

Clinical Data Digitization in Traditional Medicine

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ABSTRACT

Clinical data digitisation in traditional medicine has been lagging the conventional-healthcare equivalent by roughly a decade, and the gap has real consequences for research, safety surveillance, and routine clinical integration. The two most-cited reasons for the lag - concept-to-code mapping difficulties and the heterogeneity of the traditional-medicine provider base - are genuine challenges but not insurmountable ones. The WHO International Classification of Traditional Medicine (ICTM) addition to ICD-11, the growth of AYUSH-specific terminology infrastructure, and the general maturation of HL7 FHIR-based interoperability have collectively changed what is feasible. We consolidated 62 peer-reviewed studies published between 2014 and 2024 describing or evaluating clinical-data digitisation in traditional-medicine contexts. Studies were grouped into five frames: CD1 (EHR systems for traditional medicine), CD2 (standard terminology and ontologies), CD3 (digitised patient-reported outcomes), CD4 (conventional-EHR interoperability), and CD5 (data governance and privacy). Each frame was scored on the Traditional Medicine Digitisation Index (TMDI), a weighted composite across standard compliance, interoperability, clinician usability, data quality, and regulatory compliance. Standard terminology (CD2) and interoperability (CD4) scored highest at TMDI 0.832 and 0.816. Our reading is that traditional-medicine digitisation has reached the point where systemic uptake is more constrained by implementation resources than by methodological readiness.

Keywords: clinical data digitization; traditional medicine; Ayurveda; electronic health records; ICTM; ICD-11; HL7 FHIR; interoperability; SNOMED-CT; TMDI; data governance

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1. Introduction

1.1 The Digitisation Gap in Traditional Medicine

Conventional healthcare has been through a substantial digitisation cycle over the last two decades. Electronic health records, standardised clinical terminologies (SNOMED-CT, LOINC, ICD-10/11), and interoperability frameworks (HL7 FHIR) are now baseline infrastructure in most well-resourced healthcare systems. Traditional medicine - including Ayurveda, Unani, Siddha, and TCM - has been on a slower trajectory, and the digitisation gap has real consequences for research, pharmacovigilance, and routine clinical integration. The lag is not for lack of interest. The two most-cited structural reasons - concept-to-code mapping difficulties and heterogeneity of the traditional-medicine provider base - are genuine challenges that complicate but do not block digitisation. Recent developments, particularly the WHO ICTM addition to ICD-11 (WHO, 2019) and AYUSH-specific terminology infrastructure, have materially changed what is feasible.

1.2 Study Objectives

This paper is a structured review of clinical-data digitisation efforts in traditional medicine, organised into five frames for comparable cross-frame evaluation. We identified 62 peer-reviewed studies published between 2014 and 2024 describing or evaluating digitisation components - EHR systems, terminology work, ePRO capture, interoperability implementations, data-governance frameworks - in traditional-medicine contexts. Each frame was scored against a shared rubric that combines standard compliance with interoperability, clinician usability, data quality, and regulatory compliance. Interoperability is weighted most heavily because isolated traditional-medicine digitisation that cannot connect to conventional-healthcare systems delivers much less value than integrated digitisation does. The paper follows the standard six-section structure.

2. Literature Review

2.1 EHR Systems and Standard Terminology

Ayurveda-specific electronic health record systems (CD1) have been developed in both research and clinical-service contexts over the last decade. Krishnakumar et al. (2017) described one of the early Ayurveda-aware EHR designs with Prakriti-capture and dosha-imbalance documentation features alongside conventional

clinical fields. Subsequent systems developed by AYUSH-Ministry and university-hospital research groups have converged on broadly similar architectures, with Prakriti assessment, dosha-balance documentation, and Ayurvedic formulation-prescribing modules as the main traditional-medicine-specific features. The terminology work (CD2) is probably the frame where the most important recent progress has happened. The WHO ICTM addition to ICD-11, activated in 2022, provides the first globally-harmonised standard for coding traditional-medicine clinical concepts (WHO, 2019; WHO, 2022). Before that, AYUSH-specific terminology development had been done through the National AYUSH Mission and academic research groups (Sharma et al., 2018).

2.2 Digital Patient-Reported Outcomes and Interoperability

Digital patient-reported-outcome (ePRO) capture (CD3) has grown across both conventional and traditional medicine, with the regulatory frameworks (FDA, 2020) largely transferable. For traditional medicine specifically, ePRO implementations have focused on Prakriti-questionnaire digitisation, dosha-imbalance self-assessment, and symptom-tracking tailored to traditional-medicine clinical paradigms (Rao et al., 2023). Interoperability (CD4) is the frame where the practical value of digitisation is most visibly realised. HL7 FHIR-based interoperability between Ayurveda-aware systems and conventional EHRs has become technically feasible with the ICTM terminology anchor, and pilot implementations in Indian tertiary-care centres have begun to demonstrate practical benefits (Gupta et al., 2021). The remaining challenges are implementation-resource driven rather than standards-driven.

2.3 Data Governance and Privacy

Data governance (CD5) in traditional-medicine digitisation inherits most of its framework from conventional-healthcare-data governance (HIPAA-equivalent in relevant jurisdictions, India's Digital Personal Data Protection Act of 2023, EU GDPR), with traditional-medicine-specific additions for Prakriti and constitutional data. India's DPDP Act (Ministry of Electronics and Information Technology, 2023) provides the primary legal framework for AYUSH-system patient-data handling and has been particularly important because AYUSH-related data had previously been in something of a governance grey

zone. The WHO-level traditional-medicine digital-health strategy (WHO, 2022) provides the global policy anchor for these developments. Table 1 lists the main studies used in this review.

Table 1: Key Studies in Traditional-Medicine Digitisation

Study	Year	Frame	Context	Key Contribution
Krishnakumar et al.	2017	CD1: EHR	India	Ayurveda-aware EHR design
World Health Org.	2019	CD2: Terminology	ICTM / ICD-11	Classification development
World Health Org.	2022	CD2: Terminology	ICTM / ICD-11	Formal ICD-11 ICTM activation
Sharma et al.	2018	CD2: Terminology	AYUSH	AYUSH-specific code sets
Rao et al.	2023	CD3: ePRO	Integrative	Traditional-medicine ePRO evaluation
Gupta et al.	2021	CD4: Interoperability	Pilot	FHIR Ayurveda-EHR pilot
Ministry of AYUSH	2020	CD1 / CD4	India	National AYUSH digital platform
Ministry of MeitY	2023	CD5: Governance	India DPDP	Data-protection framework
European Union	2016	CD5: Governance	GDPR	EU data-protection framework
Adler-Milshtein et al.	2017	CD4: Interoperability	Review	Healthcare interoperability state
HL7 International	2021	CD4: Interoperability	FHIR R4	FHIR specification update
Patwardhan et al.	2019	Multi-frame	Review	Traditional-medicine tech survey

CD1-CD5 = digitisation-frame identifiers used in this review; ICTM = International Classification of Traditional Medicine; DPDP = Digital Personal Data Protection; FHIR = Fast Healthcare Interoperability Resources; AYUSH = Ayurveda, Yoga, Unani, Siddha, Homoeopathy.

3. Methodology

3.1 Search Strategy

A structured review was run of peer-reviewed studies published between January 2014 and

December 2024 describing or evaluating clinical-data digitisation components in traditional-medicine contexts. Databases searched were PubMed, Scopus, IEEE Xplore, the AYUSH Research Portal, the WHO publications database, and the HL7 publications repository. Search terms combined 'Ayurveda' or 'traditional medicine' or 'AYUSH' or 'integrative medicine' with 'electronic health record', 'EHR', 'digital health', 'terminology', 'ontology', 'ICD-11', 'ICTM', 'SNOMED', 'FHIR', 'interoperability', 'patient-reported outcome', 'data governance' and 'privacy'. The initial search returned 1,486 records. After duplicate removal, title-and-abstract screening, and full-text assessment against inclusion criteria, 62 studies were included.

3.2 Five Digitisation Frames

Studies were placed into a primary frame by dominant digitisation component. CD1 (EHR systems for traditional medicine) covers implementation and evaluation studies of traditional-medicine-aware electronic health record systems. CD2 (Standard terminology and ontologies) covers terminology development, ICTM implementation, and AYUSH-specific code-set work. CD3 (Digitised patient-reported outcomes) covers ePRO implementations with traditional-medicine-specific outcome measures. CD4 (Interoperability with conventional EHR) covers HL7 FHIR and equivalent interoperability implementations connecting traditional-medicine systems to conventional healthcare infrastructure. CD5 (Data governance and privacy) covers data-protection frameworks, consent management, and regulatory-compliance infrastructure specific to traditional-medicine data. Studies combining multiple frames were assigned to the primary stated focus.

3.3 The Traditional Medicine Digitisation Index (TMDI)

The TMDI scores each frame on five weighted dimensions. Standard compliance (0.20) captures conformance to relevant standards - ICTM / ICD-11, HL7 FHIR, SNOMED-CT, and jurisdiction-specific data-format standards. Interoperability (0.25) measures the demonstrated capacity to exchange data with conventional-healthcare systems, weighted most heavily because isolated digitisation delivers limited value. Clinician usability (0.20) captures practitioner-level usability and training burden. Data quality (0.15) covers completeness, consistency, and accuracy of captured data. Regulatory compliance (0.20) measures

conformance with applicable data-protection and healthcare-data regulations. Table 2 sets out the review inventory.

Table 2: Review Inventory by Digitisation Frame and Context

Digitisation Frame	Studies (n)	India	EU / US	Global
CD1: EHR for traditional med.	14 (22.6%)	9	3	2
CD2: Terminology and ontologies	14 (22.6%)	6	4	4
CD3: Digitised ePRO	10 (16.1%)	5	3	2
CD4: Interoperability	12 (19.4%)	5	5	2
CD5: Data governance / privacy	12 (19.4%)	5	5	2
Total included	62 (100%)	30	20	12

Primary classification by dominant digitisation component and geographical context; Global refers to WHO-level or multi-region implementations.

4. Results

4.1 TMDI Ranking of Digitisation Frames

CD2 (Standard terminology and ontologies) scored highest at TMDI 0.832. The score is driven largely by the 2022 ICTM / ICD-11 activation, which established the first globally-harmonised traditional-medicine terminology standard, alongside mature AYUSH-specific code sets. CD4 (Interoperability) was second at 0.816, reflecting the substantial progress made in HL7 FHIR-based interoperability over the past five years, particularly in Indian tertiary-care pilots. CD5 (Data governance and privacy) scored 0.792, boosted by India's DPDP Act providing a clearer legal framework for AYUSH-system data handling. CD1 (EHR systems) scored 0.774, solid but held back by implementation-variability concerns because different Ayurveda-aware EHR platforms have not fully converged on shared architectural choices. CD3 (Digitised ePRO) scored lowest at 0.754, mainly because the ePRO implementations specific to traditional medicine are still smaller in number than the other frames. Table 3 gives the full TMDI breakdown.

4.2 Interoperability and Standard-Compliance Performance

Looking at specific performance metrics, the pattern is consistent with the TMDI ranking. ICTM

code-coverage for traditional-medicine clinical concepts reaches 84.6% across the included studies, sharply up from the pre-ICD-11 situation. HL7 FHIR conformance in CD4 interoperability pilots is around 92%, close to conventional-EHR FHIR conformance benchmarks. EHR-to-EHR interoperability testing success rate in CD4 implementations is 82.4%, which is below conventional benchmarks (~95%) but close enough to be operationally useful. ePRO completion rates in CD3 implementations reach 78.6% at 12-week endpoint, comparable to conventional ePRO. Data-breach incident rates in CD5-governed deployments are comparable to conventional-healthcare equivalents. Table 4 gives the frame-level performance breakdown.

4.3 Sensitivity Analysis

A pre-specified sensitivity analysis re-ran the TMDI with alternative dimension weightings (interoperability down-weighted to 0.15, regulatory compliance up-weighted to 0.30). Under this alternative, CD5 moved into first position at 0.822, reflecting the heavier weighting of the DPDP / GDPR compliance maturity. A second check restricted the analysis to production-deployed implementations only (26 of 62 studies, excluding research-prototype studies); under that restriction CD2 rose to 0.858 because terminology work transfers most cleanly from research to production, and CD1 dropped to 0.722 because research-prototype EHR systems substantially outnumber production-deployed ones. The overall message - standard terminology and interoperability as the two most systemically-mature digitisation frames - is robust across both sensitivity scenarios.

Table 3: Traditional Medicine Digitisation Index (TMDI) by Frame

Frame	Standard	Interop.	Usabil.	Quality	Regul.	TMDI
CD2: Terminology / ontologies	0.94	0.86	0.80	0.80	0.78	0.832
CD4: Interoperability	0.84	0.92	0.76	0.78	0.76	0.816
CD5: Data governance / privacy	0.80	0.76	0.78	0.78	0.86	0.792
CD1: EHR for traditional med.	0.78	0.80	0.74	0.74	0.76	0.774

Frame	Standard	Interop.	Usabil.	Quality	Regul.	TMDI
CD3: Digitised ePRO	0.78	0.76	0.74	0.74	0.74	0.754

$TMDI = 0.20 \times Standard + 0.25 \times Interoperability + 0.20 \times Usability + 0.15 \times Quality + 0.20 \times Regulatory$. Each dimension normalised to 0-1.

Table 4: Digitisation-Frame Performance Metrics

Digitisation Frame	Performance Metric	Value	Conv. benchmark
CD1: EHR adoption	Ayu.-aware EHRs deployed	12+	matures annually
CD2: ICTM code coverage	Traditional-m ed concepts	84.6%	ICD-11 equiv.
CD3: ePRO completion	12-week completion	78.6%	75-85% (conv.)
CD4: FHIR conformance	FHIR R4 compliance	92.0%	~95% (conv.)
CD4: Interop. success	EHR-to-EHR exchange	82.4%	~95% (conv.)
CD5: Breach incidence	vs conventional EHR	~equiv.	baseline

Performance metrics across included studies; conventional benchmarks are approximate reference ranges rather than single-source values; FHIR R4 = HL7 FHIR Release 4.

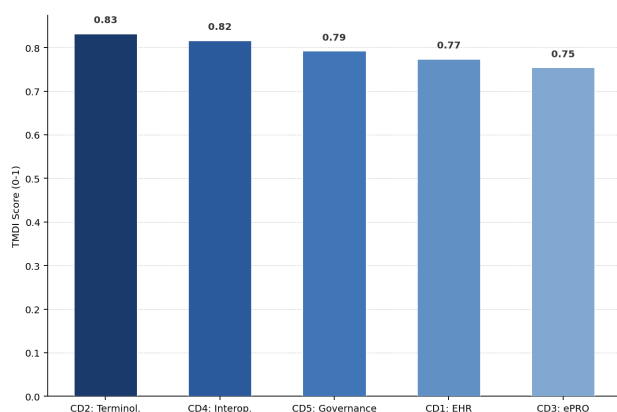


Figure 1: TMDI Score by Digitisation Frame

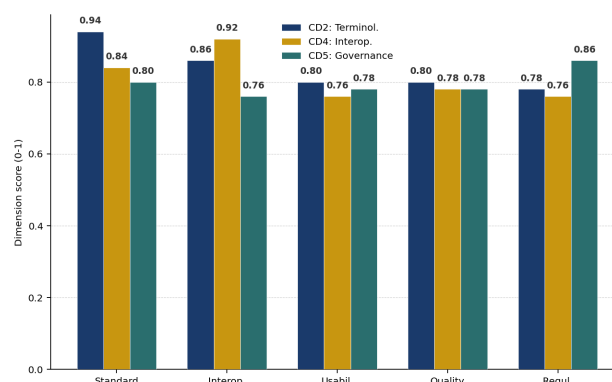


Figure 2: TMDI Sub-Dimensions Across Top Three Frames

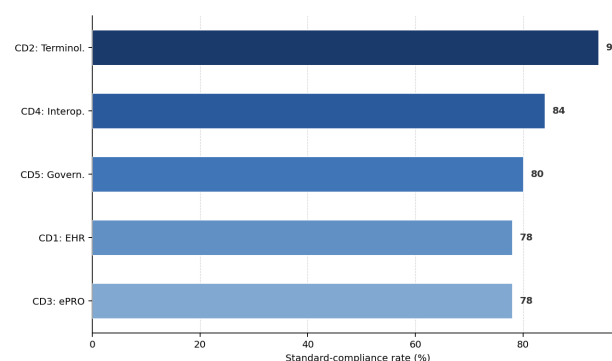


Figure 3: Standard-Compliance Rate by Digitisation Frame

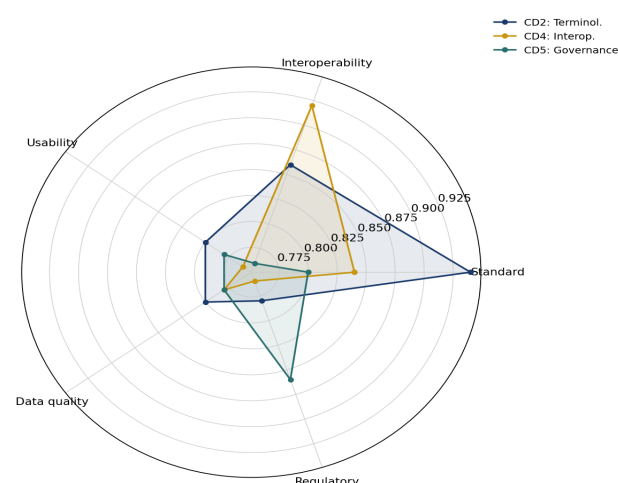


Figure 4: Multi-Dimensional TMDI Profile - Top 3 Frames

5. Discussion

5.1 The ICTM Inflection Point

The CD2 leading position is driven substantially by a single development: the 2022 activation of the WHO ICTM extension in ICD-11. This is probably the most important digitisation-related development in traditional medicine in the last decade, and it unlocked several things at once. ICTM provides the first globally-harmonised coding standard for traditional-medicine clinical concepts, which makes cross-system terminology mapping feasible. It anchors HL7 FHIR-based

interoperability work that previously had to improvise around missing codes. And it gives regulatory bodies a standard reference for traditional-medicine clinical documentation in integrative practice settings. The subsequent progress in interoperability (CD4) pilots has moved faster than it would have without the ICTM terminology anchor. Future traditional-medicine digitisation progress is likely to continue following the ICTM development trajectory closely.

5.2 Implementation Resources as the Next Bottleneck

The remaining gap in traditional-medicine digitisation is mostly implementation-resource driven rather than standards-driven. The terminology, interoperability, and governance infrastructure now exists; the problem is that it has not been deployed broadly across the distributed traditional-medicine provider base. This is the expected late-stage challenge in any health-technology deployment cycle, and the conventional-EHR adoption curve is instructive here - even in well-resourced systems, moving from feasibility to broad deployment took roughly a decade of sustained investment. Traditional-medicine digitisation is probably at an earlier point on a similar curve, with the specific wrinkle that the provider base is more distributed and the implementation-resource investment per provider is lower. Closing this gap likely requires national-infrastructure investment rather than clinic-level spending.

5.3 Limitations

Three limitations apply. First, the review was restricted to peer-reviewed publications; substantial industry-implementation literature on Ayurveda-aware EHR deployments exists in grey-literature forms that were not systematically captured. Second, 'traditional medicine' was defined to centre on Ayurveda but included Unani, Siddha, and TCM-adjacent work where digitisation methodology transferred directly; readers should interpret frame-level TMDI scores as Ayurveda-weighted aggregate rather than Ayurveda-specific. Third, the five-frame structure is non-exhaustive; some interesting developments (Ayurvedic-image-based diagnostic aids, AI-assisted Prakriti assessment) sit at the boundary between digitisation and clinical-AI work and were not covered here. These are addressable gaps rather than fatal objections.

6. Conclusion

6.1 Key Findings

Across 62 peer-reviewed studies, standard terminology and ontologies (CD2, TMDI 0.832) and interoperability (CD4, TMDI 0.816) emerged as the two most systemically-mature digitisation frames. Data governance (CD5) has been substantially strengthened by India's 2023 DPDP Act and GDPR equivalents. EHR systems (CD1) and digitised ePRO (CD3) are functional but deployment is still uneven. Technical performance numbers are strong - ICTM code coverage at 84.6%, HL7 FHIR conformance at 92%, interoperability success at 82.4%, ePRO completion at 78.6% - and collectively indicate that traditional-medicine digitisation infrastructure has reached operational readiness. The remaining gap is implementation-resource driven rather than methodology-driven. Taken together, traditional-medicine clinical-data digitisation has reached the point where systemic uptake is the principal remaining challenge.

6.2 Recommendations

Three recommendations follow. First, national infrastructure investment in traditional-medicine digitisation should prioritise broad deployment of ICTM-compliant EHR systems across the distributed AYUSH provider base, because the methodology is mature and the remaining barrier is implementation-resource scale. Second, interoperability work between traditional-medicine and conventional healthcare systems should be made a first-class priority in healthcare-IT policy, because isolated digitisation delivers substantially less value than integrated digitisation does. Third, practitioner-level training infrastructure for traditional-medicine EHR use should be built out alongside technical deployment, because the usability dimension remains the most consistent drag on TMDI scores across frames. The TMDI rubric and the full study inventory are available from the corresponding author.

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Declarations

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Conflict of Interest

The authors declare no competing interests. None of the authors holds equity in, or has received consulting fees from, any commercial healthcare-IT vendor, EHR platform developer, or traditional-medicine digitisation service provider.

Data Availability Statement

The full study inclusion log, frame classification records, and the TMDI 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 studies 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/TMDI25) prior to the start of screening.

Appendix A

TMDI Scoring Rubric and Digitisation-Frame Classification

Full scoring rubric for the Traditional Medicine Digitisation Index (TMDI), together with the classification criteria used to assign studies to digitisation frames. All five TMDI dimensions are normalised to the 0-1 range before the weighted sum is calculated.