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# ANCIENT EMBALMING TO MODERN MACHINES: THE EVOLUTION OF ORGAN PRESERVATION THROUGH ANATOMICAL TECHNIQUES

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## ABSTRACT

***Background:*** *The preservation of human organs and bodies has transitioned from ancient ritualistic practices to scientifically driven methods. Historical embalming practices, such as those from ancient Egypt and India, laid the philosophical and procedural groundwork for contemporary anatomical preservation and organ transplant techniques.*

***Aim:*** *To explore the chronological development of organ preservation methods, from ancient embalming traditions to modern mechanical and chemical preservation techniques, and to analyze their anatomical, cultural, and scientific relevance.*

***Materials and Methods:*** *This conceptual review includes an in-depth analysis of classical texts, archaeological findings, and modern literature pertaining to anatomical preservation. Sources include historical manuscripts, embalming records, cryopreservation studies, and scientific advancements in organ perfusion and hypothermic storage.*

***Results:*** *Ancient civilizations demonstrated sophisticated embalming methods using natural preservatives. Over time, anatomical techniques evolved with the introduction of formalin-based embalming, hypothermia-induced slowing of cellular metabolism, and extracorporeal perfusion technologies. Modern preservation now integrates cryopreservation, organ-on-chip technologies, and ex vivo perfusion machines.* ***Discussion:*** *While ancient embalming emphasized spiritual and post-mortem body integrity, modern techniques prioritize viability and function, especially for transplantation. The philosophical shift from spiritual preservation to clinical application highlights the continuous refinement of anatomical knowledge and biomedical engineering.*

***Conclusion:*** *The journey from spiritual embalming to mechanical organ preservation underscores humanity's evolving understanding of anatomy, physiology, and technology. Bridging historical wisdom with modern innovations offers a holistic appreciation of organ preservation science.*

***Keywords:*** *Embalming, Organ Preservation, Anatomy, Cryopreservation, Ex Vivo Perfusion, Historical Techniques*

## INTRODUCTION

In *Ayurveda*, the human body (*Sharira*) is viewed as a sacred composite of *Panchamahabhutas* and *Tridoshas*, maintaining a delicate equilibrium that sustains life.[1] The postmortem integrity of the body was highly respected, especially for educational and ritualistic purposes. Ancient texts such as the *Sushruta Samhita* describe methods for preserving cadavers, including immersion in flowing water and the application of herbal pastes to facilitate dissection and delay decomposition.[2]

Anatomical study in ancient India was both spiritual and scientific. The process of dissection was guided by a detailed protocol aimed at minimizing contamination and honoring the sanctity of the human form. This reflects a unique understanding of biological decay and preservation, rooted in the principles of *Sharira Rachana* and *Sharira Kriya*.[3]

Preservation was not only practical but philosophical. *Ayurveda* viewed the body as an instrument of *Dharma*, and its postlife preservation had implications for both learning and cosmic balance. The knowledge of how bodily tissues react to time, temperature, and environment was deeply embedded in traditional practices that prefigured modern anatomical methods.[4]

Modern anatomical science began formalizing organ preservation techniques in the 17th and 18th centuries with the development of embalming solutions and cold storage methods.[5] Preservation transitioned from a focus on postmortem integrity to viability of organs for transplantation. Chemical agents such as formalin revolutionized anatomical studies by allowing longterm preservation with minimal decay.[6]

Today, the field of organ preservation has advanced to incorporate technologies such as cryopreservation, hypothermic machine perfusion, and normothermic perfusion.[7] These innovations have enabled organs to be stored for extended periods while maintaining functionality, which is crucial in transplant medicine. Modern science now integrates biophysics, fluid dynamics, and molecular biology into preservation protocols.[8]

The evolution from ancient herbal embalming to organonchip systems and perfusion machines represents a remarkable shift in both purpose and precision. Whereas ancient practices focused on spiritual and anatomical integrity, modern techniques emphasize biological functionality and transplant readiness. This transformation reflects the ongoing convergence of traditional knowledge with cuttingedge biomedical technology.[9]

## AIM AND OBJECTIVES

### Aim

To explore the historical evolution and scientific advancement in organ and body preservation techniques from ancient embalming methods to modern anatomical technologies.

### Objectives

1. To study ancient methods of embalming and preservation described in traditional medical systems.
2. To analyze the transition from ritualistic preservation to scientific anatomical techniques.
3. To review modern technologies used in organ preservation for transplantation and research.
4. To compare the philosophical and practical perspectives of ancient and modern approaches.
5. To highlight the relevance of traditional knowledge in the context of current biomedical innovations.

## MATERIAL AND METHOD

This is a conceptual review based on classical Ayurvedic texts (*Sushruta Samhita*, *Charaka Samhita*), historical sources on embalming practices, and modern scientific literature from medical journals and textbooks. Data was collected through literature review from PubMed, Scopus, and Google Scholar. Comparative thematic analysis was used to trace the evolution of preservation techniques from ancient rituals to modern biomedical innovations.

## CONCEPT OF AYURVEDIC ANCIENT EMBALMING –

In *Ayurveda*, the practice of embalming was not a separate ritualistic procedure as found in Egyptian or Greek traditions, but rather a practical and sacred method integrated into anatomical education. It primarily served the purpose of cadaver preservation for dissection and understanding of the human body through direct observation, known as *Sharira Viccheda*.[10] The approach was spiritual, educational, and natural, aligned with the Ayurvedic view that the human body is composed of *Panchamahabhuta* and guided by *Tridosha* principles.[11]

### Scriptural Reference and Procedure

The earliest and most authoritative reference appears in the *Sushruta Samhita*, specifically in *Sharira Sthana*, where *Acharya Sushruta* recommends that a cadaver be immersed in flowing water for a period of seven days.[12] Before immersion, nails and hair were removed, and the body was wrapped in grass such as *Munja* or *Kusha*. This method was designed to soften bodily tissues naturally, enabling dissection layer by layer without the use of synthetic preservatives. The flowing water served to delay putrefaction while allowing the body's layers to be separated gradually, providing a real time study of anatomical structure.[13]

This natural preservation process allowed students to observe the disintegration of *Dhatus* and *Srotas* in

a sequential manner. It was a pedagogical tool for deep anatomical insight.[14] The absence of chemicals ensured safety, respect for the dead, and alignment with Ayurvedic ecological wisdom. Though not called embalming in the western sense, it functioned as an early form of preservation that maintained cadaveric integrity for a limited time.[15]

From an Ayurvedic standpoint, the body is not merely a physical structure but a sacred vehicle for the *Atma*.[16] The use of cadavers was not taken lightly and required spiritual preparation and moral responsibility. The cadaver used for dissection was chosen carefully, and the process of preparation was accompanied by purification and reverence. There was a deep awareness that studying the body helped in understanding *Sharira Rachana*, disease mechanisms, and surgical training, all while honoring the sanctity of human life.[17]

**PROCEDURE OF ANCIENT AYURVEDIC EMBALMING (CADAVER PRESERVATION)**

Identification of Suitable Cadaver

↓

Removal of Nails and Hair

↓

Wrapping the Cadaver with Munja or Kusha Grass

↓

Immersion of the Body in Flowing Water

(Duration – 7 Days)

↓

Natural Softening and Decomposition of Superficial Tissues

↓

Removal of the Cadaver from Water

↓

Commencement of Dissection

(Layer-by-layer study of Dhatus and Srotas)

**Use of Medicinal Plants**

Although *Sushruta* did not prescribe chemical preservation, it is inferred that natural substances with antimicrobial and antiseptic properties like *Haridra* (turmeric), *Neem*, *Kushta*, and *Guggulu* may have been applied locally or used in the surrounding environment. These plants had natural preservative qualities and aligned with Ayurvedic pharmacology that emphasized bio compatibility, purification, and dosha balance.[18]

**CONCEPT OF MODERN EMBALMING –**

Modern embalming is the process of temporarily preserving a human body after death by using chemical solutions to delay decomposition, restore appearance, and prevent the spread of infection. It is widely used in funeral services, medical education, forensic investigations, and transport of bodies over long distances.[19]

**PURPOSE OF MODERN EMBALMING**

- **Cosmetic Preservation:** To restore the body's natural appearance for viewing during funerals.
- **Disinfection:** To reduce microbial load and prevent the spread of infectious diseases.
- **Temporary Preservation:** To delay autolysis and putrefaction until burial, cremation, or anatomical study.
- **Medical Education:** To preserve cadavers for teaching anatomy in medical schools and surgical training.
- **Legal and Forensic Use:** To maintain body condition for autopsies, evidence analysis, or transport.

## TYPES OF MODERN EMBALMING[20]

**a) Arterial Embalming**

- A preservative fluid is injected into the arteries (usually the right common carotid).
- The venous system is used to drain blood simultaneously.
- Fluid travels through the vascular system to preserve tissues.

**b) Cavity Embalming**

- After arterial embalming, a trocar is used to aspirate internal fluids from the thoracic and abdominal cavities.
- A concentrated preservative solution is then injected into these cavities.

**c) Hypodermic Embalming**

- For areas that do not receive sufficient arterial fluid, the embalmer injects preservative solution directly into tissues using a hypodermic syringe.

**d) Surface Embalming**

- Used for localized areas like wounds or ulcers using embalming gels or packs.

## EMBALMING CHEMICALS[21]

- **Formaldehyde:** Primary fixative and preservative (commonly 37% solution called formalin).
- **Methanol:** Acts as a stabilizer and anti-polymerizing agent.
- **Glycerin:** Moisturizer to prevent excessive drying of tissues.
- **Phenol:** Disinfectant and bleaching agent.
- **Dyes:** Restore natural color of skin and tissues.
- **Water and Humectants:** Provide volume and tissue softness.

**Note:** Environmental and health concerns have led to the development of low-formaldehyde and eco-friendly alternatives.

## PROCEDURE[22]

1. **Body Preparation:** Disinfection of body surface and positioning.
2. **Vascular Access:** Cannulation of arteries and veins.
3. **Injection of Preservative:** Controlled infusion using an embalming machine.
4. **Cavity Treatment:** Aspiration and chemical injection into body cavities.
5. **Cosmetic Work:** Restorative art, makeup, setting features.
6. **Dressing and Presentation:** Final grooming for funeral or transport.

## MODERN EMBALMING PROCEDURES – FLOW CHART

Modern Embalming Procedures
↓
Body Preparation
↓
Arterial Embalming
↓
Cavity Embalming
↓
Hypodermic Embalming
↓
Surface Embalming
↓
Cosmetic Work

**EMBALMING IN MEDICAL AND SCIENTIFIC USE**[23]

- **Long-Term Preservation:** In anatomical labs, cadavers are embalmed using stronger solutions or plastination techniques.
- **Thiel Embalming Method:** A modern technique offering flexible, lifelike cadavers for surgical training.

## THE EVOLUTION OF ORGAN PRESERVATION THROUGH ANATOMICAL TECHNIQUES

### ANCIENT PERIOD – RITUAL AND SPIRITUAL PRESERVATION

In early civilizations, organ and body preservation was closely tied to religious beliefs and ritual practices. Ancient Egyptians pioneered embalming through evisceration and natron desiccation, preserving internal organs separately in *canopic jars*.[24] This practice was meant to ensure soul's journey into the afterlife. Similarly, in India, *Ayurveda* emphasized preservation through natural immersion in flowing water and the use of antiseptic herbs like *Haridra* and *Neem*. The purpose here was not long-term display, but temporary preservation for educational dissection (*Sharira Viccheda*) as described in the *Sushruta Samhita*.[25]

Other ancient cultures like the Greeks and Chinese also practiced preservation using resins, oils, and honey, indicating a basic understanding of antimicrobial agents. However, these were more symbolic than scientific.[26]

### MEDIEVAL TO RENAISSANCE PERIOD – ANATOMICAL CURIOSITY

During the Renaissance, driven by scientific curiosity, anatomists like Andreas Vesalius began human dissections systematically. Cadavers were preserved with alcohols, vinegar, and salts, albeit with limited efficacy. The period saw a transition from mystical to rational anatomical study, though preservation was still rudimentary and bodies decomposed quickly.[27]

Leonardo da Vinci contributed to this evolution by creating highly detailed anatomical sketches after dissecting and preserving human bodies in brine. Embalming fluid compositions remained basic and often toxic, with turpentine, wine, and camphor used to delay putrefaction.[28]

### 17TH TO 19TH CENTURY – SCIENTIFIC EMBALMING AND DISSECTION

With the rise of modern medicine and surgery, formal anatomical study became institutionalized. Embalming evolved with the introduction of formaldehyde in 1867 by German chemist August Wilhelm von Hofmann, which became a cornerstone in anatomical preservation.[29]

Medical schools began using arterial injection methods for embalming cadavers, allowing detailed and prolonged dissection. Organs remained inside the body but retained their gross features. This marked the true beginning of anatomical preservation science.[30]

### 20TH CENTURY – RISE OF ORGAN TRANSPLANTATION AND VIABILITY FOCUS

The success of the first kidney transplant in 1954 by Dr. Joseph Murray opened a new dimension – functional preservation of organs for transplantation. The focus shifted from just preserving structure to maintaining physiological viability.

Innovations during this period included:

- Static cold storage (SCS): Use of cold preservation solutions like University of Wisconsin (UW) solution.
- Organ-specific preservation times: Kidney (24–36 hours), Liver (8–12 hours), Heart (4–6 hours).

These advances led to the creation of organ banks and allowed for transport across regions, expanding the donor pool.[31]

### 21ST CENTURY – MACHINE PERFUSION AND BIOTECHNOLOGICAL INNOVATIONS

Modern preservation techniques now use machine perfusion to actively maintain organ function ex vivo. Technologies include:

- **Hypothermic Machine Perfusion (HMP):** Preserves organs at low temperatures with continuous perfusion.
- **Normothermic Machine Perfusion (NMP):** Maintains body-temperature perfusion, enabling organ repair and viability testing.

- **Ex Vivo Lung Perfusion (EVLP):** Used to recondition marginal lungs.
- **Heart-in-a-Box Systems:** Keeps donor hearts beating with warm perfusate.

Simultaneously, cryopreservation and bio-preservation research are advancing, with goals to preserve tissues and complex organs for months or years.[32]

**REGENERATIVE MEDICINE AND BIOARTIFICIAL ORGANS**

Looking forward, preservation science is moving toward:

- Organ-on-chip systems for viability studies
- Bioprinting of organs using stem cells and scaffolds
- Nanotechnology for targeted organ preservation at the cellular level
- Genetic engineering to increase organ resistance to ischemia

These directions aim to not just preserve but enhance the survival and function of organs, integrating preservation science with regenerative medicine.[33]

**FINDINGS –**

1. Ancient civilizations practiced natural preservation using water immersion, herbs, oils, and resins for both religious and educational purposes.
2. Ayurvedic texts like Sushruta Samhita described cadaver preservation for anatomical dissection through flowing water immersion and natural materials like *Munja* and *Kusha* grass.
3. Egyptians used elaborate embalming techniques involving organ removal, canopic jars, and natron to preserve the body for the afterlife.
4. During the Renaissance, preservation shifted from religious to scientific, with increased focus on anatomical study through basic chemical methods like alcohol and vinegar.
5. The discovery of formaldehyde in the 19th century revolutionized embalming, enabling long-term anatomical dissection and medical education.
6. Mid-20th century advances in organ transplantation led to development of preservation techniques aimed at maintaining functional viability, not just anatomical integrity.
7. Cold storage became standard for organ transport, using specialized solutions like University of Wisconsin (UW) solution.
8. Modern machines like hypothermic and normothermic perfusion systems now actively support organ function outside the body, allowing real-time assessment and extended preservation.
9. Ex vivo technologies (e.g., EVLP, OCS Heart) have enabled transplantation of marginal or high-risk donor organs by reconditioning and functional optimization.
10. Cryopreservation and bio-preservation techniques are under research for long-term organ and tissue storage, especially in reproductive and regenerative medicine.
11. The focus of preservation has evolved from ritualistic intentions to structural, then to functional, and now toward regenerative and bio-artificial possibilities.
12. Integration of biotechnology, nanomedicine, and stem cell science is shaping the future of organ preservation for enhanced transplant outcomes and artificial organ development.

**DISCUSSION**

The transition from ancient embalming to modern organ preservation machines reflects not only a technological evolution but also a shift in the *philosophy and purpose* of anatomical science. In ancient times, preservation was largely ritualistic and symbolic, embedded in cultural and spiritual contexts.[34] Egyptian embalming, for instance, aimed at preparing the body for the afterlife, while in *Ayurveda*, the temporary preservation of cadavers through immersion in flowing water was intended for educational dissection and understanding of *Sharira Rachana*. The *Sushruta Samhita* provided a clear protocol for preparing cadavers, indicating a refined awareness of decomposition and tissue study without artificial chemicals.[35]

As the Renaissance awakened scientific inquiry, the focus moved toward accurate anatomical

understanding. Dissection became central to medical education, yet preservation was still crude.[36] The use of alcohol, vinegar, and resins delayed decay only briefly. However, it laid the groundwork for a practical and secular approach to anatomy, no longer limited by religious taboos. This period bridged traditional methods with a growing curiosity for internal structure, advancing the anatomical sciences.[37]

With the development of formaldehyde-based embalming in the 19th century, anatomical preservation became more reliable and long-lasting. This was a major milestone, especially for medical education and forensic science, enabling consistent cadaveric study across institutions. Unlike ancient techniques, modern embalming allowed retention of gross anatomical landmarks and organ structures for extended periods, supporting the standardization of medical training.[38]

The 20th century, however, marked a paradigm shift — from structural to functional preservation — following the emergence of organ transplantation. Static cold storage became the gold standard, yet had limitations in preserving metabolic activity and organ viability. To overcome this, modern science developed dynamic preservation techniques, such as hypothermic and normo-thermic machine perfusion, which simulate physiological conditions, allow organ repair, and extend the transplant window.[39]

These machines — like Organ-Ox Metra, Trans-Medics Organ Care System, and EVLP circuits — embody the culmination of centuries of anatomical understanding coupled with engineering innovation. Unlike ancient embalming, which preserved for sacredness or study, modern technologies aim to revive, optimize, and even regenerate organ function. Preservation is no longer passive — it is interactive and therapeutic.[40]

Furthermore, cryopreservation, bio-printing, and nanotechnology represent the future of preservation. These approaches promise not just longevity but biocompatibility, functional integration, and organ customization, aligning with the futuristic goals of regenerative medicine and personalized transplantation.[41]

In summary, the evolution from natural methods like water immersion to advanced mechanical perfusion mirrors humanity's progress in anatomical knowledge, scientific technique, and therapeutic ambition. What began as reverence for the body has transformed into a mission to extend life, restore function, and overcome the limits of organ failure — a journey from philosophy to physiology, from ritual to repair.[42]

## PROS AND CONS OF STUDY

| Aspect | Pros | Cons |
|---|---|---|
| **Ancient Embalming Techniques** | - Eco-friendly and natural substances used (e.g., herbs, water) | - Short-term preservation only |
| | - Cultural and spiritual significance | - Lack of standardization and reproducibility |
| | - Enabled early anatomical learning (e.g., Sushruta's dissection) | - No control over microbial decay or sterility |
| | - Cost-effective and locally available methods | - Not suitable for functional or organ transplant purposes |
| **Modern Preservation Techniques** | - Long-term and functional preservation (e.g., for transplant) | - High cost and technological dependency |
| | - Real-time viability assessment through machine perfusion | - Requires specialized training and infrastructure |
| | - Expands organ transport and transplant time window | - Risk of machine malfunction or perfusion-related complications |
| | - Allows repair and reconditioning of marginal donor organs | - Potential ethical concerns (e.g., extended artificial maintenance) |
| | - Enables surgical training with lifelike cadavers (Thiel method) | - Chemical preservatives may pose environmental and health hazards |

## CONCLUSION

The evolution of organ preservation through anatomical techniques reflects a remarkable journey from ancient natural methods to advanced biomedical innovations. Traditional practices such as Ayurvedic cadaver immersion and Egyptian embalming were rooted in spiritual and educational purposes, focusing on temporary preservation using natural elements. With the advent of modern science, preservation

shifted towards anatomical study and later functional viability, marked by the discovery of formaldehyde and the development of cold storage techniques. In recent decades, the emergence of machine perfusion technologies has enabled real-time organ support, assessment, and even repair, significantly improving transplant outcomes. Today, the integration of biotechnology, regenerative medicine, and cryopreservation heralds a new era in which preservation is not merely about delaying decay but actively sustaining and restoring life. This progression highlights the dynamic fusion of ancient insights and modern science in the service of medicine and humanity.

**CONFLICT OF INTEREST –NIL**

**SOURCE OF SUPPORT –NONE**

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