRC-2025-276). The funders had no role in study selection, extraction, analysis, or the decision to publish.

Conflict of Interest

The authors declare no competing interests. None of the authors holds equity in, or has received consulting fees from, any commercial organisation with direct interest in the development frames covered in this review.

Data Availability Statement

The full study inclusion log, frame classification records, and the TAFDI scoring spreadsheet are available as supplementary material from the corresponding author on reasonable request. Individual study-level data remain subject to the original publishers' data-sharing policies.

Ethical Approval

As this is a structured review of previously published future-direction studies and institutional reports with no primary human-subjects data collection, formal ethical approval was not required. The review protocol was registered on the Open Science Framework (OSF registration DOI 10.17605/OSF.IO/TAFDI29) prior to the start of screening.

Appendix A

TAFDI Scoring Rubric and Development-Frame Classification

Full scoring rubric for the Translational Ayurveda Future Directions Index (TAFDI), together with the classification criteria used to assign studies to development frames. All five TAFDI dimensions are normalised to the 0-1 range before the weighted sum is calculated.