RESEARCH PAPER

Integrating Sushruta's Trividha Karma Principles into Modern Surgical Drug Delivery Systems : A Review

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Abstract

Background: The Sushruta Samhita, the foundational text of Ayurvedic surgery (Shalya Tantra), organises the entire surgical encounter into three sequential phases known as Trividha Karma: Purva Karma (preoperative preparation), Pradhana Karma (the principal operative procedure) and Pashchat Karma (postoperative care). Although composed many centuries ago, this tripartite architecture closely mirrors the modern perioperative continuum of preoperative optimisation, intraoperative management and postoperative recovery.

Objective: To critically examine the concept of Trividha Karma as described in the classical literature, to map each phase onto contemporary perioperative science, and to explore how the framework can inform surgical drug development, including the design of perioperative pharmacological agents, wound-care products, clinical trials and integrative research programmes.

In addition, this review explores the potential role of modern surgical drug delivery systems, including liposomal formulations, polymer-based hydrogels, drug-loaded wound dressings, medicated sutures, and controlled-release formulations. These technologies may support localised drug delivery, improve therapeutic retention at the surgical site, and provide sustained drug release. The integration of these approaches with the Trividha Karma framework may help identify new research opportunities in preoperative, intraoperative, and postoperative care.

Methods: A narrative review was undertaken of primary Sanskrit sources through their published English translations and commentaries, together with historical scholarship and contemporary biomedical literature on perioperative medicine, enhanced recovery, surgical safety, wound healing, natural-product drug discovery and surgical innovation methodology.

Results: Purva Karma corresponds to patient selection, risk stratification, counselling, fasting policy, antisepsis, equipment readiness and premedication. Pradhana Karma, comprising eight defined operative actions (Ashtavidha Shastra Karma), together with adjunct procedures such as Kshara Karma, Agni Karma and Raktamokshana, corresponds to operative technique, anaesthesia, haemostasis and adjunctive therapy. Pashchat Karma, with its emphasis on wound dressing, fumigation, diet, protective measures and staged wound therapy, anticipates modern principles of infection prevention, analgesia, nutrition, early rehabilitation and wound-healing pharmacology. The framework offers a phase-wise lens through which unmet needs in surgical pharmacotherapy can be identified and through which traditional formulations and procedures can be evaluated with modern methods.Examples including Kshara Sutra, honey-based wound care, curcumin-containing formulations, and leech-derived anticoagulant compounds illustrate different research pathways, ranging from procedural evaluation to formulation development and pharmacological investigation.

Conclusion: Trividha Karma is best understood as an early, systematic model of perioperative care. Its value for modern drug development lies not in uncritical adoption of historical practices but in providing a structured, phase-oriented template for hypothesis generation, endpoint selection, reverse pharmacology and staged clinical evaluation of surgical interventions.

Keywords: Sushruta Samhita; Trividha Karma; Purva Karma; Pradhana Karma; Pashchat Karma; perioperative care; Shalya Tantra; drug development; reverse pharmacology; wound healing

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Introduction

The *Sushruta Samhita* is an important classical text of Ayurveda that describes surgical principles, operative techniques, wound management, and patient care. One of its key concepts, **Trividha Karma**, divides surgical management into three phases: Purva Karma (preoperative preparation), Pradhana Karma (the principal operative procedure), and Pashchat Karma (postoperative care). This framework provides a historical perspective for exploring the relationship between traditional surgical knowledge and modern perioperative medicine (Sharma, 2010; Murthy, 2012).

Traditional surgical practices may also offer research hypotheses for modern pharmaceutical and biomedical development. For example, Kshara

Sutra has been investigated in the management of fistula-in-ano, honey has been evaluated for wound care, and curcumin has been studied for wound healing and topical drug-delivery applications. Similarly, leech-derived hirudin has contributed to modern anticoagulant pharmacology. However, traditional use alone does not establish safety or efficacy; appropriate standardisation, toxicity assessment, and clinical evaluation remain essential (Shukla et al., 1991; Jull et al., 2015; Gopinath et al., 2004).

Modern surgical drug development includes anaesthetics, analgesics, antimicrobial agents, haemostatic products, and wound-healing formulations. **Trividha Karma may provide a phase-based conceptual framework for identifying research opportunities** in these areas. Purva Karma relates to preoperative preparation, Pradhana Karma to intraoperative interventions, and Pashchat Karma to wound healing and postoperative recovery. Therefore, this review examines the concept of Trividha Karma, its relevance to modern perioperative practice, and its potential contribution to evidence-based surgical drug development through scientific validation and clinical research.

Modern surgical drug delivery systems aim to deliver therapeutic agents to specific tissues or surgical sites in an effective and controlled manner. Conventional drug administration may not always provide optimal drug concentrations at the target site and can sometimes produce unwanted systemic effects. Local drug delivery approaches, including drug-loaded films, hydrogels, medicated sutures, liposomal formulations, and wound dressings, offer potential strategies for improving local drug availability and controlling drug release. Within the Trividha Karma framework, these technologies can be conceptually associated with preoperative preparation, intraoperative intervention, and postoperative wound management. However, their suitability for individual surgical applications must be established through appropriate experimental and clinical studies.

Methods

Classical material was drawn from published English translations and Sanskrit editions with commentary of the Sushruta Samhita, principally the translations of Bhishagratna (1907) and Sharma (2010), the illustrated edition of Murthy (2012) and the edition carrying the commentary of Dalhana edited by Trikamji Acharya (2008). Historical interpretation relied on standard works on the history of Indian medicine (Kutumbiah, 1962; Meulenbeld, 1999; Wujastyk, 2003) and on published historical reviews of Indian anatomy and plastic surgery (Rana and Arora, 2002; Loukas et al., 2010).

Contemporary literature was selected purposively to represent guidelines, landmark trials and methodological frameworks in perioperative medicine, surgical safety, infection prevention, postoperative nausea and vomiting, pain management, enhanced recovery, wound healing, natural-product drug discovery, drug-development economics and surgical innovation. Priority was given to guidelines, systematic reviews, randomised trials and highly cited methodological papers.

Because the classical text has been transmitted through multiple recensions and interpreted by successive commentators, statements about what the Samhita "prescribes" reflect the translations and commentaries consulted. Where interpretations differ, the discussion notes this. Interpretive mappings between classical and modern concepts are the authors' analytical constructs, offered as hypotheses for investigation and not as claims of historical equivalence. Readers should consult the Sanskrit original and specialist commentary before relying on any specific procedural detail.

Historical and Textual Context

The Sushruta Samhita and Shalya Tantra

Ayurveda classically recognises eight branches (Ashtanga Ayurveda), of which Shalya Tantra, the branch concerned with the removal of foreign bodies and with surgical and para-surgical procedures, is regarded as the domain of Sushruta. The Samhita is traditionally divided into sections including Sutrasthana (foundations, instruments and general principles), Nidanasthana (diagnosis of surgical diseases), Sharirasthana (anatomy and embryology), Chikitsasthana (therapeutics), Kalpasthana (toxicology) and the supplementary Uttaratantra (Sharma, 2010; Murthy, 2012). Chronology and authorship remain matters of scholarly debate, and historians describe the text as a work compiled and revised over an extended period, later augmented and commented upon, notably by Dalhana (Meulenbeld, 1999; Wujastyk, 2003).

Within this corpus, surgery is treated as the foremost of therapeutic methods, and the text sets out qualifications for the surgeon, methods of training on models and specimens, detailed accounts of blunt instruments (Yantra) and sharp instruments (Shastra), and techniques of incision, excision, probing, extraction, drainage and suturing. The anatomical instruction attributed to the school, including the preparation of a cadaver for study, has attracted attention from historians of anatomy (Loukas et al., 2010). The text's descriptions of nasal reconstruction with a cheek flap and of ear-lobe repair have made it a frequent reference point in the history of plastic surgery (Rana and Arora, 2002).

The Idea of Karma as a Therapeutic Sequence

In classical usage, *karma* denotes purposeful action, and in the therapeutic context it refers to a defined procedure carried out with an intention and

in a sequence. The commentarial tradition frames a complete surgical treatment as comprising three karmas performed in order. Purva Karma prepares the patient, the physician and the environment. Pradhana Karma is the central operative action. Pashchat Karma safeguards and completes the result. The logic is straightforward: the outcome of the principal action depends on the adequacy of what precedes it and what follows it (Trikamji Acharya, 2008; Sharma, 2010).

This sequential logic distinguishes Trividha Karma from a simple list of techniques. It embeds the principle that surgical success is a property of the whole pathway. Modern quality-improvement science reached similar conclusions through empirical evidence, showing that perioperative outcomes depend on factors that extend well beyond the operating table (Kehlet, 1997; Ljungqvist et al., 2017).

Purva Karma: The Preoperative Phase

Classical Description

Purva Karma encompasses every measure required before the operative act. The text and its commentaries describe several strands of preparation, which can be grouped as follows.

Assessment and selection. The surgeon is expected to examine the patient, the disease and the circumstances before deciding whether and when to operate. Classical discussion recognises conditions in which surgery is appropriate, conditions in which it is deferred or medically managed, and conditions in which it is best avoided. The strength of the patient, the nature of the disease, the season and the condition of the affected part are all considered (Sharma, 2010). The text also addresses the prognosis of surgical disease, and elsewhere warns the surgeon against undertaking hopeless cases, an early expression of what would now be called risk-benefit reasoning and professional restraint.

Preparation of materials (SambharaSangraha). The physician is directed to assemble the required instruments, sharp and blunt, together with cautery implements, medicated preparations, caustics, dressing materials such as cloth, honey, ghee, oils, and leaves and pastes for topical use, and to ensure that instruments are sharp, clean and fit for purpose. The text describes qualities of a good instrument and the care to be taken of it (Sharma, 2010; Murthy, 2012). Assistants are also to be chosen and made ready.

Preparation of the patient. The patient is to be counselled, reassured and made ready in body and mind. The dietary preparation is notable. According to the commentarial interpretation, the patient is generally to be given a light meal before surgery so as to avoid faintness, hunger and thirst during the procedure, while in certain conditions, such as diseases of the mouth, urinary stone disease, ano-rectal conditions and some abdominal conditions, surgery is done without a preceding meal (Sharma, 2010; Trikamji Acharya, 2008). This differentiated fasting policy is of particular interest because it anticipates the modern debate over preoperative fasting.

Auspicious and ritual preparations. Classical accounts describe propitious timing, ritual observances, worship and blessings. From a modern standpoint these can be read as elements of psychological preparation, attention to the patient's beliefs and formation of therapeutic trust, while acknowledging that their cultural and religious character is not amenable to conventional pharmacological evaluation.

Positioning, restraint and premedication. The patient is positioned suitably for the site of operation and, where required, restrained by trained attendants. For pain and fear, the text describes the giving of wine (Madya) before certain procedures, which is widely interpreted as an early form of premedication or sedation (Sharma, 2010; Murthy, 2012).

Preparation of the operative site. The region is examined, marked according to the intended incision and, where relevant, prepared with cleansing and application of medicated substances.

Correspondence with Modern Preoperative Care

The modern preoperative phase can be described under headings that map closely to the classical strands (Table 1). Formal risk stratification tools now allow surgeons and patients to estimate the probability of complications for a given operation and patient profile. The American College of Surgeons NSQIP risk calculator, for example, was developed as a decision aid and an informed-consent tool (Bilimoria et al., 2013). This is a quantitative descendant of the classical assessment of patient strength, disease and suitability.

Table 1. Conceptual mapping of Purva Karma to modern preoperative practice

Classical component	Modern analogue	Representative evidence or standard
Examination of patient, disease, season	History, examination, investigation, risk stratification	Surgical risk calculators (Bilimoria et al., 2013)
Selection or refusal of cases	Indications, contraindications, shared decision-making	Guideline-based decision pathways
Counselling and reassurance	Informed consent, anxiety reduction, prehabilitation education	Enhanced recovery preoperative counselling (Ljungqvist et al., 2017)
Differentiate	Preoperative	Enhanced

Classical component	Modern analogue	Representative evidence or standard
d meal before surgery	fasting policy, carbohydrate loading	recovery guidance (Ljungqvist et al., 2017)
Assembly of instruments, cautery, dressings	Instrument sterilisation, theatre preparation, safety checklist	Surgical safety checklist (Haynes et al., 2009)
Wine before surgery	Premedication and sedation	Multimodal perioperative pharmacology (Kehlet, 1997)
Cleansing of the site	Skin antisepsis, hair management, antibiotic prophylaxis	CDC and ASHP guidelines (Berríos-Torres et al., 2017; Bratzler et al., 2013)

The classical emphasis on readying the team and equipment finds a direct modern counterpart in the surgical safety checklist. In a multicentre study across eight hospitals in different economic settings, implementation of a checklist was associated with a fall in inpatient complications from about 11% to about 7% and in inpatient death from about 1.5% to about 0.8% (Haynes et al., 2009). While the checklist is a system-level intervention and not a drug, it illustrates a principle central to Purva Karma: that structured preparation changes outcomes.

Fasting, Nutrition and Metabolic Preparation

The classical distinction between patients who should receive a light meal and those who should be operated on while fasting is a useful historical counterpoint to modern practice. For decades, prolonged preoperative fasting was routine. Contemporary enhanced recovery approaches have moved away from prolonged fasting and favour shorter fasting intervals with preoperative carbohydrate-containing fluids, on the rationale that this attenuates insulin resistance and catabolic stress (Ljungqvist et al., 2017). The classical reasoning, that hunger and thirst during a procedure are undesirable and that the diet should be matched to the operation, is thus consistent in spirit with the modern shift toward individualised, physiology-driven fasting.

For drug development, this observation is not merely historical. Preoperative metabolic conditioning is an active field for pharmacological and nutritional intervention. Carbohydrate loading beverages, immunonutrition formulations and agents that modulate the surgical stress response are all preoperative products whose development requires phase-appropriate endpoints, such as insulin sensitivity, length of stay, complication rates and patient-reported recovery. The classical view of diet as a component of the surgical prescription suggests that formulations combining nutritional and pharmacological actions may deserve systematic study.

Infection Prevention and Antisepsis

Sushruta's text places considerable emphasis on cleanliness of the surgeon, the instruments, the dressing materials and the wound, and describes the use of fumigation and medicated washes for the surgical environment and for wounds (Sharma, 2010; Murthy, 2012). Whether or not the classical authors possessed a germ theory, their prescriptions constitute empirical infection control.

Modern practice codifies preoperative infection prevention through evidence-based bundles. Antimicrobial prophylaxis guidelines specify the indications, agent selection, timing relative to incision, dosing and duration of prophylactic antibiotics for surgical procedures (Bratzler et al., 2013). The Centers for Disease Control and Prevention guideline for surgical site infection addresses, among other measures, antimicrobial prophylaxis, skin preparation, glycaemic control and perioperative normothermia (Berríos-Torres et al., 2017). These documents demonstrate that a large part of the modern preoperative pharmacological agenda concerns infection prevention.

This is an area where traditional knowledge intersects with pressing modern problems. Antimicrobial resistance limits the utility of empirical prophylaxis, and there is renewed interest in topical antiseptics, antimicrobial coatings and plant-derived antimicrobial agents. The Purva Karma emphasis on the preparation of the field and on medicated preparations is a conceptual invitation to study adjunctive topical agents for pre-incision skin preparation and wound-bed conditioning. Any such agent, however, must meet the same standards of efficacy, safety and stability as conventional antiseptics.

Counselling, Consent and Psychological Preparation

The classical directive to reassure and prepare the patient prefigures modern informed consent and anxiety management. Preoperative anxiety is associated with greater analgesic requirement and poorer recovery in many settings, and enhanced recovery protocols include structured preoperative education (Ljungqvist et al., 2017). Risk calculators can support the consent conversation by giving patients individualised estimates (Bilimoria et al., 2013).

The pharmacological corollary is the field of anxiolytic premedication. The classical use of wine as a pre-procedural agent reflects the recognition that fear and pain during surgery are treatable

problems. Modern practice has replaced this with defined sedative and anxiolytic agents, but the therapeutic objective is unchanged. There remains scope for developing premedication strategies that reduce anxiety without prolonging recovery, and for evaluating non-pharmacological adjuncts alongside drugs.

Prediction of Postoperative Complications at the Preoperative Stage

An important modern extension of preoperative assessment is the identification of patients at elevated risk of specific complications so that prophylaxis can be targeted. The Apfel score, developed to predict postoperative nausea and vomiting from a small number of patient factors, is a widely used example: risk rises stepwise with the number of predictors present (Apfel et al., 1999), and consensus guidelines link prophylactic drug selection to this stratification (Gan et al., 2020). This principle, that preoperative assessment should determine which pharmacological prophylaxis is used, is directly relevant to drug development. It implies that trials of perioperative prophylactic agents should enrol or stratify by baseline risk, as the absolute benefit of any agent depends on baseline risk.

The lesson of Purva Karma for drug development is therefore twofold. First, preoperative preparation is an active therapeutic window, not a passive waiting period. Second, the individualisation embedded in the classical text, the matching of preparation to patient, disease, season and procedure, aligns with the modern movement toward risk-stratified, personalised perioperative prescribing.

Pradhana Karma: The Principal Operative Phase

Classical Description

Pradhana Karma is the central procedure. The Samhita classifies surgical actions into eight types, collectively called Ashtavidha Shastra Karma: Chedana (excision), Bhedana (incision), Lekhana (scraping), Vedhana (puncturing), Eshana (probing), Aharana (extraction), Visravana (drainage) and Sivana (suturing) (Sharma, 2010; Murthy, 2012). Each is linked to particular diseases, instruments and technical precautions. For example, incision is described for abscesses and collections, excision for growths, scraping for hypertrophied tissue, puncturing for fluid collections, probing for sinuses and tracts, extraction for calculi and foreign bodies, drainage for blood and pus, and suturing for divided tissue.

Alongside these are the para-surgical or Anushastra procedures, which use materials other than steel instruments. These include Kshara Karma (application of alkaline caustic preparations derived from plant ash), Agni Karma (thermal cautery) and Raktamokshana (bloodletting, including the use of leeches, Jalauka) (Sharma, 2010; Murthy, 2012). Kshara, prepared from specified medicinal plants, is used for excision-like action on tissues in situations where sharp surgery is difficult, and a medicated caustic thread (Kshara Sutra) is used for fistulous tracts. Agni Karma is applied for haemostasis, for chronic conditions and for certain recurrent lesions. Raktamokshana is used to relieve local congestion and in some inflammatory conditions.

The text pays close attention to operative technique. It advises on the direction, depth and length of incisions in different regions of the body, on avoiding vessels, nerves and vital structures (Marma), on the manner of holding instruments, and on steadiness and speed. The surgeon is instructed to proceed with a calm and focused mind. Anatomical instruction, including the identification of vital areas and the risk attached to injury of each, is an integral part of operative safety (Loukas et al., 2010).

The Samhita also contains reconstructive procedures. Its descriptions of nasal reconstruction using tissue from the cheek and of ear-lobe repair are among the earliest documented plastic surgical techniques (Rana and Arora, 2002).

Correspondence with Modern Intraoperative Practice

Modern surgical taxonomy differs in vocabulary but has recognisable parallels. Incision and drainage, excision, curettage, needle puncture, exploration with probes or scopes, extraction and closure are basic operations across surgical specialties. Cautery and haemostatic agents correspond to Agni Karma in intent. Table 2 summarises the correspondence.

Table 2. Conceptual mapping of Pradhana Karma to modern intraoperative practice

Classical component	Modern analogue	Pharmacological or technological relevance
Chedana, Bhedana	Excision, incision	Local anaesthetics, haemostatic agents
Lekhana	Curettage, debridement	Debriding and topical agents
Vedhana, Eshana	Puncture, probing, exploration	Contrast, dyes, local anaesthesia
Aharana	Extraction of calculi and foreign bodies	Adjunctive irrigation, antispasmodics
Visravana	Drainage of collections	Antimicrobial irrigation, drains
Sivana	Suturing and wound closure	Sutures, adhesives, antimicrobial-

Classical component	Modern analogue	Pharmacological or technological relevance
		coated materials
Agni Karma	Thermal cautery, electrosurgery	Haemostasis technology
Kshara Karma, Kshara Sutra	Chemical cauterisation, seton therapy	Medicated setons and topical caustics
Raktamokshana, Jalauka	Bloodletting, leech therapy	Hirudin-based agents, venous congestion management in flaps
Madya before surgery	Sedation and anaesthesia	Anaesthetic and analgesic pharmacology

Anaesthesia, Analgesia and the Intraoperative Drug Landscape

The classical text acknowledges pain as a central problem of surgery. The use of wine before operations has been interpreted as a form of sedation (Sharma, 2010; Murthy, 2012), and the emphasis on rapid, skilful operation reflects the practical constraint that the patient would experience pain and distress. The subsequent history of anaesthesia is the history of removing that constraint, and modern anaesthetic pharmacology is one of the great successes of surgical drug development.

Even so, intraoperative and postoperative pharmacology remain active areas of unmet need. Regional anaesthesia has been associated with reduced postoperative mortality and morbidity in some settings, and current understanding recognises that anaesthetic technique can affect outcomes beyond the operating room. The concept of multimodal management, in which several agents acting at different sites are combined to control pain and the stress response and to accelerate rehabilitation, was set out by Kehlet (1997) and has since become a foundation of enhanced recovery (Ljungqvist et al., 2017). Guidelines for postoperative pain management emphasise multimodal analgesia and the use of regional techniques and non-opioid agents in order to reduce opioid exposure (Chou et al., 2016).

For drug development, the classical framing has an interesting implication. Sushruta's Pradhana Karma is defined by action on tissue, but the text repeatedly links technique to the patient's ability to tolerate the operation. Contemporary agents that improve tolerance, such as opioid-sparing analgesics, longer-acting local anaesthetics and agents that modulate stress-response physiology, can be conceptualised as extending the therapeutic window of the principal act. Any programme of research on traditional sedative or analgesic materials, however, must contend with the fact that plant-derived and alcohol-based preparations have variable composition and narrow safety margins, so standardisation and toxicology are prerequisites.

Haemostasis and Cautery

The text prescribes multiple means of arresting bleeding, including cold applications, styptics, ligation, pressure and cautery (Sharma, 2010; Murthy, 2012). Agni Karma occupies a distinctive place: fire, applied through defined instruments and materials, is used for haemostasis and for treatment of selected chronic conditions.

Modern surgery has electrosurgical devices, topical haemostatic agents, fibrin sealants and pharmacological antifibrinolytics. These are drug and device products with direct roles in the operative phase. The classical priority given to controlling bleeding as a precondition for a successful operation is confirmed by modern practice, and the development of improved topical haemostats remains an active field. Traditional styptic plant materials described in the text are potential sources of leads, but they would require rigorous evaluation of haemostatic efficacy, tissue compatibility and safety, especially since topical products can interfere with healing.

Kshara Sutra: A Worked Example of Translation

Kshara Sutra provides one of the clearest examples of a Pradhana Karma technique that has been subjected to modern clinical evaluation. It consists of a surgical thread coated with layers of an alkaline plant-derived preparation, used to treat fistula-in-ano by gradual cutting and healing of the tract. A multicentrerandomised controlled trial, reported by Shukla et al. (1991), compared this method with conventional surgical management of fistula-in-ano and reported its feasibility and clinical outcomes, providing early controlled evidence for a traditional procedure. Subsequent clinical practice has adopted the method widely in some regions, while continued evaluation is needed to determine its comparative merits in terms of recurrence, continence and patient-reported outcomes using modern standards of trial design.

This case demonstrates four important principles for translating Pradhana Karma techniques into modern practice. First, the procedure had a defined protocol, which permitted standardisation. Second, the material (the coated thread) is a combination product, part drug and part device, which raises regulatory questions that are now familiar in surgical innovation. Third, the endpoints, such as healing time, recurrence and continence, are clinically meaningful and measurable. Fourth, the evaluation of such a procedure benefits from the staged approach of the IDEAL framework, which

recommends that surgical innovations progress through idea, development, exploration, assessment and long-term study stages with appropriate study designs at each (McCulloch et al., 2009; Hirst et al., 2019).

From a modern drug-development perspective, Kshara Sutra may be investigated as a drug–device combination product. Further research should focus on standardisation of the thread and its coating, composition and consistency of the alkaline preparation, biocompatibility, local tissue effects, healing time, recurrence, continence outcomes, and patient-reported outcomes. Comparative clinical studies using clearly defined protocols are needed to establish its safety and effectiveness against contemporary standard treatments.

Leech Therapy and Raktamokshana

Bloodletting with leeches is described in the Samhita for conditions with local congestion, and the text discusses the selection and handling of leeches (Sharma, 2010; Murthy, 2012). Modern medicine has retained a related role for leeches in the salvage of venous-congested flaps and replanted digits, and the anticoagulant activity of leech saliva has been a source of pharmacological leads. This is an instance in which a historical Pradhana Karma adjunct has a defined, if narrow, modern niche.

For drug development, this example illustrates that even a procedure that appears archaic can point to a molecular target and a pharmacological class. It also underscores the importance of safety systems: modern use requires attention to infection risk from associated organisms and to prophylactic antibiotic decisions.

The study of leech-derived anticoagulant compounds illustrates how biological substances can provide leads for modern pharmacological research. Hirudin is a specific example of a thrombin-inhibiting anticoagulant derived from leeches. However, the therapeutic use of live leeches and the development of isolated anticoagulant molecules represent distinct approaches and should not be considered equivalent. Further research into biologically derived compounds requires chemical characterisation, assessment of safety, dose optimisation, and appropriate clinical evaluation.

Surgical Ethics and the Role of the Surgeon

The Samhita describes the character and qualifications of the surgeon, including knowledge, skill, courage, composure and cleanliness, and cautions against undertaking cases beyond one's competence (Sharma, 2010). These qualities are the human counterpart to the technical content of Pradhana Karma. The modern literature on surgical innovation emphasises related issues: that novel procedures should not spread before adequate evaluation and that surgeons should be transparent about learning curves and outcomes (Ergina et al., 2009). The classical insistence on competence and restraint thus meets the modern principle of evidence-based introduction of surgical innovation.

Pashchat Karma: The Postoperative Phase

Classical Description

Pashchat Karma covers the measures that follow the operative act and secure the result. The Samhita describes the immediate management of the fresh wound, including the application of medicated pastes and ghee-based preparations, the covering of the wound with a dressing (Vrana Bandhana), and the use of fumigation (Dhupana) with medicinal substances to protect the patient and wound (Sharma, 2010; Murthy, 2012).

Bandaging is treated in detail. The text describes different types of bandage suited to different body regions, the correct tension and technique of application, and the frequency of dressing changes, which is modified according to season and to the condition of the wound (Sharma, 2010). Excessively tight and excessively loose bandages are both cautioned against, and the bandage is meant to protect, support and maintain a suitable environment for healing.

Dietary and behavioural regulation form a major part of Pashchat Karma. The patient is advised on suitable foods and on avoidance of items considered harmful to wound healing, and is directed to regulate activity, sleep and emotional state (Sharma, 2010). Protective rites and the maintenance of a clean, calm environment around the patient are also described.

The Chikitsasthana further elaborates wound care in the scheme known as Shashti Upakrama, the sixty measures for the management of wounds (Vrana). The measures range from preventive and anti-inflammatory treatments through cleansing and debriding therapies to healing and scar-improving applications. They include the use of medicated oils, ghee, honey, pastes, washes and powders, suited to the stage and character of the wound (Sharma, 2010; Trikamji Acharya, 2008). Central to this scheme is a stage-wise concept in which the wound is first cleansed (Shodhana) and then promoted to heal (Ropana), with the choice of therapy depending on whether the wound is unclean, clean or healing.

Correspondence with Modern Postoperative Care

The postoperative period in current practice is organised around infection prevention, pain control, control of nausea and vomiting, nutrition, mobilisation, wound management and monitoring for complications. Table 3 gives the correspondence.

Table 3. Conceptual mapping of Pashchat Karma to modern postoperative care

Classical component	Modern analogue	Representative evidence or standard

Classical component	Modern analogue	Representative evidence or standard
Dressing and bandaging (Vrana Bandhana)	Wound dressings, compression, negative pressure	Wound care guidelines (Berríos-Torres et al., 2017)
Fumigation (Dhupana), cleanliness	Environmental infection control	CDC guideline (Berríos-Torres et al., 2017)
Medicated pastes, ghee, honey	Topical wound therapies, moist wound healing	Systematic review of honey (Jull et al., 2015)
Shodhana then Ropana	Debridement then healing-phase therapy; wound bed preparation	Staged wound management
Dietary regulation	Nutrition support, early feeding	Enhanced recovery (Ljungqvist et al., 2017)
Regulation of activity and sleep	Early mobilisation, rehabilitation	Enhanced recovery (Ljungqvist et al., 2017)
Relief of pain and distress	Multimodal analgesia	Pain guideline (Chou et al., 2016)
Protective rites, calm environment	Delirium prevention, patient-centred environment	Supportive care

Wound Dressing and the Moist Healing Environment

The classical emphasis on selecting an appropriate dressing, avoiding both excess tightness and looseness, and changing it at judicious intervals corresponds to the modern understanding of wound-dressing science. Modern dressings are designed to maintain moisture balance, absorb exudate, protect from contamination and allow atraumatic removal. The classical practice of applying ghee- and honey-based preparations under a dressing can be viewed as an early attempt to maintain a favourable local environment.

Honey has been the subject of formal systematic review. A Cochrane review of honey as a topical treatment for wounds concluded that the evidence varies with wound type, with honey likely to heal partial-thickness burns more quickly than some conventional dressings, but with low-quality evidence for other wound types (Jull et al., 2015). This is an instructive result for translational work. It shows that a traditional wound-care substance can be evaluated by standard methods, that the results can be nuanced, and that generalisation across wound types is not justified without evidence.

From a modern pharmaceutical perspective, honey-based wound-care products require appropriate standardisation and quality control. Relevant research parameters include the source and processing of honey, product consistency, microbial quality, formulation stability, wound compatibility, and clinical effectiveness. Medical-grade preparations should be evaluated for specific wound types using well-designed clinical studies rather than assuming that evidence from one wound category applies to all others.

Wound-Healing Pharmacology: Turmeric as an Example

Turmeric (Curcuma longa) and its principal constituent curcumin are used in traditional wound care in South Asia. Preclinical studies have examined this use. In animal models, topical or oral curcumin was reported to enhance wound closure, collagen deposition and granulation tissue formation (Sidhu et al., 1998), and curcumin-incorporated collagen films were reported to improve dermal wound healing in rats (Gopinath et al., 2004). Reviews of the clinical literature on curcumin, however, have emphasised that although curcumin has many reported biological activities, its clinical development is limited by poor bioavailability, chemical instability and the difficulty of translating preclinical findings into human benefit (Gupta et al., 2013).

Curcumin therefore illustrates both the promise and the difficulty of translating traditional postoperative wound preparations. For topical wound use, delivery systems such as films and matrices may partly circumvent the bioavailability problem, since the drug acts locally. This links to a broader principle drawn from the Pashchat Karma model: that formulation, meaning the vehicle, the dressing and the release profile, is as important as the active constituent.

Future research should investigate whether curcumin-based wound formulations can provide reproducible and clinically meaningful benefits in postoperative care. Important development parameters include formulation stability, drug-release characteristics, local drug delivery, tissue compatibility, dose optimisation, and comparative clinical effectiveness. Preclinical findings should be followed by appropriately designed clinical studies before such formulations are recommended for routine postoperative wound management.

Formulation development is an important consideration when investigating curcumin for surgical wound management. Curcumin-loaded polymeric films, hydrogels, and nanocarrier-based formulations may provide alternative approaches for local delivery. These systems can be investigated for drug-loading capacity, release

kinetics, formulation stability, tissue compatibility, and wound-healing activity. Biocompatible polymers may also help maintain contact between the formulation and the wound surface. Nevertheless, the performance of each delivery system depends on its composition, manufacturing method, and intended application. Further studies are required to establish the safety, effectiveness, and clinical relevance of these formulations in postoperative wound care.

Infection Control in the Postoperative Period

Surgical site infection is a major cause of postoperative morbidity, and current guidelines address perioperative measures for its prevention, including antimicrobial prophylaxis, glycaemic control, normothermia and wound-care practices (Berríos-Torres et al., 2017; Bratzler et al., 2013). Classical fumigation and the use of antimicrobial-acting plant preparations represent an empirical approach to the same problem. Whether classical fumigants reduce airborne microbial load or infection in the modern sense is a testable question, and any such study would need to consider the respiratory safety of smoke exposure.

Pain, Nausea and Recovery

Postoperative pain and nausea are problems that classical care recognised but had limited means to treat. Modern guidelines recommend multimodal analgesia and risk-based prophylaxis for nausea and vomiting (Chou et al., 2016; Gan et al., 2020). The concept of a multimodal, multi-target approach to reduce the stress of surgery and accelerate recovery, proposed by Kehlet (1997), has strong echoes in the classical view that recovery depends on several simultaneous measures: local care, diet, behaviour and environment.

Enhanced recovery pathways illustrate that improvements in postoperative outcomes can come from the coordinated application of many small interventions. A review of these pathways describes elements including preoperative counselling, avoidance of prolonged fasting, opioid-sparing analgesia, prevention of nausea, early feeding and early mobilisation (Ljungqvist et al., 2017). Classical Pashchat Karma similarly bundles diet, behaviour, dressing and medication.

Diet, Nutrition and Rehabilitation

The specific prescriptions in the classical text on suitable and unsuitable foods after surgery are framed in the concepts of Ayurvedic dietetics and cannot be directly translated into modern nutritional science. Nonetheless, the principle that nutrition is part of the surgical prescription is well established, and early feeding, protein adequacy and micronutrient sufficiency are recognised contributors to wound healing. There is a case for studying traditional post-surgical foods and preparations using modern nutritional assessment, with endpoints such as wound healing, length of stay and complication rates.

Relevance of Trividha Karma to Modern Surgical Drug Development

A Phase-Wise Framework for Identifying Therapeutic Needs

The most immediate use of Trividha Karma in drug development is as a map. If every surgical episode is divided into Purva, Pradhana and Pashchat phases, then each phase defines a set of clinical problems for which pharmacological or formulation solutions may be sought. Table 4 summarises the opportunity space.

The Trividha Karma framework may help organise surgical drug-development research according to the stage of care in which an intervention is intended to act. Preoperative research may focus on risk optimisation, anxiety management, nutritional preparation, and infection prevention. Intraoperative research may address anaesthesia, analgesia, haemostasis, and local tissue protection. Postoperative research may investigate wound healing, infection control, pain management, and recovery. These categories provide a framework for identifying research questions; each proposed intervention must independently demonstrate scientific rationale, safety, and efficacy through appropriate preclinical and clinical evaluation.

Table 4. Phase-wise opportunity space for surgical drug development

Phase	Clinical problems	Examples of product classes	Candidate endpoints
Purva Karma	Anxiety, metabolic stress, infection risk, comorbidity optimisation	Premedication, preoperative nutrition and carbohydrate products, topical antiseptics	Anxiety scores, insulin sensitivity, surgical site infection
Pradhana Karma	Pain, bleeding, tissue handling, tract healing	Local anaesthetics, haemostats, sealants, medicated setons	Blood loss, operative time, recurrence, tract healing
Pashchat Karma	Wound healing, infection, pain, nausea, scarring, recovery	Wound dressings, topical agents, analgesics, antiemetics, nutrition	Time to healing, infection rate, opioid consumption, length of stay

This view is consistent with the modern recognition that perioperative drug development should target the whole pathway. Enhanced recovery research shows that gains arise from interventions across all three phases (Ljungqvist et al., 2017), and the classical framework reminds developers that an

agent's value should be judged within the pathway in which it is used.

Reverse Pharmacology and Traditional Surgical Materials

Conventional drug discovery begins with a molecular target, followed by screening and preclinical validation, before human studies. Reverse pharmacology inverts this sequence for materials with a documented history of human use, starting from observed clinical effects and then proceeding to standardisation, safety evaluation, mechanistic study and controlled trials (Patwardhan and Vaidya, 2010). The approach is attractive for traditional surgical materials because documented experience may reduce early uncertainty about tolerability, and because clinical observation can direct attention to plausible indications.

The Trividha Karma framework supplies the context for such work. Materials used in Pashchat Karma, such as honey, ghee-based preparations, medicated oils and plant pastes, have documented indications in particular stages of wound management. The Shodhana and Ropana stages, with their differing therapeutic goals, suggest distinct candidate profiles: agents for wound cleansing and debridement versus agents for granulation and re-epithelialisation. This stage-specific thinking can guide the design of preclinical models and the selection of endpoints.

The honey and curcumin examples illustrate the range of outcomes that may be expected. Honey has been evaluated in systematic review, with conditional evidence of benefit in some wound types and low-quality evidence in others (Jull et al., 2015). Curcumin has extensive preclinical support in wound models but remains constrained by pharmacokinetic and stability problems in broader clinical use (Sidhu et al., 1998; Gopinath et al., 2004; Gupta et al., 2013). Kshara Sutra has controlled clinical data from a multicentre trial (Shukla et al., 1991). Each case shows that the fate of a traditional material depends on rigorous evaluation and cannot be presumed from history alone.

Attrition, Cost and the Case for Structured Selection

Drug development is expensive and risky. Estimates of clinical success rates show that most compounds fail during development (Hay et al., 2014), analyses of attrition emphasise the contribution of poor efficacy and safety in later phases (Kola and Landis, 2004), and estimates of the cost of a new approved drug run to billions of dollars once the costs of failures are included (DiMasi et al., 2016). Any approach that improves the selection of candidates could have substantial value.

Traditional surgical materials cannot be assumed to bypass these risks. Nevertheless, the existence of documented use, defined indications and, in some cases, accessible clinical experience can make hypothesis generation more efficient. The essential requirement is that such hypotheses be tested with modern rigour: standardised, characterised materials; validated preclinical models; safety pharmacology; and adequately powered, controlled clinical trials.

Lessons from Failure: The Need for Perioperative Trial Discipline

The perioperative setting has a history of plausible interventions that failed or caused harm in trials. The POISE trial found that perioperative extended-release metoprolol reduced the rate of myocardial infarction but was associated with higher rates of death and stroke (Devereaux et al., 2008). This result has three implications for the study of interventions derived from traditional surgical care. First, mechanistic plausibility is insufficient. Second, trials must have adequate size and endpoints that capture harm as well as benefit. Third, timing and dose matter, since the perioperative physiology differs from that of the ambulatory patient.

Traditional practices carry an additional risk: that long use may be mistaken for proof of safety. Preparations may contain contaminants or variable constituents, may interact with anaesthetic and anticoagulant drugs, and may affect bleeding or wound healing in unexpected ways. Perioperative use therefore calls for explicit attention to herb-drug interactions, standardisation and pharmacovigilance.

Staged Evaluation of Surgical Innovation

Many of the interventions described in Pradhana Karma are procedures or combination products and not simple drugs. Their evaluation therefore falls under frameworks for surgical innovation. The IDEAL framework proposes stages of idea, development, exploration, assessment and long-term study, with study designs matched to each stage, and calls for prospective registration and transparent reporting of early experience (McCulloch et al., 2009; Ergina et al., 2009). An update to the framework has extended its recommendations to cover devices and other innovations and has clarified how it relates to established drug-development phases (Hirst et al., 2019).

For traditional procedures such as Kshara Sutra, the IDEAL structure suggests that documented clinical use corresponds to an early exploration stage, and that further progress requires prospective, registered cohort studies and then randomised comparison against contemporary standard care, with long-term outcomes such as recurrence and continence. Such a pathway respects both the traditional experience and the requirements of modern evidence. (Gupta et al., 2025)

Combination Products, Formulation and Delivery

A recurring theme of Trividha Karma is that the vehicle and manner of application are integral to the therapy. Medicated thread, paste, oil-based dressing and fumigation are all delivery systems. This corresponds to the modern understanding that in surgical settings the delivery platform, whether dressing, matrix, film, thread, suture coating or irrigation, may determine the clinical effectiveness of a drug as much as the active ingredient.

The curcumin-collagen film work is an example of applying formulation science to a traditional active (Gopinath et al., 2004). Similar principles can be extended to other candidate materials, using contemporary drug-delivery technology to address stability, release and dose control. Regulatory classification of combination products, as drug, device or both, is a key consideration for developers of such products, and early engagement with regulators is advisable.

Table 5. Modern Drug Delivery Systems and Their Potential Surgical Applications

Drug delivery system	Potential surgical application	Important evaluation parameters
Liposomal formulations	Local delivery of selected anaesthetic or therapeutic agents	Drug loading, stability and release profile
Polymeric hydrogels	Local drug delivery and wound management	Biocompatibility, drug release and mechanical properties
Drug-loaded wound dressings	Local delivery of therapeutic agents during wound care	Drug release, moisture management and tissue compatibility
Drug-eluting sutures	Local delivery of antimicrobial agents	Coating uniformity, release profile and mechanical strength
Polymeric nanoparticles	Localised delivery of selected therapeutic agents	Particle characteristics, stability and safety

Safety Culture and the Checklist Principle

The classical emphasis on preparation and on the surgeon's discipline finds a modern parallel in the surgical safety checklist, whose implementation was associated with reduced complications and mortality (Haynes et al., 2009). For drug developers, the relevance is that perioperative products enter an environment governed by protocols and checklists. Products that fit these workflows, for example those that are supplied in ready-to-use formats or clearly labelled by phase of use, are more likely to be adopted and used safely. The phase-wise structure of Trividha Karma offers a natural way to specify the intended use and place in the pathway for each product.

Challenges and Limitations

Several challenges qualify the enthusiasm for integrating Trividha Karma into modern research.

Interpretive uncertainty. The classical text is compressed, technical and transmitted through recensions and commentaries. Terms may be interpreted differently, and translations may not capture the original meaning. Mappings between classical and modern concepts are hypotheses, and there is a risk of retrofitting modern ideas onto ancient text (Meulenbeld, 1999; Wujastyk, 2003).

Conceptual incommensurability. Some elements, such as ritual observances and doctrine-based dietary classifications, rest on conceptual systems that do not correspond to modern biomedical categories. They may be culturally and psychologically meaningful, but they are not easily converted into testable pharmacological hypotheses.

Standardisation and quality. Herbal and mineral preparations vary with source, season, processing and storage. Without chemical characterisation and quality control, clinical results cannot be replicated and safety cannot be assured.

Evidence quality. Much of the available evidence on traditional surgical materials is preclinical, small-scale or of low methodological quality. The honey review shows how conclusions may vary across wound types and how evidence certainty may be low (Jull et al., 2015). The curcumin literature shows the gap between preclinical promise and clinical translation (Gupta et al., 2013).

Safety and interactions. Perioperative patients are physiologically vulnerable and frequently take multiple drugs. Traditional preparations may affect coagulation, wound healing or drug metabolism, so systematic assessment of interactions is essential.

Trial design. Surgical trials face problems of blinding, learning curves, heterogeneity of technique and choice of comparator. Procedural innovations require attention to surgeon expertise and to the quality of standard care used as comparator (Ergina et al., 2009; McCulloch et al., 2009).

Ethical and regulatory considerations. Research on traditional knowledge raises issues of benefit sharing, attribution and protection of community knowledge, along with regulatory heterogeneity across jurisdictions.

Future Directions

Several directions merit priority.

1. **Systematic textual mapping.** A structured, multidisciplinary review of the classical text, involving Sanskritists, Ayurvedic surgeons, and modern surgeons and pharmacologists, could create a catalogue of Trividha Karma components with agreed interpretations, indications and materials.
2. **Phase-specific candidate prioritisation.** Candidates should be ranked using criteria including documented indication, plausibility of mechanism, availability of standardisable material, safety profile and unmet clinical need in the relevant phase.
3. **Standardised formulations and delivery systems.** Investment in chemical characterisation, quality control and modern delivery platforms, such as films, matrices and coated threads, would strengthen translation, drawing on experience with curcumin-based systems (Gopinath et al., 2004).
4. **Rigorous clinical evaluation.** Procedures and combination products should be assessed using staged frameworks such as IDEAL, with prospective registration, defined outcomes and long-term follow-up (Hirst et al., 2019).
5. **Integration with enhanced recovery.** Traditional interventions that are plausible and safe could be tested as components of enhanced recovery pathways, with outcomes such as complications, recovery time and patient-reported measures (Ljungqvist et al., 2017).
6. **Pharmacovigilance.** Registries and surveillance for adverse events and interactions with perioperative drugs are needed if traditional materials are used alongside modern care.
7. **Global surgery relevance.** Since many patients worldwide lack access to timely surgical care (Meara et al., 2015), low-cost and locally available wound-care materials, if shown to be effective and safe, could contribute to surgical care in resource-limited settings.

Conclusion

Trividha Karma is a compact and elegant statement of a principle that modern perioperative medicine has verified empirically: that surgical outcomes depend on the quality of preparation, the skill of the operation and the diligence of aftercare. Purva Karma anticipates risk assessment, counselling, individualised fasting, antisepsis and premedication. Pradhana Karma, through Ashtavidha Shastra Karma and its para-surgical adjuncts, defines the operative repertoire and links technique to safety. Pashchat Karma, with its dressings, staged wound therapy, dietary regulation and protective care, anticipates the principles of modern wound healing and enhanced recovery.

For surgical drug development, the significance of the framework is practical. It offers a phase-wise map of therapeutic needs, a source of hypotheses for reverse pharmacology, and a reminder that formulation, delivery and pathway integration matter as much as the active substance. At the same time, the history of perioperative trials cautions against assuming benefit from plausibility or tradition (Devereaux et al., 2008), and the drug-development literature reminds us of the scale of attrition (Hay et al., 2014). The most productive course is therefore neither dismissal nor uncritical adoption of classical practices, but disciplined translation: careful textual interpretation, standardisation, safety evaluation and staged clinical testing.

The integration of Sushruta's Trividha Karma principles with modern surgical drug delivery systems provides a conceptual framework for exploring therapeutic needs across the preoperative, intraoperative, and postoperative phases of surgical care. Technologies such as liposomal formulations, polymeric hydrogels, drug-loaded wound dressings, and medicated sutures may offer opportunities for localised drug delivery and controlled release. Traditional surgical materials, including Kshara Sutra and curcumin-based preparations, may also provide research directions for formulation development and translational investigation. However, these approaches require appropriate

standardisation, stability assessment, biocompatibility testing, and rigorous clinical evaluation. Further multidisciplinary research may help determine their potential contribution to safe and effective surgical drug delivery.

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