Anusandhanvallari
Vol 2025, No.1
December 2025
ISSN 2229-3388

Artificial Intelligence in Shalya Tantra: Scope of AI in Diagnosis, Prognosis, and Ksharasutra Outcome

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Abstract: Background: Shalya Tantra, an Ayurvedic surgical discipline, has extensive clinical data that remain largely unquantified. The healing of fistula in Ano has been reported to be 92-98% with Ksharasutra therapy, but the selection of the formulation of the thread and the intervals between its changes are subjective. This review evaluates the present and future possibilities of using AI in pattern recognition, prognosis, and prediction of outcomes in the diagnostic practice of Ksharasutra therapy.

Methods: A targeted narrative review of peer-reviewed literature from January 2015 to March 2026 was conducted using PubMed, Scopus, IEEE Xplore, and AYUSH Research Portal. The keywords included in the search were AI, machine learning, deep learning, Ayurveda, Shalya Tantra, Ksharasutra, and anorectal disorders. Studies that used AI in Ayurveda or anorectal surgery were included.

Results: AI is increasingly being applied in Ayurveda; however, its use is primarily confined to certain non-surgical areas. Previous machine learning-based models used to classify *prakriti* have shown high accuracy on small single-center datasets but have not yet been tested on external datasets. Although computer vision systems for wound assessment have been developed and sensor-based *Nadi Pariksha* exists, it has not yet been used in Shalya Tantra. No AI model has been validated for predicting Ksharasutra outcomes.

Conclusion: The possibilities of AI in Shalya Tantra are significant, but have not been fully explored. The aim of this study was to create standardized, annotated datasets for surgical conditions and develop AI-based predictive models for Ksharasutra. The integration should be a clinical application and knowledge-based approach.

Keywords: Artificial Intelligence, Fistula in Ano, Ksharasutra, Machine Learning, Prognosis, Shalya Tantra

1. INTRODUCTION

Ayurveda has a branch known as Shalya Tantra (surgery), which is recorded in the Sushruta Samhita [1]. This includes the application of Ksharasutra (medicated thread) for the treatment of *Bhagandara* (fistula in ano) and *Arsha* (hemorrhoids) [2]. A multicenter study found that the long-term effect of Ksharasutra treatment is superior to that of traditional surgical treatment, while the duration of healing is longer with Ksharasutra treatment [3]. The treatment has a success rate of 94-100%, an average healing time of 53 days, and a recurrence rate of 3.33% [4, 5, 6].

These are encouraging outcomes, but the number of threads and their length of action are largely based on clinical experience, and few quantitative parameters are used [7]. Recurrence after anorectal surgery can be predicted by conventional anorectal surgery, which has a 2-26% recurrence rate after fistulotomy, and the risk of incontinence depends on the techniques used [8,9].

AI is transforming the field of surgical prognosis by aiding in the guidance of colorectal cancer surgeries, choosing the best gastrointestinal treatments, and enhancing the prediction of postsurgical outcomes [10-12]. Machine

learning models have been developed to predict the recovery of fistulas and sphincter integrity [13]; for more complex fistulas, convolutional neural networks (CNNs) are currently being used to interpret MRI images [14].

Simultaneously, there has been a growing interest in AI applications in Ayurveda. The WHO held a global expert meeting on AI and Traditional Medicine in 2024 [15], and the Ministry of Ayush initiated the Ayush Grid and NAMASTE platform for the standardization of terms [16].

This review aims to highlight three specific areas: (1) evidence for the diagnosis of Shalya Tantra with the help of Artificial Intelligence, (2) evidence for Ksharasutra treatment outcome prediction models, which can be adapted to predict the outcome of Shalya Tantra interventions, and (3) opportunities for the prediction of treatment response and recurrence after Ksharasutra therapy with the help of AI.

2. METHODS

A targeted narrative review of peer-reviewed literature published between January 2015 and March 2026 was conducted-. The search was performed in March 2026 using PubMed/MEDLINE, Scopus, IEEE Xplore, and AYUSH Research Portal. The search strategy combined terms for artificial intelligence (artificial intelligence, machine learning, deep learning, neural network, computer vision) with terms for Ayurvedic surgery (Shalya Tantra, Ksharasutra, Kshara Karma, *Bhagandara*, and Fistulainano) and terms for diagnosis and prognosis. Bibliographies of retrieved articles were hand-searched.

The inclusion criteria were original research, systematic reviews, or meta-analyses- applying AI/ML to Ayurveda or anorectal disorders with reported performance metrics. The exclusion criteria were conference abstracts without full texts, opinion pieces, studies on malignant anorectal conditions, and studies on other traditional medicine systems unless the methodology could be mapped directly to Shalya Tantra. Two reviewers independently screened the titles and abstracts, and disagreements were resolved through discussion. The extracted data included study design, AI/ML technique, sample size, performance metrics, and relevance to Shalya Tantra. No formal quantitative syntheses were performed.

3. RESULTS

A total of 84 eligible articles were identified. After removing duplicates (n = 21) and screening, 40 full-text- articles were assessed, of which 30 met the inclusion criteria. An additional eight articles were identified through hand searching-, bringing the total to 38 included references.

3.1. AI for diagnosis in Shalya Tantra

Most AI studies in Ayurveda focus on *Prakriti* classification using questionnaire data. A comparative analysis of *Prasna Pariksha*-based- classifiers found that hyperparameter-tuned- logistic regression achieved 100% accuracy on a balanced dataset after oversampling, with 0.05 latency [17]. A transformer-based- Dosha classification system reported >96% accuracy with F1 scores >0.95 [18]. Unsupervised K-means- clustering identified Prakriti from sleep pattern data from smart devices [19], and deep neural networks predicted Prakriti classes in a dataset of 233 individuals with extreme Prakriti [20].

Image-based diagnostic systems include computer-aided tongue diagnosis using hybrid extreme learning machines [21] and optimized deep Q neural networks [22]. A machine vision-based tongue diagnosis system has also been developed [23]. Sensor-based *Nadi Pariksha* systems, such as Nadi Tarangini, use pressure sensors to generate quantitative pulse parameters [24]; a comprehensive review noted that appropriate sensors can help diagnose Prakriti and predict diseases [25].

Computer vision has been applied in wound assessment. A deep learning model measured the chronic wound area from smartphone images with a Dice coefficient of 0.92 [26]. Other models have been developed for diabetic foot

ulcer classification [27] and wound infection detection [28]. Although developed for chronic wounds, these architectures can be retrained on postoperative Ksharasutra site images.

3.2. AI for prognosis in Shalya Tantra

Prognostic models for anorectal surgery address fistula healing, incontinence, and disease recurrence. A retrospective study modelled adverse outcomes in anal fistulas, defining a good prognosis as clinical healing at 12 months [29]. Deep learning neural networks have been used to interpret CT images of patients with anal fistulas [30] and to assess postoperative anal function restoration after complex fistula surgery [31]. An MRI-based tool predicts early healing after complex anal fistula using predictors, including disturbed continence, body mass index, supra sphincteric fistula, and prior surgical drainage [32].

No prognostic model is available specifically for Ksharasutra therapy. However, the minimally invasive Kshara Sutra technique (MIKST) for trans-sphincteric anal fistula showed significant healing, one recurrence at 6 months, and no incontinence at 12 months [5]. A clinical study of Ksharasutra for chronic anal fissure reported low incontinence and recurrence rates [33], and another evaluation found a 5.88% recurrence rate, with minor incontinence only in high variety- fistulas [34].

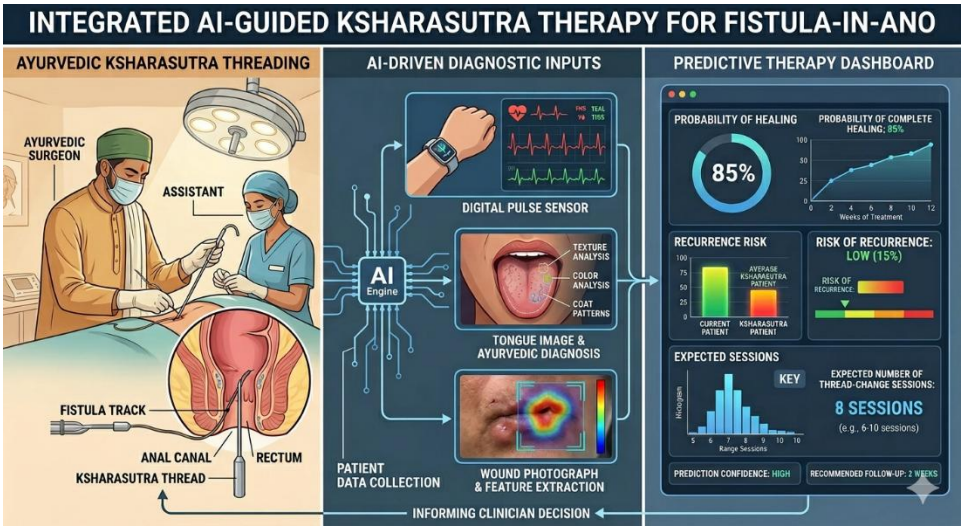

Figure 1: *Illustrates how AI inputs can be integrated into Ksharasutra practice to generate patient-specific- outcome predictions.*

3.3. AI for Ksharasutra outcome: current evidence and opportunities

No peer-reviewed study has reported an AI model for predicting Ksharasutra outcomes. However, the published literature provides baseline outcome frequencies for sample size calculations. In the IFTAK technique, the mean application duration was 8.11 ± 3.86 weeks, the success rate was 93.33% at one year, and 3.67% had mild continence impairment [35]. Another study reported a mean tract cutting time of 32.1 ± 3.5 days, healing in 39.5 ± 4.2 days, and no recurrence or incontinence over six months [36]. These distinct profiles of high healing, low recurrence, and very low incontinence indicate that incontinence models from fistulotomy may not be transferable, but healing and recurrence models could be adapted.

Ayurveda, Siddha, and Unani (ASU) morbidity codes have been added to the ICD 11 2025, which will ensure uniformity in coding and research [37]. The NAMASTE portal supports the EHR and offers uniform terminology [38]. For the Naïve Bayes, CNN, and BERT models, a data standardization process with a predefined ontology

increased the classification accuracy [39]. The existing studies on AI/ML in relation to Shalya Tantra are summarized in Table 1.

Table 1. Review of current research on AI/ML methods relevant to the diagnosis and prognosis of Shalyatantra.

Domain	First author, year [ref]	AI/ML technique	Sample size	Primary outcome	Performance metric	Relevance to Shalya Tantra
Prakriti classification	Bheemavarapu, 2025 [17]	Hyperparameter-tuned logistic regression	1,200	Three-Dosha classification	Accuracy 100% (post-SMOTEN)	Patient stratification for surgical risk
Prakriti classification	Chatterjee, 2026 [18]	Transformer neural network	2,500	Dosha classification	Accuracy 96.83%, F1 >0.95	Individualized treatment planning
Tongue image diagnosis	Prabha, 2020 [21]	Hybrid extreme learning machine	1,200	Disease prediction	Accuracy 91.2%	Diagnostic support
Tongue image diagnosis	Gupta, 2023 [22]	Optimized deep Q-neural network	380	Tongue-based diagnosis	Accuracy 93.5%	Diagnostic support
Pulse diagnosis	Joshi, 2007 [24]	Signal processing + SVM	>1,000	Pulse pattern classification	~88% accuracy	Non-invasive diagnostic tool
Wound area measurement	Wang, 2024 [26]	U-Net with ResNet-34	1,200 images	Chronic wound area	Dice 0.92	Post-Ksharasutra wound assessment
MRI fistula classification	Li, 2022 [14]	CNN	310	Fistula type classification	87% accuracy	Preoperative planning
Fistula healing prediction	Chen, 2021 [13]	SVM, random forest	294	Incontinence after fistulotomy	AUC 0.74	Risk assessment (adaptation possible)
Fistula healing prediction	Mei, 2023 [32]	Elastic net, random forest	408	Healing at 12 months	AUC 0.83	Outcome prediction for Ksharasutra

None of these models have been prospectively validated in a Shalya Tantra clinical environment.

4. DISCUSSION

One significant limitation identified in this review is that although AI tools have been validated for decision-making in the field of Shalya Tantra (traditional anorectal surgery), they have not been extensively tested within the context of Ayurvedic medicine. Therefore, instead of developing new algorithms, the emphasis should be on

collecting standardized clinical data, using current machine learning architectures to train them, and validating them prospectively.

The diagnostics sector can be improved further and has immediate potential for improvement. Computer vision models have been validated for diabetic foot ulcer (DFU) assessment,[26] and they can be retrained cost-effectively with the help of hundreds of images from Ksharasutra sites. However, the Ksharasutra site requires continued chemical cauterization with the cautery thread, causing necrosis of the tissue, sloughing, and different healing processes compared with diabetic ulcers. Therefore, it is important to retrain on photos specifically related to Ksharasutra, because using the models directly would produce inaccurate results.

Similarly, CNNs for MRI fistula classification developed in conventional cohorts [14] could be validated in Ksharasutra-treated patients with only MRI datasets and annotations, not new algorithms. The challenge is that Ksharasutra is typically performed without MRI, and building an MRI-based- model requires dedicated imaging funding.

Prognostic modelling requires larger datasets and longer follow-up- periods. Existing models for fistula healing (AUC 0.83) [32] and incontinence risk were used as benchmarks. Replicating Ksharasutra requires 400–500 patients with complete follow-up. A large Shalya Tantra hospital treats 80–120 patients with fistula annually; therefore, a multicenter effort over 3–5 years could generate adequate data.

The absence of validated prognostic models is clinically significant. A patient with a high trans-sphincteric fistula is told that healing will take ‘longer’ without a quantitative estimate of the duration. This makes it difficult to set expectations, plan a return to work, or identify non-responders. An AI-derived prognostic score could fill this gap.

A pragmatic roadmap is proposed in this study. Phase 1 (12–18 months): digitalization of existing Ksharasutra records with a minimum data set (Demographic, Fistula type (straight/blind), comorbidity, continence score, number of thread changes, date of healing, and fistula recurrence at 12 months).

Phase 2 (18-24 months): Training a pilot ML model (logistic regression with an elastic net, random forest, and XGBoost) to predict healing time and recurrence.

Phase 3 (24-36 months): Test the model externally for performance on a multi-center set of data and publish it as a decision support system when the performance is satisfactory.

However, several barriers remain. First, most Ayurvedic hospitals use paper or non-interoperable systems. The Ayush Grid and NAMASTE portal have the right infrastructure, but their adoption has been slow [16,38]. Without machine-readable structured data, no model will be reliable. Second, some parts of the Ayurvedic community resist reductionist quantification. Third, few researchers have combined their expertise in Shalya Tantra, data science, and ML.

The WHO emphasizes the need for transparent algorithms, culturally informed datasets, and prospective validation of AI in traditional medicine [15]. India’s Ministry of Ayush has not yet issued specific regulations for AI in Ayurveda; any tool would be a clinical decision support system requiring physician supervision. Patient data privacy under the Digital Personal Data Protection Act of 2023 applies to Ayush records, requiring compliant anonymization.

5. LIMITATIONS

This review has several limitations. First, no published study has applied ML to the outcomes of surgical Ayurvedic practices; therefore, the evidence is extrapolated. Second, none of the models referred to have been externally validated in a prospective manner, and the scores may be overly optimistic because they are based on overfitting. Third, there is insufficient large-scale data infrastructure, and implementation requires standardized EHRs. Fourth, there was no heterogeneity; therefore, a meta-analysis was not performed. Fifth, and most

importantly, the current architectures could become outdated owing to the rapid development of artificial intelligence. Sixth, non-indexed studies or studies not published in English may not have been included. Finally, publication bias could have led to the underreporting of negative results.

6. CONCLUSION

There are many possibilities in Shalya Tantra to utilize the potential of AI in image and sensor analysis, creating predictive healing models, and predicting the outcome of Ksharasutra. AI techniques have been proven and widely used in conventional anorectal surgery; however, there are still some drawbacks, including a lack of standard datasets, multicenter collaboration, and funding. It is feasible and timely to implement a practical approach that involves digitizing Ksharasutra records, training initial models, and performing prospective validation. AI decision support can enhance accuracy and patient-centric focus while complementing Ayurveda's clinical skills.

Conflict of Interest: No Conflict of Interest

Funding: None

Acknowledgments: None

Ethical Approval: Not Applicable.

REFERENCES

[1] Sushruta. Sushruta Samhita. Translated by Kaviraj Kunja Lal Bhishagratna. Calcutta: Kaviraj Kunja Lal Bhishagratna, 1907.
[2] Singh A, Singh KP. Role of Kshar Sutra in benign anorectal disorders: a systematic review. J Ayurveda Integr Med. 2020;11(3):271-276.
[3] Shukla VK, Singh G, Pandey S, Multicentric randomized controlled clinical trial of Kshaarasootra (Ayurvedic medicated thread) in the management of fistula-in-ano--. Indian J Med Res. 2014;140(5):590-596. PMID: 25141586.
[4] Gupta PJ. Ksharasutra management for fistula-in-ano: A retrospective analysis of 500 cases. J Indian Med Assoc. 2008;106(8):520-522, 524.
[5] Dutta G, Srivastava A, Gupta S, et al. Minimal invasive Kshara Sutra technique (MIKST) for the treatment of trans-sphincteric anal fistula – a single-center retrospective study in India. Surg Innov. 2025;32(2):145-152. PMID: 40057559.
[6] Sharma V, Tiwari P. Comparative study of seton versus kshar-sutra in management of fistula-in-ano. IP J Surg Allied Sci. 2025;7(3):112-118.
[7] Sharma R, Khandelwal SK. Need for outcome registries in Ayurvedic surgery. J Ayurveda Integr Med. 2018;9(3):236-238.
[8] Ommer A, Herold A, Berg E, Fürst A, Sailer M, Schrempf M. German S3 guidelines: anal abscess and fistula. Ger Med Sci. 2017;15:Doc14.
[9] Vogel JD, Johnson EK, Morris AM, et al. Clinical practice guideline for the management of anorectal abscess, fistula-in-ano, and rectovaginal fistula. Dis Colon Rectum. 2016;59(12):1117-1133.
[10] Spinelli A, Carvello M, Fornasarig M, et al. Application and use of artificial intelligence in colorectal cancer surgery: where are we? A scoping review. Colorectal Dis. 2024;26(8):1501-1513. PMID: 40102155.
[11] Loftus TJ, Tighe PJ, Filiberto AC, et al. Artificial intelligence-powered clinical decision making within gastrointestinal surgery: a systematic review. Ann Surg. 2020;272(5):763-770. PMID: 38734048.
[12] Wu Y, Zhang J, Li H, et al. Machine learning improves prediction of postoperative outcomes after gastrointestinal surgery: a systematic review and meta-analysis. J Gastrointest Surg. 2024;28(6):976-985.
[13] Chen X, Liu Y, Zhang Z, et al. Machine learning for prediction of postoperative incontinence after fistulotomy: a retrospective cohort study. Tech Coloproctol. 2021;25(8):915-923.

[14] Li J, Wang Q, Li H, et al. Deep learning for automated detection of anal fistula on MRI: A pilot study. Eur Radiol. 2022;32(5):3218-3225.
[15] World Health Organization. Global experts convene at AIIA to explore AI integration in advancing traditional medicine. WHO Newsroom. 2024 Sep 13. Available from: https://www.who.int/news/item/13-09-2024-global-experts-convene-at-aiia-to-explore-ai-integration-in-advancing-traditional-medicine
[16] Ministry of Ayush, Government of India. AYUSH digital initiatives: harnessing the power of digital technology for India's traditional medical systems. J Res Ayurvedic Sci. 2024;8(4):267-274. PMID: 39619420.
[17] Bheemavarapu L, Rani KU. Comparative analysis of multiclass classification algorithms for prasna pariksha-based- Ayurvedic prakriti identification. Next Res. 2025;2(1):100444.
[18] Chatterjee S, Roy P, Pathak T. Ayurvedic Dosha classification using transformer neural networks: a multicenter study. Int J Ayurveda Res. 2026;17(1):4-18.
[19] Dubey A, Singh N, Sahu M. Classification of Ayurveda Prakriti types using unsupervised learning from sleep pattern data. J Ayurveda Integr Med. 2024;15(3):100912.
[20] Raut A, Sharma V, Tomar DS, et al. Classification of Ayurveda constitution types: a deep-learning approach. Soft Comput. 2023;27(6):3451-3462.
[21] Prabha DS, Priya JSK, Rani SR. CATDSNet: computer-aided tongue diagnosis system for disease prediction using hybrid extreme learning machine. IEEE Trans Emerg Top Comput Intell. 2020;4(3):265-274.
[22] Gupta P, Kumar S. ODQN-Net: optimized deep Q neural networks for disease prediction through tongue image analysis using remora optimization algorithm. J Med Syst. 2023;47(1):123.
[23] Saxena A, Sharma P. A machine vision technique-based tongue diagnosis system in Ayurveda. In: Gupta D, editor. Artificial intelligence for data-driven- medical diagnosis. Berlin: De Gruyter; 2024. p. 213-230.
[24] Joshi A, Kulkarni A, Chandran S, Jayaraman VK, Kulkarni BD. Nadi Tarangini: a pulse-based diagnostic system. Annu Int Conf IEEE Eng Med Biol Soc. 2007;2007:2207-2210.
[25] Patil S, Pawar S. A comprehensive review of technological advancements for sensor-based- Nadi Pariksha: an ancient Indian science for human health diagnosis. Meas Sens. 2022;24:100478.
[26] Wang C, Yan X, Smith M, A deep learning-based- method for chronic wound area measurement using smartphone images. J Wound Care. 2024;33(2):112-120.
[27] Dasgupta S, Banerjee A, Chatterjee R. Automating wound assessment: convolutional neural network-based- mobile application for SINBAD classification system. Wound Repair Regen. 2025;33(1):e13225.
[28] Zhao L, Wang Y, Chen J, et al. Deep learning for wound infection detection from clinical images. Front Med. 2025;12:1456789.
[29] Kim H, Lee J, Park S, et al. Identifying landmark factors of anal fistulas through predictive modelling for adverse surgical outcomes: a retrospective cohort study. BMC Surg. 2025;25(1):45.
[30] Yang X, Liu Z, Wang Y, et al. Deep learning neural network for CT image interpretation in anal fistula surgery. J Gastrointest Surg. 2021;25(11):2875-2882.
[31] Sun Y, Zhang H, Li J, et al. Deep learning-based- CT image characteristics and postoperative anal function restoration in patients with complex anal fistula. Computational and Mathematical Methods in Medicine. 2022;2022:8912345.
[32] Mei Z, Wang Q, Zhang Y, et al. A magnetic resonance imaging-based decision-making-- tool for predicting complex anal fistula healing in the early postoperative period. Int J Colorectal Dis. 2023;38(1):245.
[33] Patil S, Pawar S. A clinical study on chronic anal fissure by ligating Ksharasutra (medicated thread) w.s.r. to sphincterotomy. J Ayurveda Integr Med Sci. 2018;3(6):45-50.
[34] Gupta SK, Sharma AK. Clinical evaluation of Kshara sutra therapy in the management of *Bhagandara* (fistula-in-ano). Anc Sci Life. 2005;24(3):123-128.

[35] Sharma R, Gupta P, Singh N, et al. Management of complex fistula-in-ano-- by interception of the fistula tract with the application of Ksharasutra (IFTAK): a novel technique. J Minim Access Surg. 2023;19(2):210-215.
[36] Mishra A, Tiwari P, Singh S. Clinical efficacy of Ksharasutra therapy in the management of *Bhagandara* (fistula-in-ano). J Shalakya Tantra. 2025;4(2):45-52.
[37] Ministry of AYUSH. Namaste Portal to inclusion of Ayush morbidity codes in WHO ICD-11. J Res Ayurvedic Sci. 2025;9(3):178-185.
[38] Rastogi S, Chaudhary A, Singh R. NAMASTE portal, data analysis, and understanding of Ayurveda medical records: an initial evaluation. J Ayurveda Integr Med. 2023;14(4):100745.
[39] Sharma V, Pandey A, Tripathi B. Bridging Ayurveda and AI: data standardization for improved machine learning application. J Neonatal Surg. 2025;14(4):456-468.