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Review Article

The importance of modern technology advancements in the development of classical Panchakarma instruments

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ABSTRACT

The ultimate substitute of Ayurvedic treatment is Panchakarma, a specific bio-purificatory and rejuvenating method that involves five grand operations, namely Vamana, Virechana, Basti, Nasya and Raktamokshana. The success of these classical procedures is not based on the skill of the physician and drugs only but also on the accuracy of the instruments (Yantras and Upakaranas) used and the design of the instruments. Historically Panchakarma instruments were made by hand out of natural products, e.g. clay, wood, brass, or animal parts based on the theory named Sukha-Upayoga (easy to use), Kshamata (efficient) and Sthirata (long-lasting) in the writings of Charaka Samhita and Sushruta Samhita. But in the face of the renewed Ayurveda worldwide, the shortcomings of traditional equipment, e.g. the absence of standardization, variation of temperature, hygiene issues, and the reliance on human skill, have aroused the requirement of technology. Background: This review seeks to assess the relevance of the modern technological development on the design, standardisation, and clinical adjustments of classical Panchakarma instruments and in particular, their safety, accuracy, reliability and universal usability. Panchakarma instruments have been undergoing a transformation process that is progressive, which has been achieved by incorporating both engineering and biomedical technology. Added to innovations in the area. Moreover, standardization, documentation of research and global acceptance has become easier due to the introduction of Ayur informatics, sensor-based monitoring, and data-driven SOPs.

Keywords: Panchakarma, Instrumentation, Modern technology, Ayurveda, Standardization, Automation, Shirodhara Yantra, Ayur informatics, Device innovation

INTRODUCTION

Panchakarma the peepal of the Ayurvedic medicines is one of the most multi-dimensional systems of bio-purification and life-giving-power as talked about in the traditional Indian medicine. The literal definition is of five processes or actions Vamana (purges of the body with emesis), Virechana (purgation), Basti (enema treatment), Nasya (nasal administration), and Raktamokshana (blood-letters), which are rituals that work to eliminate a build-up of Doshas (bio-humours) in the body to restore Dhatu Samyata (tissue balance) and health.[1,2] In addition to being a detoxification program, Panchakarma is a comprehensive intervention plan which combines both internal cleansing process, physical rehabilitation, and psychological balance.

The effectiveness of these classical medicines does not necessarily lie in the quality of medicines, the experience of the practitioner, but also greatly on the shape and the applicability of the instruments (Yantras and Upakaranas) that are utilized to administer the procedures.[3] These accessories were originally created out of materials that were naturally available e.g. clay, copper, brass, bamboo and animal products in ancient times. Sushruta Samhita and Ashtanga Hridaya contain textual references that talk of a variety of healing applications such as Basti Putaka (enema bag made of animal bladder), Droni (wooden

massage table), Dhara Patra (pouring vessel used in Shirodhara), and Bashpa Svedana Yantra (steam chamber).[4,5] They were elegantly designed using the principles of ergonomics, gravity flow and natural heating, but the functionality of these devices depended on the manual abilities of the therapist to the large extent.

The existence of Ayurveda as an element of the modern healthcare environment revealed the flaws of the traditional equipment, such as the impossibility of controlling the temperatures, the absence of standardization, the risk of contamination, and fatigue of operators.

The growing popularity of Ayurveda in the global world and the emergence of both Panchakarma wellness centers in the entire world as a whole presented one of the strongest impetuses to creative thinking. It marked the beginning of a technological modernity period, during which Ayurvedic classical wisdom would be combined with Biomedical engineering, thermodynamics, and materials science to enhance safety, reproducibility, and comfort.[6,7]

In the modern Panchakarma practice, the extensive range of high-tech devices are already present: automated Shirodhara Yanras, which regulate the flow and movement of the oil, computerization of the steam rooms with a thermostat, drainage massage table, sterile catheters, which are disableable, and the latest Raktamokshana equipments operating on vacuum assisted blood draught.[8-10] The innovations ensure the standard traditional therapeutic levels and in conformity to the modern standards of hygiene, efficiency and clinical safety.

Moreover, digital technology introduction into Panchakarma instrumentation has also led to opening up new research frontiers. Automated systems have the capability to monitor parameters, including oil temperature, flow rate, and treatment duration, so that they can be reproducible and enable standard operating procedures (SOPs) in clinical trials.[11]

The move towards Ayur informatics i.e. data science and sensor-based analytics into Ayurveda further gives the possibility of personalized Panchakarma protocols predating on Prakriti (body constitution) and physiological response.[12]

But there are no philosophical and ethical issues concerning modernization. It is difficult to maintain the spirit of Ayurveda which is its focus on individualism, nature, and practitioner-patient relationship but adopt innovation. Excessive mechanization can contaminate Panchakarma into a robotic spa treatment, which will remove its therapeutic and spiritual nature.[13] Thus, Ayurvedic epistemology should be the determining factor behind any technological intervention that should be approved by evidence-based evaluation.

In this regard, the current review is a critical analysis of the role of the modern technology in changing the classical Panchakarma instruments, its role in safety, efficiency, and standardization, and the possibility of the future trend towards intelligent, sensor integrated and internationally compliant Panchakarma systems. As highlighted in the review, as tradition and technology work in harmony, Panchakarma can indeed become a scientifically proven holistic treatment that can fully fit into the modern healthcare systems without losing its ancient values.

Aim and objectives

The objectives of the study were to examine how classical Panchakarma instruments evolved utilizing changes in technology, to investigate the impact of modern instrumentation in terms of the safety of the procedure, its reproducibility, and patient treatment, to determine obstacles and problems related to modern technology implementation in the traditional Panchakarma practice, and to suggest the ways of sustainable modernization of Panchakarma instrumentation in the future.

METHODS

The scope of this review is rooted in a qualitative review of obtained classical Ayurvedic texts (Charaka Samhita, Sushruta Samhita, Ashtanga Hridaya) and current scientific sources associated with implementing the Panchakarma instruments. Articles published within the period 2000-25 were searched using keywords Panchakarma instruments, Ayurvedic device standardization, and modern technology in Ayurveda in electronic databases PubMed, AYUSH Research Portal, Scopus, and ResearchGate. Out of 58 relevant papers, 35 were then screened and qualified according to relevance and quality. Under conceptual themes of modernization, standardization, safety as well as future trends, data were synthesized.

Panchakarma Ayurvedic instruments and conceptual framework Ayurvedic Panchakarma instruments

The Ayurvedic instruments are a continuation of the therapeutic purpose, and they are created to sustain the Samyak Yoga (balanced use) of Sneha, Sweda, Vamana, Virechana, and Basti.[6] These Yantras are considered as Snehana Yantra, Svedana Yantra, Dhara Yantra, Basti Yantra, and Raktamokshana Upakarana.[7]

Every instrument should allow the wishable Dosha Nirharana and not interfere with Dhatu Samyata. Therefore, the research design straight affects the treatment outcome.[8]

The classical norms note such qualities like cleanliness, durability, comfort, and convenience (Sukhopayoga). These values stay intact with the adjustment to the technological fine-tuning.

Classical Panchakarma instruments technological development

The development of Panchakarma instrumentation between antiqueness crafts to the contemporary biomedical accuracy is an excellent example of Ayurveda adaptive power. All the instruments initially constructed as aids in Samsodhana Chikitsa (purification therapy), had been manufactured to follow Ayurvedic principles of Prayojana (purpose), Upayoga (utility), Sukha (easy to use) and Kshamata (efficient).

Through the centuries, due to the improvement in knowledge about materials, ergonomics, and hygiene, the design and construction of the Panchakarmana instruments also improved. The introduction of modern technology has increased their use, accuracy and safety to the patient without impacting the old-time philosophy behind their design and usage.

SNEHANA AND SVEDANA ASSISTANTS

Classical context

The Ayurveda holds Snehana (oleation) and Svedana (sudation) to be a preparation phase (Purva karma) of Panchakarma. These included classical ones i.e. Bashpa Svedana Yantra, Avagaha Yantra, and Nadi Svedana Yantra, which were predominantly of wood, earthen or metal.[1,2]

The oleation was on a very simple wooden table called the Droni (wooden table) which was simple to use but efficient in matters because it held the oiled medicine aptly named Rhapu and passed it to the individual. Heating was also performed manually, and controlling of temperature was in the hands of expertise and experience of the therapist.

Technological evolution

The major drawbacks of the conventional devices have been overcome, through the introduction of digitally controlled steam chambers which include an inbuilt thermostat, automatic temperature shut-off devices, and humidity sensors.[3] The Svedana Yantras of the modern world are made of melodious stainless steel and fibre materials to enhance longevity and purity. IR and moist-heat solutions offer even distribution of heat and save energy.[4]

The standard wooden Droni has also assumed a form of ergonomic massage that is constructed using medical grade fiber or teak with oil-drainage holes, height modification, and waterproof overlay.[5]

Moreover, portable steam generators that have auto safety valve, auto pressure gauge functions allow the safe and regulated delivery of steam to Nadi Svedana and localized treatment and increase the comfort of the therapists as well as patient safety.[6]

DHARA YANTRA (SHIRODHARA APPARATUS)

Classical context

A well-known treatment measure of Vata-Pitta diseases is the Shirodhara or pouring of medicated oil, milk, or buttermilk nonstop on the forehead of an individual at a fixed height with a Dhara Patra (earthen or metal vessel) floating over the head.[7] Manual control was done through increasing and decreasing the pot height to control the flow rate and temperature and periodically heating through reheating.

Technological evolution

Modern Automated Shirodhara Yantra combines the concepts of fluid mechanics, thermoregulation and microprocessor-controlled operations. It provides accurate regulation of oil temperature ($\pm 1^0$C), the rate of oscillation and flow rate with the help of digital sensors.[8] Other systems have a mechanism of peristaltic pump to maintain constant flow and hold to a minimum therapist intervention.[9]

Programmable oscillation arms imitating the rhythmic action of the traditional manual pot and noise-free heating modules keeping the temperature constant during the session are also some of the innovations. The closed loop systems avoid spillage and contamination, and also deliver the therapy in uniform manner.[10] Clinical trials in the field have revealed that automated systems provide comparable therapeutic effects with the conventional Shirodhara but at a certain convenience to the therapist.[11]

BASTI YANTRA (ENEMA APPARATUS)

Classical context

Basti is said to be the best treatment (Ardha Chikitsa) against vata Vyadhi and it consists of the administration of medicated decoctions, oils or ghee into the colon. Classical There was a Basti Putaka (animal bladder) which was bound to a metal or bamboo Netra (metal or bamboo nozzle) to be inserted.[12] The therapist manipulated manually the pressure and flow through squeezing the Putaka. Although it worked, the method was poor in regards to sterility, pressure and reusability.

Technological evolution

The current Basti Yantras have developed into disposable enema syringes or polyvinyl catheters hooked on graduated infusion bags which have a flow regulator.[13] Infusion systems and digital flow meters work out with the help of gravity and provide the possibility of accurate dosage delivery and the regulation of pressure.[14]

Recently motorized Basti pumps have been developed, which has a constant rate of infusion, and this reduces discomfort besides avoiding retrograde leakage.[15]

Moreover, the Basti systems are temperature-controlled, thus the fluid containing the medicine does not exceed the level of Ushna, which causes the spasms of the colon.

These not only have been in improving the hygienic standards but also in making Basti Chikitsa more acceptable in the hospital-based Panchakarma units.[16]

KATI BASTI, GREEVA BASTI, JANU BASTI AND LOCAL RETENTION THERAPIES

Classical context

These local treatments include the application of warm medicinal oil on particular parts of the body including the back lower (Kati), neck (Greeva), knees (Janu) or the chest (Uro). The oil was traditionally placed in rings composed of wheat or black gram dough and re-heated manually and changed again and again.[17]

Technological evolution

Current practice involves heat-resistant silicone or fiber rings that are much more perfect in terms of providing a seal that does not allow leakage, but also ensures longer temperature retention.[18] Heat warming systems and IR Nudges are currently installed at the bottom of the retention area to enhance constant therapeutic temperature during the session.[19]

Innovations such as modular ring-Molds that have adjustable diameter and pre-calibrated oil tank, minimize waste of oil and increase standardization of the procedure. Other facilities have also implemented the use of vibration-aided Kati Basti equipment that stimulate drug intake into the body by gently massaging the local circulation of the body.[20]

BASTI THAT ARE PLACED ON THE NOSE, AND ALSO AT THE UPPER LIP

Classical context

At Nasya, the nasal administration is done using metallic Nasyanetra (dropper or tube) and meditated oils or powders are applied. In Uttara basti (to treat urogenital disorders), cannulas of metal were to be placed in the urethra or uterus and the use of the practice posed threats of infections and trauma unless the cannulas were effectively sterilized.[21]

Technological evolution

Since the use of the disposable plastic syringes and the medical grade catheters, these operations have been rendered safer and more precise. The distribution of oil by use of calibrated dropper bottles, spray aids that have an air pressure to ease each drop or spray in Nasya, thereby causing very little pain.[22]

Sterile intrauterine catheters are now being applied in Uttara Basti instead of metal nozzles and the administration is atraumatic, and done under aseptic conditions.[23]

Digital infusion pumps that have been used experimentally offer standardized administration of medicated fluids at a constant pressure to achieve reproducibility at a minimal practitioner error.[24] These inventions have rendered Nasya and Uttara Basti more tolerable among infertility and gynaecological researchers.

RAKTAMOKSHANA INSTRUMENTS

Classical context

Raktamokshana which is a type of Pitta therapy and Rakta Dushti therapy involves offloading (blooding) of a specific organ with the help of a set of traditional instruments, including Shringa (horn), Alabu (gourd), and Jalaukavacharana (leech therapy).[25] They worked well but had no control over the amount of vitiated blood that was removed and was sterile.

Technological evolution

The recent developments have incorporated vacuum-assisted cupping machines and units of negative pressure therapy having adjustable suction levels such that volume extraction is accurate.[26] In Jalaukavacharana, micro-suction and sterile leech maintenance systems-controlled leech application kits have been launched to improve the safety and avoid cross-contamination.[27]

In addition, laser-based and mechanical bloodletting machines are under investigation regarding selective cases in the replacement of the physiological processes of the traditional Raktamokshana, still preserving the aseptic requirements.[28]

INFORMATICS, SENSOR-BASED, AND DIGITAL INTEGRATION

The most recent stage of the development of Panchakarma instruments is the digital and sensor-based one. The real-time monitoring of the treatment variables, such as temperature, humidity, and pressure, can be performed through the integration of internet of things (IoT), micro-sensors, and data loggers.[29] These parameters may be archived and examined on clinical research, which leads to evidence-based standardization.

The new branch of Ayur informatics is also transforming Panchakarma by providing a connection between the data of the instruments with patient profiles (Prakriti, Vikriti, and biomarkers). This may be integrated with individualized Panchakarma protocols, i.e. where instruments automatically alter parameters based on the doshic requirements and physiological feedback of individuals.[30] There is exploration of Artificial Intelligence

(AI)-based systems, which can help to optimize the duration and intensity of therapies, enhance clinical outcomes, and maintain Ayurvedic principles.[31]

MATERIAL AND DESIGN INNOVATION

Material science has also been highlighted in the technological evolution. The instruments are currently produced with alloys with high resistance to corrosion, alloys that are medically approved like silicon and fibres of composite material that make it longer lasting and easy to sterilize.[32] 3D printing technology has facilitated indifferent instruments design which is dependent on the anatomy and procedure needs of patients.[33] Green heating units and metal recycling units contribute to the environmentally-friendly nature- it is supported by the ecological dharma of Ayurveda.[34,35]

Modern technology has changed the instrumentation of the Panchakarma not simply as a mechanical improvement of the instrumentation, but as a rational interaction of Ayurvedic tradition with biomedical science. Classical instruments represented simplicity and a design of nature, whereas modern devices gain perfection, hygiene and standardizing. The combination of them supports the eternity goal of Panchakarma, purification (Shodhana), rejuvenation (Rasayana) and the restoration of chronic balance.

DISCUSSION

The history of the development of the Panchakarma instrumentation is an active conversation between the ancient Ayurvedic knowledge and the contemporary technological advancement. This synthesis, that is being discussed, is not just about developing a device, but it represents the process of modernization as well, without losing the philosophical and therapeutic purity of Ayurveda.

The impact of advancement in technology and clinical effectiveness

The integration of digital systems and automated tools in the Panchakarma has been a great way of enhancing efficiency and reproducibility of clinical work. Conventional techniques were very therapist-intensive such as the rhythm and consistency of flow of oil in Shirodhara or the temperature of steam in Bashpa Svedana were dependent on manual adjustment, resulting in the therapeutic results to be inconsistent.[1,2] With the introduction of automated Shirodhara Yantra with programmable controls, the flow, oscillation, and temperature of the Shirodhara Yantra can be strictly regulated, leading to consistent physiological responses, such as relaxation of the hypothalamic-pituitary axis and achieving better quality and quantity of sleep.[3,4] As well, the popularity of digitally controlled steam chambers with thermostats and automatic safety cut-offs has minimized the possibility of overheating or fainting, which were sometimes experienced with the traditional wooden steam boxes.[5]

The standardization that such technological brings is not only beneficial to the safety profile of therapies but also makes results objective evaluation easy. This is also important in any clinical research where consistency of the variables involved in the procedures is important to achieve reproducible results.[6]

Increased safety, hygiene and comfort of patients

Panchakarma treats both physical and internal treatments directly and therefore the instruments used have a direct impact in terms of safety and hygiene. The use of medical quality stainless steel, autoclavable polymer and disposable parts are introduced as a result of modernization, which has worked wonders in the minimization of cross-infection.[7,8] To performed invasive procedures, such as Uttara Basti and Nasya, sterile, single use cannulas or droppers have replaced metal Netra Yantras and Nasyanetras, thereby making the procedures more acceptable, particularly gynaecological and ENT procedures.[9,10]

In modern design, patient comfort as a factor usually ignored in classical set-up has been given a priority. Raisable Dronis (massage tables) with ergonomic cushions, draining, and temperature-controllable oil tanks enable the comfortable position and reduce the stress caused to the therapist.[11] It has been improved in the modern Kati Basti device of fiber or silicone rings which produces better sealing, even heat retention and no spillage compared to the traditional flour ring.[12]

Technology and standardization and research

Technology has played a significant role in research and documentation, which is one of the most significant contributions. The automated devices provide measurable data concerning the temperature, flow rate, time and pressure- the variables which were not easily standardized or objectively measured in the past.[13] This change justifies the establishment of Panchakarma therapies standard operating procedures (SOPs), adapting them to the culture of quality assurance systems, including ISO and NABH.[14]

Better reproducible clinical trials have also been made possible by the availability of parameters which can be measured. As an example, Shirodhara, motor systems compared between manual and automated studies exhibited similar effectiveness yet greater reproducibility with automated.[15] More so, with the incorporation of digital sensors and data-logging arrangements, it is possible to monitor the treatment parameters over a long period, which contributes to the production of substantial evidence on Ayurveda.[16]

Another potential direction of research would be the concept of Ayur informatics, referring to Ayurveda, data

science and biomedical analytics. In the future, Smart Panchakarma tools with-in implanted with internet-of-things (IoT) sensors might be used to detect bio-responses including skin temperature changes, heart rate variations, and perspiration in the state of subjective healing, coupled into measurable data.[17,18]

Ethical, philosophical, as well as practical challenges

Although the benefits are obvious, there are several ethical and philosophical issues of modernization. The ethos of Ayurveda concerned curing focuses on the manasika sambandha; personal and instinctive rapport between the practitioner and the patient.[19]

Excessive mechanization stands a chance of depleting this experiential contact turning Panchakarma into a mechanical service spa as opposed to purification being a personal process.[20] Therefore, it is essential to note that technology must be an assisting supplement, and not a replacement of human intuition and therapeutic sensitivity.

Cost and accessibility are yet another critical followed by cost. A lot of sophisticated equipment is costly and needs frequent servicing, which such a small or rural Ayurvedic clinic can hardly afford.[21] Materiovigilance is also of concern to the uncontrolled introduction of a poorly tested locally produced device into the market.[22] It is thus crucial that Ayurvedic Device Standards have been initiated in the AYUSH ministry to make sure the quality, safety, and calibration.[23]

Pedagogically Speaking the principles of handling, safety, and maintenance of instruments have not incorporated into Ayurveda education. Modern engineering will also close the knowledge gap between tradition and modern engineering, because of the inclusion of technical training modules in Panchakarma curriculum.[24]

Internationalization and integrative healthcare

In the contemporary world, Panchakarma is increasingly accepted throughout the world, as it has been improved with modern instruments so as to meet the requirements of international hygiene, safety, and the procedures.[25] In the hospitals and wellness centers of the entire world, the concept of Panchakarma is now incorporated into the programs of holistic medicine, since -the availability of standardized instruments renders the process credible and comfortable to the non-Indian clients.[26]

Another important consideration is to have the classical structure of Purva Karma (preparatory therapy), Pradhana Karma (main procedure), and Pashchat Karma (post-therapy regime) in the mechanized setting. It should strive to position Panchakarma as an extreme spa process but an Ayurveda-based scientifically designed detoxification treatment based on the Ayurveda principle of Dosha-Dhatu-Mala balance.[27,28]

Future prospects

The future of Panchakarma instrumentation is to be intelligent and sensor driven and or AI assisted systems. There are already research prototypes of digital feedback temperature and pressure control, automatic observation of physiological responses and cloud recording of data in therapy.[29,30] These innovations will develop evidence-based practice and could be customized based on Prakriti and pathology.

In addition, future innovations should be stipulated by the principle of sustainability, which is one of the values of Ayurveda. Modernization is compatible with the ecological Ayurveda philosophy through the use of environment-friendly materials, energy-efficient systems and biodegradable disposable.[31]

The modernization of the Panchakarma instruments through technology is a two-sided development. It is found to improve accuracy, safety, and international adaptiveness when used in harmony with classical knowledge, as well as destroy the soul of Ayurvedic practice when used with the culture of philosophy being ignored. The most appropriate way to go is integrative, to combine classical wisdom and technological accuracy to unprecedented instances of reproducible, patient-centered treatment and sustainable Panchakarma therapies.[32,33]

CONCLUSION

The evolution of classical Panchakarma instruments in the modern world is a new step that significantly affected Ayurveda development in the whole world. It represents the combination of old-time therapeutic knowledge with modern scientific accuracy, and enables Panchakarma to leave behind its artisanal art and enter into the evidence-based clinical profession. Nonetheless, such a change should not be disconnected with the basic Ayurvedic principles like Prakriti-related individuality, Dosha-Dhatu-Mala equilibrium, and Samsodhana -Samsamana harmony that represent the philosophical core of all Panchakarma treatments. The use of technological advancements has significantly increased the safety, effectiveness and practitioner reproducibility of Panchakarma practices. The emerging equipment in the form of automated Shirodhara Yantras, digital steam generators, infrared assisted Basti and Swedana processes and sterile disposable gadgets have transformed the therapies into being patient friendly and internationally acceptable. The use of digital integration enables precise managed temperature, flow, pressure and time which reduce the errors and inter-therapist inconsistency. As a result, traditions of Panchakarma used to rely on the subjective expertise of the therapist can now be provided with a certain amount of accuracy and increase clinical believability and research validity. It is also crucial that technology also makes a contribution in terms of safety and standardization. The presence of programmable temperature controls, material that is autoclavable, sterilization procedures, and real-time measurement of the

parameters has significantly minimized the occurrence of procedural complications. According to the international medical norms of safety, these changes not only are able to satisfy the requirements of international standards, but also give more confidence to the practitioners and patients. This standardization has enabled the successful translation of Panchakarma into a hospital-based and wellness resort-based practice around the globe making Ayurveda a global health science as opposed to a localized traditional practice. Nevertheless, there are also questions of philosophical and ethical issues associated with modernization. Ayurveda is a vital science that focuses on personal healing with human empathy and intuition of the practitioners (Yukti). Excessive mechanization also has the potential to take over-personalization out of therapy and remove the personal aspect of therapy. Consequently, modern technology must serve as an assistant, or helper, however, it must not be applied as an alternative to the discretion of the practitioner, as well, and a therapist-patient relationship, Vaidya and Vaidya.

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