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Contents

Original Articles

- Study of Variant Acromion Process of Scapula and its Clinical Significance** 41
SharadKumar Pralhad Sawant, Shaheen Rizvi
- Accessory Piriformis Muscle: Anatomical Variant & it's Clinical Imolications** 49
Suganitha Balasundaram, Priya Ranganath, Sumathi S, Latha J

Review Articles

- A Journey of Cadaveric Preservation from Ancient Cultures to Modern Period** 52
SharadKumar P Sawant, Shaheen Rizvi
- Guidelines for Authors** 59

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Study of Variant Acromion Process of Scapula and its Clinical Significance

¹SharadKumar Pralhad Sawant, ²Shaheen Rizvi

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Abstract

Shoulder pain is the common cause for the compromised quality of life of the individuals and is due to shoulder impingement syndrome (SIS). A variant acromial morphology and consequent subacromial space reduction is deliberated as the chief basis of subacromial impingement. There are four types of acromion process. Type 1 - flat shaped acromion process, Type 2 - curve shaped acromion process, Type 3 - hook shaped acromion process, Type 4 - convex or upturned acromion process. Type 2 - curved acromion process is most common. Rotator cuff diseases are associated with anatomical variations in the morphology of the acromion process. The aim of the study was to understand the variations of the acromion process, and note its clinical importance so as to help clinicians dealing with rotator cuff diseases.

Material and Methods: A total 100 dry ossified scapulae were studied in the Department of Anatomy of K. J. Somaiya Medical College, Sion, Mumbai. The acromia were classified into the 4 types, according to their shape. The length of the acromion and the acromio - glenoid distance was also taken into consideration. Photographs of the acromion process of scapula were taken for the ready reference.

Results: The number of specimens showing type II acromion is greater than Type I while Type III was present in the least number of specimens.

Conclusion: This correlation between length of acromion and acromio-glenoid length is due to the reduction in the subacromial space in the hooked acromia, which more often leads to shoulder impingement syndrome. The study thus helps in diagnostic studies on diseases of the shoulder and aids in treatment and in surgical correction.

Keywords: Acromion, Rotator Cuff, Acromio-Glenoid Distance, Subacromial Space, Shoulder Impingement Syndrome.

Introduction

The acromion process is one of the three processes of the scapula other two are coracoid process and spinous process. The acromion process continues as spinous process of the scapula and forms the summit of the shoulder. The acromion projects laterally overhanging the glenoid cavity. It articulates with the acromial end of the clavicle to form the acromioclavicular joint which is plain variety of synovial joint. Its superior surface gives attachment to the fibers of the deltoid muscle. Its inferior surface is related to subacromial (subdeltoid) bursa which is largest bursa in the body. The thick lateral border of acromion process gives tendinous origins of the middle fibres of the deltoid muscle. The medial border gives attachment to trapezius muscle. In its approximate centre, there is a small oval surface for articulation with the acromial end of the clavicle to form the acromioclavicular joint. The coracoacromial ligament is a triangular ligament, the apex of which is attached to the tip of the acromion and the base to the lateral border of the coracoid process. The three structures, namely the acromion process, the coracoacromial ligament and the coracoid process, together form coracoacromial arch, which is known as the secondary socket for the head of the humerus.¹ There are four types of acromion process. Type 1 - flat shaped acromion process, Type 2 - curve shaped acromion process, Type 3 - hook shaped acromion process, Type 4 - convex or upturned acromion process. Type 2 - curved acromion process is most common.²

Rotator cuff also known as muscolutendinous cuff of the shoulder is a fibrous sheath formed by the four flattened tendons which blend with the capsule of the shoulder joint and strengthen it. The muscles which form the cuff take their origin from the scapula and are inserted into the lesser and greater tubercles of the humerus, namely subscapularis muscle, supraspinatus muscle, infraspinatus muscle and teres minor muscle. Their tendons, while crossing the shoulder joint, become flattened and blend with each other on one hand and with the capsule of the shoulder joint on the other hand, before reaching their points of insertion.³ The aim of the study was to understand the variations of the acromion process, and note its incidence so as to help orthopaedics to diagnose and treat pathologies related to acromion and rotator cuff. These anatomical findings are significant for dealing with rotator cuff diseases.

Material and Methods

Hundred ossified, dry human scapulas were taken for study in the Department of Anatomy of K. J. Somaiya Medical College. 55 were of the left side and 45 belonged to the right side. Damaged and degenerated bones were excluded from the study. The sliding Vernier Calliper was used to measure the length of the acromion. The highest point of the acromion process was noted. If the height of the acromion was less than 2% of the acromial length, it was classified as Type 1. If the highest point was above middle third of acromial length, it was classified as Type 2, If the highest point was above anterior third of acromial length, it was classified as Type 3. If the under surface of the acromion was convex (upturned) near the distal end, showing the presence of a lowest point it was classified as Type 4. To confirm our findings, the acromio-glenoid distance, from the tip of the acromion to the supraglenoid tubercle was also taken into consideration. Photographs of the acromion process of scapula were taken for the ready reference.

Results

Out of the 100 acromion process examined, type 1 (flat shape) was seen in 46% of the specimens and type 2 (curved shape) was seen in 47% of the specimens. Hence, they contributed to the majority of the specimens. Type 3 (hook shape) seen in 5% of the specimens while type IV was observed in 2 specimens. Variations of the acromion process of

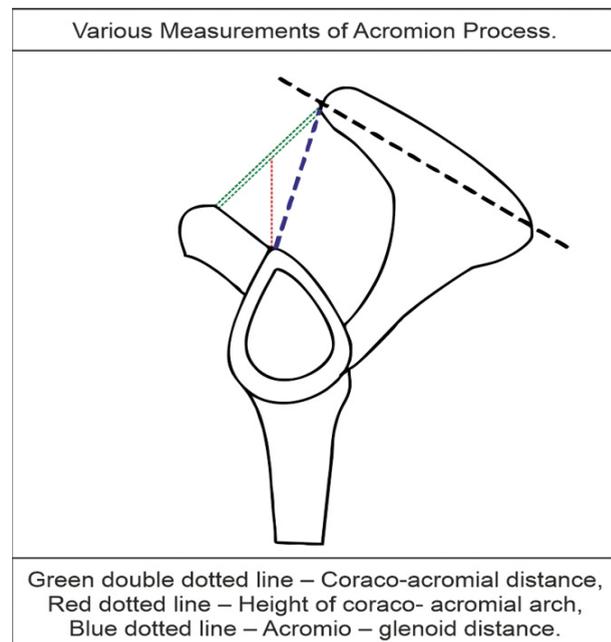


Fig. 1: Showing line diagram of various measurements of acromion process.

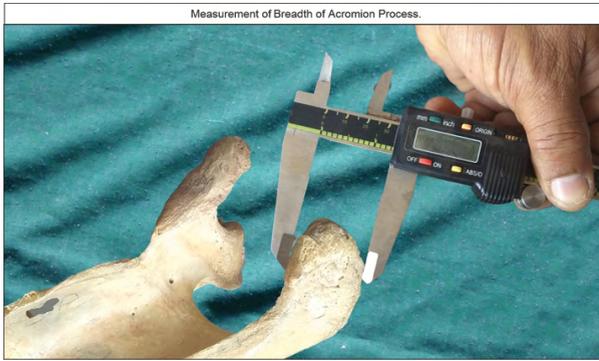


Fig. 2: Showing photographic presentation of measurement of breadth of the acromion process



Fig. 3: Showing photographic presentation of measurement of the acromio-glenoid distance.

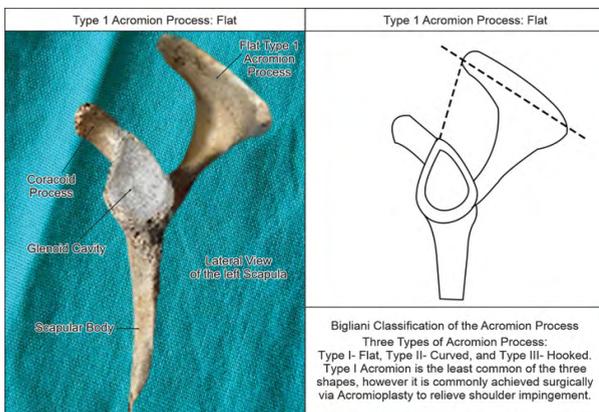


Fig. 4: Showing photographic presentation of Type 1 Flat acromion process.

scapula were unilateral.

The average length of the acromion process is 41.72 ± 5.20 mm, breadth is 21.42 ± 3.06 mm and thickness is 6.68 ± 1.76 mm of the both right and left scapulae.

Discussion

Rotator cuff tendinopathy or rotator cuff injury can be a cause of pain with disability in the shoulder region and may sometimes require

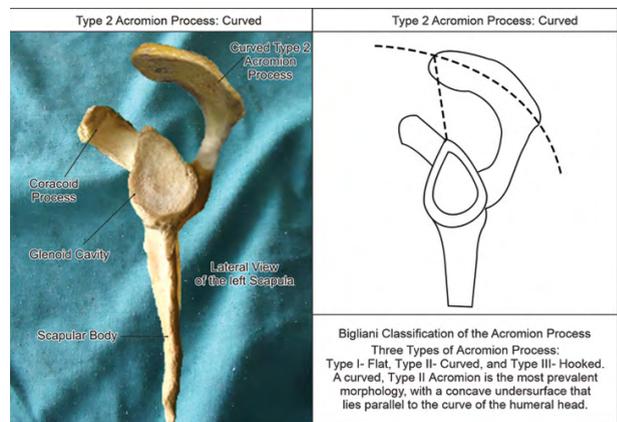


Fig. 5: Showing photographic presentation of Type 2 Curved acromion process.

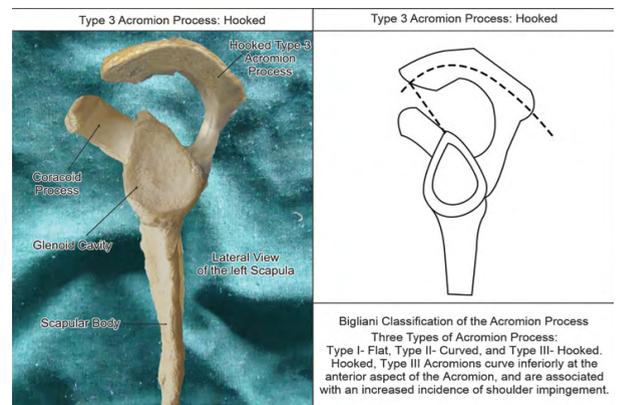


Fig. 6: Showing photographic presentation of Type 3 Hooked acromion process.

surgical correction. In 1931, Codman and Akerman suggested that degeneration of the tendons are responsible for rotator cuff tears.⁴ Subsequently, in 1949, Armstrong and later Neer stated that impingement was the main cause for up to 95% of rotator cuff tears and treated successfully with anterior acromioplasty.^{5,6}

In 1986, Bigliani et al classified the shape of the acromion process into three types: Type 1 -- flat shaped acromion process, Type 2 - curve shaped acromion process, Type 3 - hook shaped acromion process. He found a more incidence of rotator cuff tears in patients with a hook shaped acromion process than with a curve shaped or flat shaped acromion process. It was the first classification system to try to define morphology of acromion process. They also observed that slope of acromion process increased from Type 1 to Type 3 and thus influenced tear of rotator cuff.⁷ Epstein et al proposed a modified classification in which Type 1 acromion had a height less than 2% of the length of acromion process and distinguished between Type 2 and Type 3 acromion process.⁸ Park et

Table 1: Types of acromia as obtained by different authors.

	Type 1 %	Type 2 %	Type 3 %
Nicholson et al (1996) ¹⁰	32	42	26
Natsis et al (2007) ¹¹	12.1%	56.5	28.8
Paraskevas et al (2008) ¹²	26.1	55.6	18.1
Schetino et al (2013) ¹³	5.6	57.89	36.84
Naidoo et al (2015) ¹⁴	34.6	51.1	14
Saha et al (2016) ¹⁵	35	61	4
Vinay G and Sivan S (2017) ¹⁶	37.1	47.5	15.2
Sinha et al (2018) ¹⁷	24.59	49.18	26.22
Present study (2020)	39	47	12

Table 2: The correlation between length of acromion and acromio-glenoid length as obtained by different authors

	Mean Length of acromion (mm)	Mean Acromio-glenoid length (mm)
Torrens et al ¹¹	49.6	29.5
Paraskevas et al (2008) ¹⁴	46.1	17.7
Mansur et al ²²	46.6	31.4
Saha et al (2016) ²³	41.9	26.6
Present study (2020)	42.8	25.7

al proposed a different evaluation criterion for classifying morphology of acromion process which was more objective.⁹

Literature has shown the types of acromia as obtained by different authors.

On comparison it is seen that our study is consistent with that obtained from other authors.¹⁰⁻¹⁷

The number of specimens showing type 2 acromion is greater than Type 1 while Type 3 was present in the least number of specimens.

Xiaoguang Guo studied 292 scapulas. He attributed the higher type 1 and type 2 numbers and lower type 3 numbers.¹⁸ In the most recent classification of acromion process, Prescher observed that type 2 and type 3 acromion process have a close anatomical feature as morphology of type 3 acromion process is quite similar to type 2 acromion process.¹⁹ Farley et al. introduced a classification which includes a type 4 of acromion.²⁰ It was observed in literature in the study of Natsis et al as 2.6%.¹¹ In our study we observed Type IV acromion in 2 (2%) specimens.

The correlation between length of acromion and acromio-glenoid length is suggestive of reduction in the dimensions of the subacromial space in the hook shaped acromion process, which leads to tear of the rotator cuff.²¹

In our study the mean length of the acromion was

42.8mm which was more than the length observed by Saha et al. but less than Torres et al, Paraskevas et al and Mansur et al.^{11,14,22,23}

Many researchers had reported impingement and its association with acromion process. In coming days, a reliable classification is needed to diagnose rotator cuff disease and their surgical corrections in order to avoid recurrence.^{24,25}

Clinical significance

Moderate to severe pain is associated with both type 2 – curve shaped and type 3 – hook shaped acromion process and mild pain has been associated with type 1 – flat shaped acromion process. The acromion plays an vital role in shoulder pathology diagnosis of shoulder joint diseases and its treatment like intra articular shoulder injection, and arthroscopic surgeries on shoulder joint.²⁶

An acromioplasty is a procedure performed on acromion process. If the procedure has to be done with accuracy, it is important have knowledge of morphology of acromion process.²⁷ Acromioplasty usually alleviates impingement pain but it is a problem during arthroscopic procedure. Advance acromioplasty can lead to fracture of acromion process or weakness of deltoid muscle. Hence several authors have opined the importance of morphological parameters of acromion process before planning surgery.²⁸

Conclusions

Variations in the morphology i.e. size and shape of the acromion process and length of acromio-glenoid space, which were documented in the present study, will be of immense help for orthopaedicians to deal with impingement syndromes. The study thus contributes towards diagnostic studies on shoulder pathologies and aids in treatment and in surgical planning.

Competing interests

The authors declare that they have no competing interests.

Authors' Contributions

SR drafted the manuscript, performed the literature review & SPS assisted with writing the paper.

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Accessory Piriformis Muscle: Anatomical Variant & it's Clinical Imolications

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Abstract

The piriformis muscle originates from the anterior part of sacrum and inserts into the greater trochanter. Then it passes transversely through the greater sciatic foramen via the sciatic notch and inserts on the greater trochanter. It is one of the lateral rotator muscle of the hip & an important land mark in the gluteal region. Since the sciatic nerve descends to the thigh by passing deeper to the piriformis muscles, it is mostly associated with the irritation of nerve which is known as piriformis

syndrome. In this study the accessory piriformis muscle was observed in a 59 year-old female cadaver. The abnormality reported in the present study may lead to neurovascular compression syndrome in the upper limb. Knowledge of anatomical variations in the muscular structure and its related neurovascular entrapment is important surgically for orthopaedic surgeons, neurologists and also physiotherapists clinically.

Keywords: Accessory Piriformis Muscle, Piriformis Muscle, Piriformis Syndrome, Pseudo Sciatica, Sciatic Nerve Entrapment.

Introduction

Piriformis muscle is one of the lateral rotators of the hip. It originates from the anterior part of the sacrum between the sacral foramen by digitations, then it passes transversely through the greater sciatic foramen via sciatic notch, and it inserts on the greater trochanter.¹ the pyramidal shaped piriformis muscle almost covers the foramen.

The neurovascular bundle related above to the muscle is superior gluteal nerve & vessels. The neurovascular bundle related below to the muscle

is sciatic nerve, inferior gluteal vessels and nerve and pudendal nerve and vessels.¹

Since the proximal part of sciatic nerve is covered by a trunk of piriformis muscle, compression or inflammation of the proximal part of sciatic nerve within this muscle is called as piriformis syndrome. Rarely, accessory fibres of piriformis muscles are also present in some cases which is an most important factor to increase the percentage of entrapment of sciatic nerve.

Hence the present study was done to observe the

anatomical variation in the gluteal region related with sciatic nerve.

Materials & Method

The study was conducted on 30 lower limbs from embalmed cadavers in the Department of Anatomy, Bangalore Medical college & Research Institute, Bangalore. After reflecting the gluteus maximus muscle, the deeper layers of muscles were exposed including piriformis. Photographs were taken for proper documentation and ready reference.

Results

In 30 specimens (96.6%), the piriformis was present as a single trunk with 4 cm thickness in the middle trunk. Interestingly in one specimen (3.34%) another trunk of muscle, the accessory piriformis, was noticed immediately below the main trunk of piriformis. The thickness of the accessory muscle was 2.5 cm in the middle. The sciatic nerve was passing deeper to these two trunks of muscles. The accessory head was also inserted immediately 1mm below the piriformis over the greater trochanter. The course of all other neuro vascular structures were normal. Other gluteal and neurovascular

structures were normal.

Discussion

Many authors^{2,3,5} have observed accessory piriformis muscle located inferior to the proper muscle. Belly of the accessory muscle was crossing under the trunk of the n. ischiadicus. Since the main trunk or branches of the nerve is not piercing the muscle but passing between the muscle bellies, this makes this topographical relationship an unclassified variation according to Benson's classification. Belly of the accessory muscle was thick and mostly tendinous. Direction of the fibers was not similar to the proper muscle which makes the case different from previously reported muscle slips, double or three-bellied variations.

Ravindranath et al⁴ have reported three cadaver cases of accessory piriformis muscle originating from the sacrotuberous ligament or the fascia overlying the gluteus medius. Accessory slips of these cases merged with the main tendinous part of piriformis muscles. However, the sciatic nerve was deeply related to the accessory slip and the main piriformis muscle.

Natsis et al⁶ reported an extremely rare cadaver

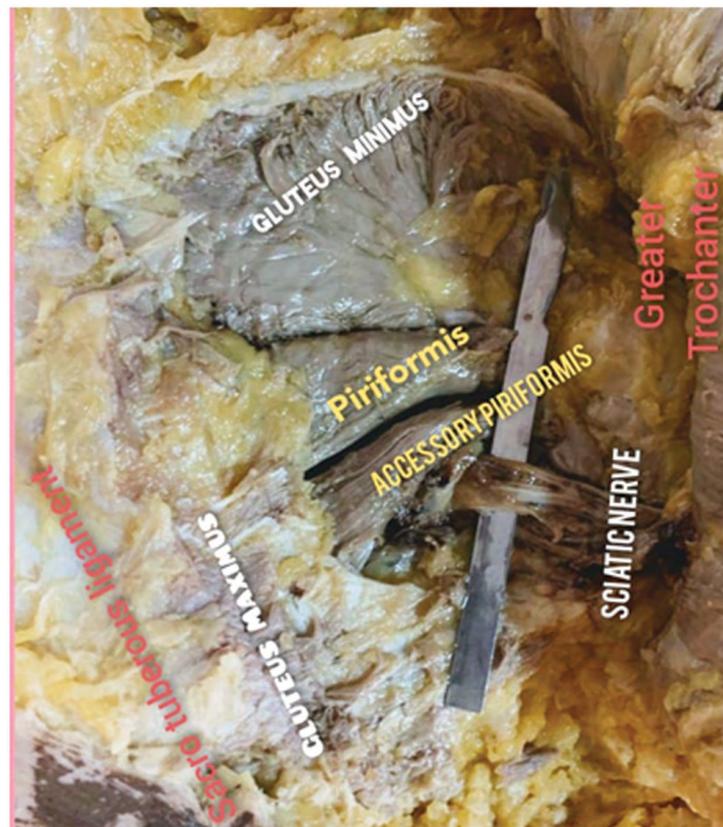


Fig. 7: Shows the anatomical variant of Accessory piriformis and it's relation with the Sciatic nerve

case of anatomical variation, showing that the piriformis muscle has three muscle bellies. Unlike other cases described previously, their patient had an accessory belly of the piriformis muscle which originated at the inferior aspect and the proximal third portion of the main piriformis muscle coursed deep to the sciatic nerve, and attached separately into the greater trochanter.

Beaton and Anson³ classified possible anatomical relationships between sciatic nerve and piriformis muscle into six types. However, only a few cases of anatomic variation of the piriformis muscle have been reported as a cause of piriformis syndrome, especially regarding the accessory piriformis muscle.⁷

The present study was different from that of Beaton and Anson classification.

Conclusion

Recent study stated that the accessory trunk of piriformis muscles was present immediately below the main trunk of piriformis muscle which also covered the upper part of sciatic nerve. It is very important clinically for those suffering with low back pain radiating down to the leg the abnormality reported in the present study may lead to neurovascular compression syndrome in the lower limb. Knowledge of anatomical variations in the muscular structure and its related neurovascular entrapment is important surgically for orthopaedic surgeons, neurologists, and also physiotherapists clinically. Therefore, the knowledge about this kind of rare variations are important for surgeons to

avoid mislead diagnosis and treatment.

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A Journey of Cadaveric Preservation from Ancient Cultures to Modern Period

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Abstract

Cadaveric dissection serves as an educational tool for training of health science students and also an important research tool. Hence proper preservation of the cadaver is important and it is done with the help of embalming. Embalming is the art and science of preserving human remains by treating them with chemicals to forestall decomposition. In this article, we look at how embalming has evolved from ancient cultures to modern times. In Ancient Cultures, Egyptians embalmed the body for eternal life of the soul. For this, they divested the body of all moisture for preservation and removed organs except the heart because they believed that heart is where the soul resides. Later the body was wrapped in layers upon layers of linen sheets creating a new being of divine character and able to live forever. Different methods of embalming were also seen in Spain, Northern Greece and China. In the Middle Ages embalming became widespread in Europe. Evisceration was carried out and body cavities were filled with herbs and spices; then the body was sewed and wrapped in waxed cloth. The period

of the Middle Ages and the Renaissance is known as the 'Anatomists' Period of Embalming'. New techniques like injections into hollow structures and injections of the vascular system with different types of solutions started. Arsenic was one of the contents used, funeral embalming began and in 1920 formaldehyde was first used in the embalming fluid. The period from 1861 is known as the 'Funeral period of Embalming' as there was separation of the fields of embalming by undertakers and embalming for medical and scientific purposes. The bodies of Abraham Lincoln and Vladimir Lenin were embalmed in this period. In 'Modern Embalming', the embalming fluid comprises different kinds of chemicals like preservatives, disinfectants, buffers, humectants, anticoagulants, dyes and masking agents or deodorants. Today embalming has come a long way and is being replaced with processes like 'Plastination' and 'Cryopreservation'.

Keywords: Cadaveric Dissection, Embalming, Decomposition, Ancient Cultures, Middle Ages, Anatomists' Period of Embalming, Funeral period of Embalming, Modern Embalming, Plastination, Cryopreservation.

Introduction

Cadaveric dissection is one of the oldest methods of learning human anatomy in medical colleges.

Students of health science courses either learn on prosected specimens or dissect themselves. Dissection not only serves as an educational tool for training of surgeons but is also an important

research tool. For training of health workers, there is nothing better than a human body. For Anatomists it is defined as a student's first teacher. It can never be considered as a simple biological model because it was once a living human, it shows variations and gives a student a three dimensional view along with an excellent tactile experience.¹ Never the less, the use of cadavers for research and teaching and training purposes has raised several concerns like restricted availability as well as ethical reservations; these include health hazards and religious sentiments of people involved.

Proper preservation of the cadaver is an important requisite for cadavers being utilised for research and training purposes. This is done with the help of embalming. Embalming is the art and science of preserving human remains by treating them with chemicals to forestall decomposition. Embalming is carried out by using chemicals like formaldehyde to retard decomposition as long as possible. The harmful effects of formaldehyde are another concern for those against dissection.²

The aim of this article is to give a synopsis of the history of embalming in order to understand how embalming has evolved from ancient cultures to modern times.

Ancient Cultures

While studying the history of embalming in ancient cultures it is of vital importance to know the reasons behind cadaver embalming in those times. Ancient Egyptian cultures held religious beliefs that 'eternal living' was linked with a well preserved and well-maintained body. According to the understanding of the ancient Egyptians themselves, the preservation of the human body was necessary so that the soul had a place on earth to which it could return in order to receive offerings and thus survive eternally. If the body decomposed the person would be excluded from living till eternity and wouldn't have an afterlife. Hence Egyptians divested the body of all moisture for preservation and removed organs except the heart because they believed that heart is where the soul resides. The body cavities were then filled with chemicals and spices to prevent any bacteria from growing. The body was then left covered in salt to become dry. After 40 days, the body would be wrapped in linen bandages while chanting spells. A mask was put over the head of the mummified body so that it could be recognised in the afterlife. These religious beliefs originated from the fact that when buried under certain conditions, natural preservation

took place and the bodies did not decompose. Natural means of preservation comprised freezing, desiccation either by dry heat or dry cold, or the specific nature of the soil at the burial site.³

The Chinchorro culture of Atacama Desert of present day Chile and Peru are among the earliest cultures known to have performed artificial mummification as early as 5000–6000 BCE. Artificial means of preservation included the application of simple heat or cold, powders of sawdust mixed with zinc sulphate, immersion in alcohol, brine, etc.⁴

With increasing population, techniques of preservation were enhanced in Egypt starting as early as 3200 BC. Specialized persons were in charge of these activities; they became members of the priest caste. With time the priests brought about two main advances from natural means of preservation to sophisticated embalming. One they started using materials like natron, herbs, cedar oils, resins, incense and gums. Secondly, they introduced evisceration. These two methods ensured preservation for a long time. The body was wrapped in layers upon layers of linen sheets.⁵ It is important to understand, however, that it was not just the preservation of the human bones and tissues that was intended. The wrapping with linen changed forever the shape of the human body and created a new being which was believed to be of divine character and able to live forever.⁶ Another method used was immersion in honey which was introduced by Persians. The cadaver of Alexander the Great was treated in this way, the need being long distance transport.⁷ The ancient Tibetans and Nigerian tribes predominantly used large quantities of alcohol concentrate, potash, herbal leaf (African basil) and kernel oil.⁸ The oldest recognized artificial preservation in Europe has been found in Spain in the dolmenic burial 'La Velilla' in Osorno where 5000-year-old human bones have been discovered, judiciously covered by pulverized cinnabar.⁹ The occurrence of resins from coniferous and pistacia trees, myrrh and other spices in a partly mummified body dating to 300 A.D found in Northern Greece, point to preservation methods used in Greek and Roman times.¹⁰ In China, the extremely fresh-looking corpse of Xin Zhui of the Western Han Dynasty (between 187 and 145 BC) was discovered in 1971. When workers opened her tomb, they found it to be remarkably well preserved. Her skin hadn't decayed and her muscles and tendons were still malleable enough for her joints to flex. The cadaver was found immersed in liquid, the composition of which is still unknown.¹¹

Middle Ages

Embalming became widespread in Europe and the methods used have been well maintained in the writings of contemporary physicians, like Peter Forestus (1522–1597) and Ambroise Pare (1510–1590). The methods were defined as evisceration, washing with cold water and aqua vita, filling cavities with consecutive layers of Aqua vita moistened cotton, and powder of herbs and spices like aloes, myrrh, wermut, rosemary, pumice, majoran, storacis calamata and zeltlinalipta muscate; then sewing the body, and finally wrapping it in waxed cloth. In later years embalming included evisceration, immersion of the body in alcohol, insertion of preservative herbs into incisions formerly made, and wrapping the body in tarred or waxed sheets.¹²

Period of Renaissance

The period of the middle ages and the renaissance is known as the 'Anatomists' Period of Embalming'. Dissection was prevalent and cadavers were required for dissections. Embalming progressed significantly as it became influenced by advances in Medicine.¹³ Embalming methods became more sophisticated. New techniques like injections into hollow structures started but injections of the vascular system were still underway. Alessandra Giliani used an arterial injection of coloured solutions which hardened with time.¹⁴ Leonardo da Vinci's (1452–1519) embalming fluids were mixtures of turpentine, camphor, oil of lavender, vermilion, wine, resin, sodium nitrate, and potassium nitrate and injection of wax to the ventricles.¹⁵ Jacobus Berengar (1470–1550) injected warm water into veins, Bartholomeo Eustachius (1520–1574) injected warm ink. Reinier de Graaf (1641–1673) added mercury. Jan Swammerdam (1637–1680) injected a wax-like material for hardening.¹⁶ Frederik Ruysch (1638–1731) injected liquor balsamicum a prepared chemical preservative which contained clotted pig's blood, Berlin blue and mercury oxide.¹⁷ His work of embalming was so nearly perfect that people thought the dead body was actually alive

The Scottish surgeon William Hunter was the first to use an arterial injection of a number of oils like turpentine, oil of chamomile and oil of lavender with Vermillion which was used as a dye and a preservative. His brother, John Hunter, applied these methods and advertised his embalming services to the general public from the mid-18th century.¹⁸ In France also a number of approaches were tried which were fairly successful. Cuvier (1769–1832) used pure alcohol, Thenard

(1777–1857) used alcoholic solution of dichloride of mercury, Chaussier (1746–1823) immersed eviscerated bodies in a solution of dichloride of mercury, and Sucquet (1840–1870) used 20% zinc chloride solution. Jean Nicolas Gannal (1721–1783) became a funeral embalmer. His embalming fluid contained a solution of acetate of alumina among other substances. His formula was patented and he was the first to document and publish his studies on embalming.¹⁹ The British, French and Italian scientists perfected arterial and cavity embalming techniques, thus aiding the embalming fluid from spreading to every part of the cadaver. After Lord Nelson was killed in the Battle of Trafalgar, his body was preserved in brandy and spirits of wine mixed with camphor and myrrh for over two months. At the time of his state funeral in 1805, his body was found to still be in excellent condition and completely plastic.²⁰ In Italy, arsenic solutions were used for arterial injection successfully by Guiseppe Tranchina (1797–1837). This technique was the very first documented method that did not involve evisceration. Until the early 20th century, embalming fluids often contained arsenic. There was concern about the possibility of arsenic from embalmed bodies contaminating ground water supplies and legal concerns that people suspected of murder by arsenic poisoning might claim in defense that levels of poison in the deceased's body were the result of post-mortem embalming and not homicide.²¹ Alfredo Salafia (1869–1933); was not an anatomist but only an embalmer. He embalmed several important persons, but his most prominent body was Rosalia Lombardo, an Italian child born in 1918 in Palermo, Sicily who died of pneumonia on 6 December 1920. She is extremely well preserved, and all of her organs are still intact. Due to an optical illusion involved the way light filters into the glass coffin, many have observed that Rosalia opens and closes her eyes. The body is located in the Capuchin Catacombs of Palermo. Salafia left behind a hand written manuscript revealing that his solution was one of the very first formulas that contained formaldehyde.²²

Funeral Period

The period from about 1861 is sometimes known as the funeral period of embalming and is marked by a separation of the fields of embalming by undertakers and embalming (anatomical wetting) for medical and scientific purposes. Modern embalming for mere funeral purposes begun in 1861 in the American Civil War, to permit burial

without any urgency and to avoid the spread of infection. Thus, the corpses of dead Union officers were embalmed so as to return to their families. Military authorities also permitted private embalmers to work in military controlled areas. Cosmetic work was also permitted to reinstate bruised facial features.²³ The passage of Abraham Lincoln's body home for burial was made possible by embalming, and it brought the possibilities and potential of embalming to wider public notice. This type of embalming comprised elimination of blood and gases from the body and the insertion of a disinfecting fluid; the viscera was removed and immersed in an embalming fluid and then replaced in the body. The body and viscera are covered with a preservative powder. Fluid contained arsenic, creosote, mercury, turpentine and various forms of alcohol. Arsenic based solutions were generally accepted and frequently used as embalming fluid in the 19th and early 20th centuries but has since been supplanted by formaldehyde.²⁴ Some famous mummies of ancient times have been that of King Tutankhamun, an Egyptian pharaoh of the 18th dynasty. His mummy was discovered in 1922 and one of the members of the expedition died a few months after the discovery which stirred the legend of the 'Mummy's Curse'. The mummy of Ramesses II, Egypt's most powerful pharaoh is now on display in the Cairo Museum.²⁵ The mummification of Vladimir Lenin, the architect and first head of the USSR and father of Russian Communism, was carried out for the benefit of future generations since no process of mummification had ever been attempted before this, in modern times. Generations of Russian scientists have spent almost a century fine-tuning preservation technique that have maintained the look, feel and flexibility of Lenin's body. The body gets re-embalmed once every other year; a process that involves submerging the body in separate solutions of glycerol solution baths, formaldehyde, potassium acetate, alcohol, hydrogen peroxide, acetic acid solution and acetic sodium. Also, occasional parts of skin and flesh are substituted with plastics and other materials.²⁶

Modern Anatomical Preservation

Modern embalming is most often executed for better presentation of the deceased to friends and relatives, in medical colleges to preserve the dead bodies for the purpose of dissection for training and research and when the dead body has to be transported from one country to another for burial or cremation and the time taken in transit is such as

would ordinarily lead to decomposition.²⁷ It is also carried out when the dead body of some important personality has to be preserved for public viewing. Thus, embalming has evolved into a restorative and mortuary cosmetic art.²⁸

Today embalming involves arterial embalming, cavity embalming, hypodermic and surface embalming. The embalming fluid comprises different kinds of chemicals like preservatives, disinfectants, buffers, humectants, anticoagulants, dyes and masking agents or deodorants.²⁹ A new embalming technique developed by anatomist Walter Thiel at the Graz Anatomy Institute in Austria retains the body's natural colour, texture and plasticity after the process. Cadavers conserved by Thiel Method have greater antibacterial properties, no detectable odour, highly flexible joints and muscle and viscera colour appear natural.³⁰ Today there are institutes which carry out newer processes like 'Plastination' where tissues are replaced by polymers and 'Cryopreservation' where the body is preserved at sub-zero temperatures.

Conclusion

Preservation of a cadaver has evolved in a big way since ancient times. Preservation techniques like soft embalming by Thiel method as well as recent advances like Plastination and Cryopreservation hold much potential for more innovative advances in embalming techniques.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

SR drafted the manuscript, performed the literature review & SPS assisted with writing the paper.

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