Anat Morphol. 2025;1(1):12-17

Received: 2025-04-18 / Accepted: 2025-06-11

Room Temperature Plastination of Hollow Viscera (Cecum, Appendix, and Colon): First Experience at High Altitude in Bolivia

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RODRIGUEZ-TORREZ VH. Room temperature plastination of hollow viscera (cecum, appendix, and colon): First experience at high altitude in Bolivia. *Anat Morphol. 2025;1(1)*:12-17

ABSTRACT: This study presents the first documented experience of plastination of hollow human viscera (cecum, appendix, and colon) in Bolivia, specifically in the city of La Paz, located at 4,150 meters above sea level. The primary objective was to assess the technical feasibility of performing plastination at room temperature, taking advantage of the reduced atmospheric pressure as a potential benefit during the forced impregnation stage. A human specimen fixed in 10% formalin was used, with prior vascular treatment using resin, and progressively dehydrated with acetone until reaching a concentration of 99.5%. Forced impregnation with flexible resin (silicone) was carried out using an active-passive vacuum protocol, adapted to high-altitude conditions, with alternating 8-hour phases of active and passive vacuum. The specimen was then positioned and periodically inflated with air during the polymerization process, using tetraethyl orthosilicate (TEOS) for curing. The results indicated successful anatomical preservation without structural collapse, achieving optimal handling and morphological stability of the plastinated specimen. This pioneering experience demonstrates the technical viability of room-temperature plastination at high altitude and represents a valuable contribution to the development of didactic anatomical resources within the Bolivian academic context.

KEY WORDS: Plastination, Hollow organs, Room temperature technique, High altitude, Anatomical preservation

INTRODUCTION

In recent decades, anatomical preservation techniques for cadaveric specimens, whether human or animal, have undergone significant advancement, driven by the need to improve safety, durability, and educational utility. Among these, plastination has emerged as one of the most effective and innovative methods. Developed by Gunther von Hagens in the late 1970s, plastination enables long-term preservation of biological tissues by replacing water and lipids with curable polymers, resulting in dry, odorless, and non-toxic specimens suitable for both teaching and display purposes (von Hagens, 1979; Pashaei, 2010; Ottone, 2023).

The advantages of plastination are numerous: specimens maintain their morphological integrity, can be handled without gloves or protective equipment, and do not require refrigeration or the use of toxic preservatives such as formalin (von Hagens, 1986; Starchik & Henry, 2015; Ottone *et al*., 2015). This makes plastinated specimens particularly valuable in medical and veterinary education, as they allow for repeated use in practical teaching, promote active learning, and reduce dependence on fresh cadaveric material (Latorre *et al*., 2001, 2007; Ottone, 2023).

Room-temperature plastination, a modification of the original technique, has been developed to optimize workflows in settings without access to sophisticated vacuum equipment or temperature control system. This adaptation has proven especially useful in academic environments in low- and middle-income countries, where traditional plastination may not be economically or logistically feasible (Fonseca-Matheus, 2018; Ottone, 2023).

Importantly, the environmental conditions at high altitudes, such as reduced atmospheric pressure and oxygen concentration, could influence certain steps of the plastination process, particularly those related to dehydration and polymer impregnation. La Paz, Bolivia, located at over 3,600 meters above sea level, presents a unique setting to explore whether natural hypobaric conditions may serve as a passive facilitator for some phases of room-temperature plastination. This approach could potentially enhance efficiency, reduce costs, and provide a locally adapted alternative for the preparation of anatomical specimens in high-altitude regions.

Therefore, the main objective of the present work is to assess the feasibility and benefits of implementing room-temperature plastination under high-altitude conditions, leveraging the natural environment to support an eco-friendly and accessible anatomical preservation method.

MATERIAL AND METHOD

This experimental, observational, and descriptive study was carried out with a human specimen at the Anatomy Amphitheater of the Faculty of Health Sciences at Universidad del Valle, La Paz campus.

The room-temperature plastination protocol using flexible resin or silicone was followed. The objective was to demonstrate the application of the technique on a hollow organ for the first time in Bolivia and to present the plastinated specimen for final exhibition.

The specimens were fixed with 10% formalin (Fig. 1). Before this, a vascular treatment process was performed by injecting fluid resin through arterial conduits.

Dehydration was performed using acetone as the primary medium to remove water from the tissues. Initially, nail polish remover was used due to the difficulty and legal restrictions in obtaining acetone in Bolivia (Fig. 2). Each acetone replacement lasted seven days before being substituted with pure acetone. After five changes, the final concentration, measured with an acetonometer, reached 99.5%, which is acceptable to proceed to the next step in the plastination process (Fig. 3).

Forced impregnation was carried out in a vacuum chamber at room temperature. The specimens were submerged in flexible resin or silicone (without catalyst) for 24 hours prior to vacuuming (Fig. 4). Then, the chamber

Fig. 1. Cadaveric specimen fixed with 10% formalin, undergoing vascular treatment by injecting fluid resin.

Fig. 2. Specimen undergoing dehydration with acetone.

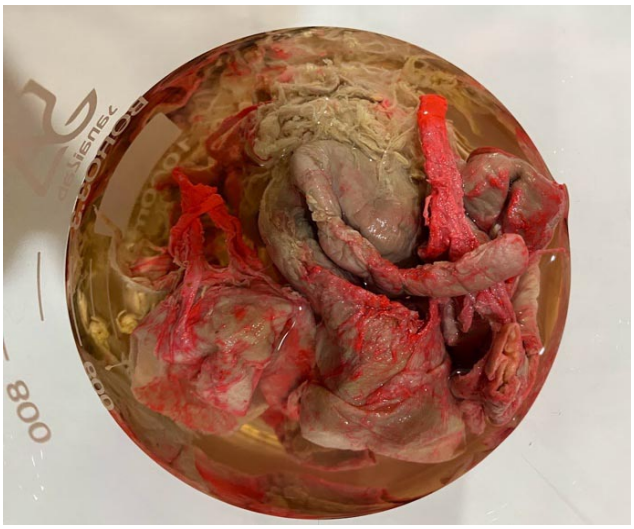

Fig. 3. Specimen dehydrated with acetone to 99.5% post-stabilization.

Fig. 4. Acetone removal and replacement by flexible resin or silicone, observed through bubble formation.

was sealed, and the vacuum was applied, starting at 495 mmHg (at La Paz's altitude) and reduced to 20 mmHg.

The room-temperature plastination with flexible resin or silicone included cycles of active and passive vacuuming, each lasting 8 hours. This forced impregnation process involves the replacement of acetone with flexible resin through vacuum creation, keeping the temperature between 15°C and 20°C. The pressure is reduced over 24 hours, from 760 mmHg to 20 mmHg, according to the active-passive forced impregnation protocol (Ottone *et al*., 2015; Ottone, 2023).

Unlike sea-level studies, the atmospheric pressure in La Paz, Bolivia, is 495 mmHg. Therefore, our impregnation began at this pressure and consisted of two 8-hour cycles of active vacuuming (16 hours total) interspersed with an 8-hour passive impregnation phase where the vacuum pump was turned off.

During the process, the acetone extraction and its replacement by flexible resin or silicone were evidenced by the appearance of multiple bubbles of varying sizes. These bubbles indicated acetone evaporation from the tissues. Over time, the bubbles diminished, appearing only sporadically, signifying the end of the forced impregnation stage, reached at 20 mmHg at the end of the second 8-hour active vacuum cycle.

The polymerization of the flexible resin or silicone followed a conventional method including pigmentation of the specimens. Before this step, the cadaveric specimen was positioned using clips and fishing line into a desirable shape for exhibition (Fig. 5). Since the specimen was a hollow organ, it was connected to a compressor air outlet to inflate it periodically during polymerization (Fig. 6).

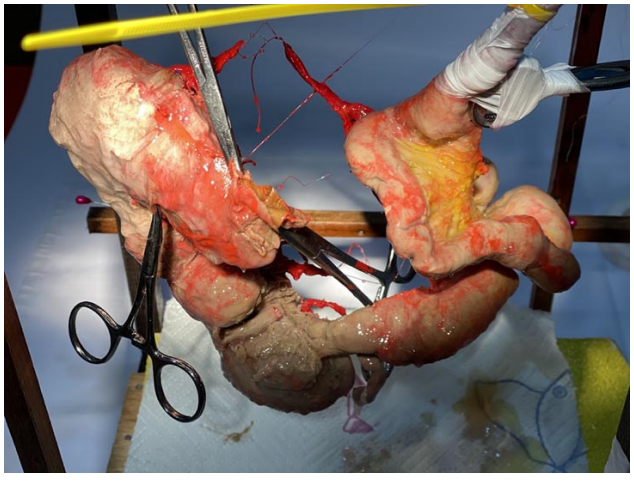

Fig. 5. Positioning of the specimen using clips and fishing line.

For curing, a chamber was created using the catalyst tetraethyl orthosilicate (TEOS), a process that took approximately two weeks (Fig. 7). During this period, TEOS was vaporized two to three times a day, depending on time availability. The absence of gas or vacuum leakage was verified by detecting a drop in internal pressure. Gasification was performed using an aquarium air pump, which allowed oxygenation and facilitated resin hardening.

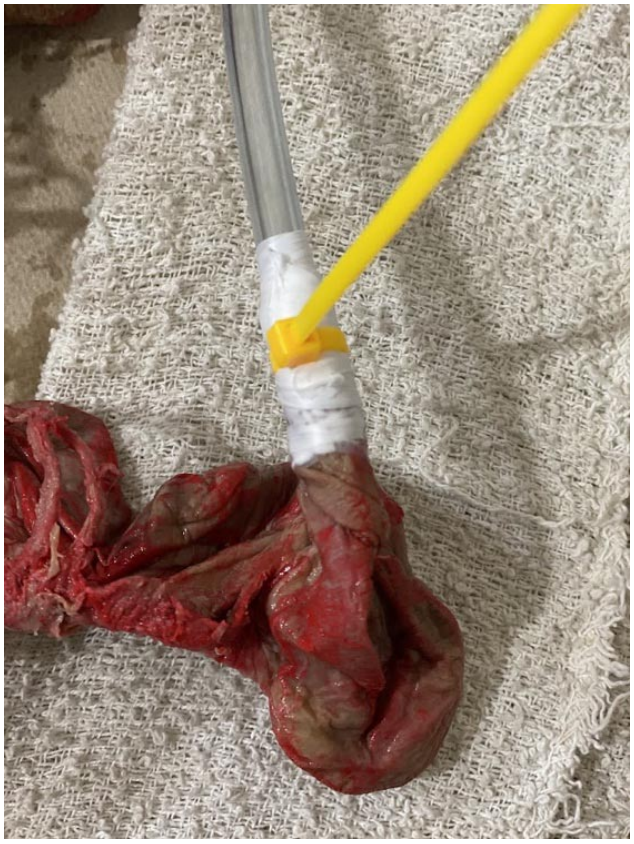

Fig. 6. Connection to air compressor for continuous airflow to maintain desired shape.

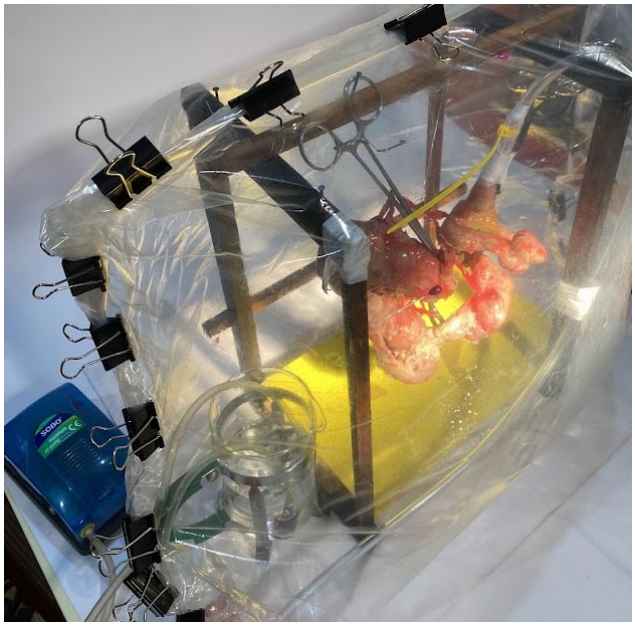

Fig. 7. TEOS gasification using an aquarium air pump for oxygenation and resin curing.

As a result of the procedure described, a hollow organ was successfully plastinated using the developed room-temperature protocol, preserving its anatomical structure, luminal integrity, and flexibility for didactic purposes (Fig. 8).

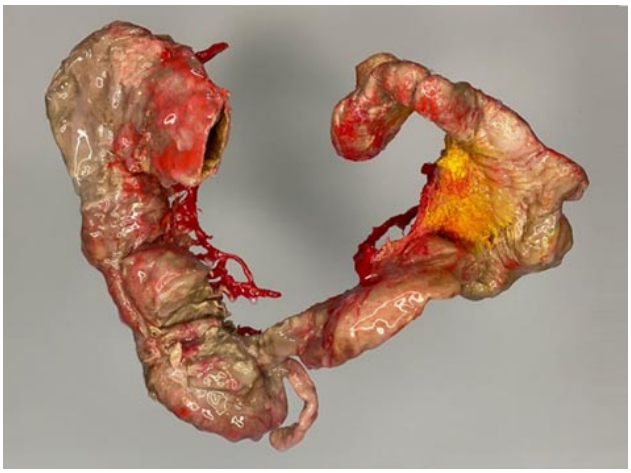

Fig. 8. Plastinated hollow organ.

RESULTS AND DISCUSSION

Throughout the forced impregnation process, no macroscopic structural changes were observed in the hollow organ specimen. This structural stability can be attributed to the controlled pace of the procedure, which minimized the risks of shrinkage or collapse typically associated with rapid acetone evaporation or uneven resin infiltration. The visual disappearance of bubbles during the vacuum phase was a reliable qualitative indicator of the successful replacement of acetone with flexible resin, a phenomenon well-documented in plastination protocols as a sign of effective tissue impregnation. This observation aligns with standard recommendations and reinforces the notion that vacuum monitoring remains essential for determining the end point of the forced impregnation phase (von Hagens, 1979; Starchik & Henry, 1997).

One of the most noteworthy aspects of this study was the performance of the plastination process at high altitude (4,150 meters above sea level), specifically in La Paz, Boli-

via. The reduced atmospheric pressure (approximately 495 mmHg) appeared to facilitate the diffusion of resin into the tissues, potentially enhancing the efficiency of the impregnation process. While plastination has been thoroughly described at sea level, where atmospheric pressure approximates 760 mmHg (Ottone *et al*., 2015), few studies have examined its behavior under high-altitude conditions. Our findings suggest that the naturally low-pressure environment of La Paz mimics conditions typically achieved through artificial vacuum, thereby accelerating or supporting resin infiltration without the need for high mechanical vacuum input.

Additionally, the room-temperature setting allowed for better control over resin viscosity and polymerization rate. Since temperature fluctuations can significantly affect the curing behavior of silicone resins, maintaining a stable ambient range between 15?°C and 20?°C was crucial. The use of passive-active vacuum cycles enabled a balance between gradual acetone evaporation and resin substitution, effectively reducing the risk of gas entrapment and tissue distortion (Ottone *et al*., 2015; Ottone, 2023).

The use of flexible silicone resin (such as Biodur® S10/S15 or similar formulations) proved advantageous in this context. Given the hollow nature of the specimen, a careful approach was implemented during the polymerization phase. The organ was periodically inflated using compressed air to preserve its luminal shape and anatomical relationships, a strategy aligned with techniques previously proposed for delicate or collapsible structure. This method, although rarely documented, offers a valuable approach for plastinating organs such as the gastrointestinal or respiratory tracts. The final product retained excellent anatomical definition, elasticity, and manipulability, making it suitable for both didactic and exhibition purposes.

The curing phase, which incorporated TEOS gasification, was prolonged over two weeks to ensure complete cross-linking of the resin. The use of an aquarium pump for oxygenation represents a low-cost and accessible alternative to more sophisticated curing systems, a strategy particularly beneficial in resource-constrained environments (Ottone, 2023). The reproducibility of this curing method, combined with continuous gas exchange and air circulation, suggests that it may serve as a viable solution for plastination laboratories operating in low-budget institutions or developing countries.

From a broader perspective, this study contributes to the growing body of evidence that plastination techniques can be adapted and optimized according to geographic and environmental variables. The successful plastination of a hollow organ in Bolivia, using flexible silicone at room temperature and under naturally low atmospheric pressure, underscores the versatility of the technique and opens the door for further regional adaptations.

CONCLUSIONS

This study successfully demonstrated the feasibility of performing room-temperature plastination at high altitude, leveraging the naturally low atmospheric pressure of La Paz, Bolivia, to facilitate forced impregnation. The findings highlight that local environmental factors, such as barometric pressure and temperature stability, can play a supportive role in anatomical preservation techniques traditionally dependent on controlled laboratory environments.

In addition to methodological success, this work proposes a low-cost and effective alternative for anatomical preservation in settings with limited access to advanced infrastructure. The strategy of using compressed air inflation for hollow organ stabilization and aquarium pump gasification for curing underscores the potential for innovation and resourcefulness in plastination protocols.

Future studies should aim to quantify impregnation durations under varying barometric pressures and compare tissue integrity, shrinkage, and histological characteristics between specimens plastinated at sea level versus those at high altitude. Comparative analyses of energy efficiency, curing consistency, and long-term durability of specimens will also be instrumental in establishing optimized protocols tailored to geographical settings.

Ultimately, this investigation contributes to the democratization of plastination techniques, paving the way for broader application across universities and research centers in high-altitude regions and promoting accessibility to high-quality anatomical materials for education and outreach.

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