

## Manuscript Details

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<b>Title</b>	Autoptic practices in 16th-18th century Florence: skeletal evidences from the Medici family
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### Abstract

During the late Middle Ages and the Renaissance autopsy started to be practised for medico-legal purposes, in order to investigate the causes of death. The other reason for dissecting a body was embalming, a diffused custom typical of the elitarian classes. The exploration of the Medici tombs in the Basilica of San Lorenzo in Florence offered the opportunity to investigate the practice of autopsy on these aristocratic personages of the Renaissance and Early Modern Age. A total of 25 currently skeletonized individuals were exhumed. Accurate examination of the skeletons revealed evident signs of autoptic practices such as horizontal and oblique craniotomies, longitudinal and transversal cuts of the sternum, and sectioning of the sternal extremities of the ribs. In this group women were treated differently to men at autopsy, as only men underwent craniotomy; autopsy and embalming were carried out also for the illegitimate members of the family and for subadults. The extremely rich documentary archives of the Medici family confirm that the corpses were in several cases submitted to autopsy. The present study offers important direct information on the 16-18th century autoptic practices that the court surgeons in Florence performed on the members of the elitarian class.

<b>Keywords</b>	Renaissance; Early Modern Age; Medici; autopsy; embalming; craniotomy; thoracotomy.
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<b>Suggested reviewers</b>	Urszula Bugaj, Piers Mitchell, Jenna Dittmar
<b>Opposed reviewers</b>	Donatella Lippi

## Submission Files Included in this PDF

### File Name [File Type]

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Dear Editor,

during the late Middle Ages and the Renaissance dissection started to be practised for medico-legal purposes, in order to investigate the causes of death. The other reason for dissecting a body was embalming, a diffused custom typical of the elitarian classes; the funerary ceremonies of the ruling dynasties usually required long times and implied direct exposition of the corpse, so that the treatment of the corpses became an instrument of legitimacy and a symbol of sovereignty.

The exploration of the Medici tombs in the Basilica of San Lorenzo in Florence, carried out by the Division of Paleopathology between 2004 and 2013, offered the opportunity to investigate the practice of autopsy on these aristocratic personages of the Renaissance and Early Modern Age. A total of 25 currently skeletonized individuals, almost all of which formerly artificial mummies, were exhumed. Accurate examination of the skeletons revealed evident signs of autoptic practices such as horizontal and oblique craniotomies, longitudinal and transversal cuts of the sternum, and sectioning of the sternal extremities of the ribs. Two children showed the presence of vegetal substances that had been used to fill the thoracic cavity for embalming. The extremely rich documentary archives of the Medici family confirm that the corpses were in several cases submitted to autopsy.

The present study offers important direct information on the 16-18<sup>th</sup> century autoptic practices that the court surgeons in Florence performed on the members of the elitarian class.

We wonder if you could be interested in publishing this article in the International Journal of Paleopathology.

All authors declare no conflict of interest.

The present work has not been published previously, it is not under consideration for publication elsewhere, its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and, if accepted, it will not be published elsewhere including electronically in the same form, in English or in any other language, without the written consent of the copyright-holder.

Yours sincerely,

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Title: Autoptic practices in 16th-18th century Florence: skeletal evidences from the Medici family  
International Journal of Paleopathology

**Dear Editor,**

**we revised the manuscript, according to the referees' comments.**

**Here in bold type a detailed list of the changes and the rebuttal against each point. In the manuscript the changes are highlighted in yellow.**

Reviewer #1:

This is an interesting piece of research that investigates autopsy and embalming practices in the famous extended family of the Medici. I am glad to see you have integrated osteological and historical evidence as this strengthens your argument. While embalming does not fall within the remit of this journal, autopsy in order to look for evidence of disease would be an appropriate topic for this journal. Here are some suggestions that I think would help you improve the article still further:

a) It would be helpful if you include a distinct paragraph in your introduction stating the different functions of autopsy and embalming. You have written about autopsy versus dissection, but not about embalming. Autopsy is performed to determine the cause of death, and embalming is performed by removing soft tissue internal organs and packing with preservative materials in order to ensure artificial mummification. Embalming can lead to many of the same cut marks on bone that can be found in autopsy, so it is important that you help the reader understand the difference.

**Reply: a paragraph about embalming has been added in the introduction. It is of course impossible to differentiate between the cuts of autopsy and embalming in skeletal remains but, for the Medici, we have in many cases the archive documents with the results of autopsies performed before the embalming. Only in two children we have found the materials of embalming, because the bodies were already studied by the Italian anthropologists in the '40ies, as stated in the materials and methods and in the discussion.**

b) In much of this article you write as if the two practices of autopsy and embalming were interchangeable for the Medici. At the bottom of page 3 you write that autopsy was 'performed

mainly to embalm the bodies'. In section 3.1 of page 5 you write that Maria Salvati underwent autopsy 'for embalming'. On p.14 you state that after death all the members of the Medici family underwent autopsy followed by embalming. However, table 1 shows that there was actually a large amount of variation in how the body of each individual was treated. How can you be sure they all underwent autopsy and embalming if the cut marks on the bone vary so much? Please make your viewpoint clearer.

**Reply: We tried to explain our viewpoint clearer by adding a new paragraph in the discussion.**

c) Table 1. Please add in a column stating the sex of each individual, as it may not be clear to readers who do not know Italian names well.

**Reply: a column with sex of each individual has been added.**

d) You write that women were treated differently to men at autopsy, as only men underwent craniotomy. This is an important finding and should be stated clearly in your abstract and conclusion. To provide historical context for this, I think you would find it helpful to look at this book about the dissection of women in Renaissance Italy, which is not currently included in your references: Park, K. *Secrets of Women: Gender, Generation, and the Origins of Human Dissection*. New York: Zone Books, 2006.

**Reply: the different treatment reserved to woman and men has been now clearly stated in the abstract and conclusion. Reference to the suggested book has been added.**

Reviewer #2

The authors present a post-mortem examination of the Medici family. The study is potentially interesting but can be improved if the following considerations are addressed:

#### INTRODUCTION

Page 3: In addition to providing information about the Western countries, authors should include a briefly mention about earlier dissection in Eastern Empires (for example something like: *The history of anatomy in Persia. Shoje MM & Tubbs, RS, 2006 J.Anat, 210(4):359-378*)

**Reply: In our knowledge dissections on human corpses in the Eastern Empire (ancient Egypt, Mesopotamia etc.) were not performed; authors affirming that this practice were carried out,**

such as Shoje & Tubbs, 2014, are based on pure speculations and not true evidences. Therefore, we prefer not include the reference suggested by the reviewer.

Page 3 : Please, add the reference "Brickley 2001" to the reference list .

**Reply: the reference was in the reference list, but the year of publication was wrong. This mistake has been corrected.**

Page 3: I would suggest that the references of the paragraph about osteoarchaeological evidences of postmortem examination should be sorted by date instead of alphabetically.

**Reply: references of the paragraph about osteoarchaeological evidences of postmortem examination has been sorted by date.**

Page 3: the expression "*craniotomies remains uncertain*" referring to 15<sup>th</sup> century study of Valentin & D'Errico, 2015, should be explained.

**Reply: the expression has been better explained.**

Page 4: A question to the authors: Are there any previous autopsies performed in aristocratic or royal individuals in Western countries? Is this the first examination in this category of individuals?

**Reply: yes there are the autopsies performed on the Aragonese king and nobles, which we discussed in the paper.**

## MATERIAL & METHODS

Page 4: I suspect that the individual was deposited into Zinc coffin after he was skeletonized, because zinc coffins favored the corification of corpses (a type of mummification in non defleshed individuals)

**Reply: yes, these individuals were deposited into zinc coffins by anthropologists of the 20<sup>th</sup> century, who removed all traces of soft tissue which were still eventually present. This is explained in the Materials and methods.**

## RESULTS

Pages 6-7-8: Please unify typography (italics or not) of terms Gladiolus and Sternum along the manuscript.

**Reply: the typography of both terms has been uniformed.**

Page 8: Is it accurate to speak about Costotome in the 16<sup>th</sup> century?

**Reply: it is more appropriate the word pincer.**

Page 9: I consider that it would be interesting if authors mention what kind of embalming plants were used in as, for example, Filippo.

**Reply: the embalming plants detected through the palynological analyses have been mentioned.**

## DISCUSSION

Page 12: The absence of oblique craniotomy in comparison with the Aragonese family has been pointed out. However, in your manuscript there are 3 described which is significant. Could the authors provide any hypothesis about such difference?

**Reply: The orientation of the cut (horizontal or oblique) in our opinion should be simply attributed to the choice of the surgeon who performed the autopsy.**

## LEGEND Figures

Please, in the figure 4b add the term "*in detail*"

**Reply: the term "in detail" has been added in the figure 4b.**

## BIBLIOGRAPHY

References by the same first author should be ordered by year of publication.

Please check if the following references are cited in the text: *Fornacciari et al, 2010 and Galluzzi, 1781.*

**Reply: the mistakes in the bibliography have been corrected.**

Best regards

Valentina Giuffra

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# **Autoptic practices in 16th-18th century Florence: skeletal evidences from the Medici family**

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## **Abstract**

During the late Middle Ages and the Renaissance autopsy started to be practised for medico-legal purposes, in order to investigate the causes of death. The other reason for dissecting a body was embalming, a diffused custom typical of the elitarian classes.

The exploration of the Medici tombs in the Basilica of San Lorenzo in Florence offered the opportunity to investigate the practice of autopsy on these aristocratic personages of the Renaissance and Early Modern Age. A total of 25 currently skeletonized individuals, almost all of which formerly artificial mummies, were exhumed. Accurate examination of the skeletons revealed evident signs of autoptic practices such as horizontal and oblique craniotomies, longitudinal and transversal cuts of the sternum, and sectioning of the sternal extremities of the ribs. **In this group women were treated differently to men at autopsy, as only men underwent craniotomy; autopsy and embalming were carried out also for the illegitimate members of the family and for subadults.**

The extremely rich documentary archives of the Medici family confirm that the corpses were in several cases submitted to autopsy. The present study offers important direct information on the 16-18<sup>th</sup> century autoptic practices that the court surgeons in Florence performed on the members of the elitarian class.

**Article type:** Full Length article

**Key words:** Renaissance, Early Modern Age, Medici, autopsy, embalming, craniotomy, thoracotomy

## **1. Introduction**

Dissection for anatomical studies and teaching reappeared in the Western world with the work of Mondino de' Liuzzi in Bologna who, in 1315, performed his first public dissection in the presence of medical students and of other spectators. From this moment dissections were incorporated in the medical curriculum of the universities.

However, anatomical dissections should be distinguished from autopsies performed for medico-legal purposes, the first records of which go back to the second half of the 13<sup>th</sup> century (Busacchi, 1965); from the 14<sup>th</sup> century onward, the practice of autopsy for assessing the causes of death became increasingly common (Park, 1994).

Another practice attested in the same period is embalming, performed by removing soft tissue internal organs and packing them with preservative materials in order to ensure artificial mummification (Marinozzi and Fornaciari, 2006).

Although the history of autopsy can be reconstructed from the archival documents, skeletal remains providing evidence of autoptic practices can be used as a direct source of information. Significant overlap is possible between anatomical dissection and autopsy in osteoarchaeological remains, but a method for differentiating these two post-mortem investigative procedures has been recently proposed (Dittmar and Mitchell, 2015). Osteoarchaeological evidences of post-mortem examination from Europe have been reported, but go back mainly to the 18-19<sup>th</sup> centuries (Henderson et al., 1996; Chapman, 1997; Signoli et al., 1997; Hillson et al., 1998; Brickley et al., 1999; Brickley et al., 2001; Anderson, 2002; Hull et al., 2003; Boston et al., 2005; Miles et al., 2008; Boston et al., 2009; Mitchell et al., 2011; Chamberlain, 2012; Mitchell, 2012; Bugaj et al., 2013; Charlier et al., 2013; Western and Bakvalac 2015). The most ancient specimens with evidences of craniotomies come from France and are date back to the 13<sup>th</sup> (Charlier et al., 2013) and 15<sup>th</sup> century (Valentin and D'Errico, 1995); in the first case the procedure was aimed at obtaining an anatomical preparation, whereas in the second case it has not been possible to determine if the craniotomies should be attributed to embalming, to autopsy or to both procedures.

As for embalming, mummified human remains preserve evident traces of the body treatment, but in completely skeletonized remains it is impossible to differentiate between the cuts on bones made to perform of autopsy from that attributable to embalming; however, for particular categories of individuals, such as ruling dynasties, the archive documents in many cases attest the practice of embalming after autopsies. The Aragonese kings and nobles buried in the church of S. Domenico Maggiore in Naples, whose corpses exhibited evidences of craniotomies and thoracotomies, represent an interesting sample for the study of autoptic practices, performed mainly to embalm the bodies, during the Renaissance and the Early Modern Age (Fornaciari, 2006).

The exploration and osteoarchaeological study of the skeletal remains of members of the Medici family, buried under the vaults of the Basilica of San Lorenzo in Florence, offered the opportunity of investigating the practice of autopsy in these aristocratic personages. The Medici were one the most powerful families of the Italian Renaissance, who accumulated vast wealth through banking, commerce and skilful political ventures. Their bodies were opened soon after death and were treated before burial, as imposed by the political system, considering the importance of the social status of these personages. In this case the osteoarchaeological study can be supported by the information provided by the extremely rich documentary archives of the family, which in some instances attests the autopsy performed by the court surgeons (Pieraccini, 1986).

## **2. Materials and Methods**

The Medici Project, a multidisciplinary study aimed at exploring the 49 burials of the Medici housed in the Basilica of San Lorenzo, was started in 2004. However, some burials had already been explored in the second half of the 19<sup>th</sup> century (Sommi Picenardi, 1888), and again after the Second World War (Genna, 1948). For these reasons, most of the human remains were not located in their original burial place, but were arranged in zinc coffins, not in anatomical position. All traces of the soft tissues have disappeared and the bodies are at present skeletonized, although they were originally almost all artificial mummies. In fact, the anthropologists of the past, interested mainly in

craniology and osteometric studies, removed all traces of soft tissues in order to better observe the skeletons. Only a hidden crypt hosting the remains of Giangastone, the last Medici Grand Duke (1671-1737), and of 8 children of the family, had never been explored, and therefore the burials were found intact. Unfortunately, the infantile bodies were damaged during the flooding of Florence in 1966, preventing the observation of further signs of embalming in some children of the family. Two other tombs, explored in 2013 during the restoration works of the Medici Chapels, revealed the intact burials of two minor and probably illegitimate members of the Medici family, but also in this case the soft tissues were not preserved.

A total of 25 out of 49 individuals, including the children found in the crypt of Giangastone, have been studied so far (Fornaciari et al., 2007). An osteoarchaeological study using macroscopic examination was performed in 14 adults, 10 males and 4 females, and in 11 subadults, aimed at detecting any signs of the autoptic practices of the court surgeons on the bodies of these aristocratic personages.

### **3. Results**

Here we present the results of the examination of the skeletal remains of the members of the Medici family: 13 individuals out of 25 showed signs of autopsy and/or embalming. A summary of the examined skeletal remains and the results are reported in Table 1.

#### *3.1 The family of Cosimo I*

The father of Cosimo I, the famous military captain Giovanni delle Bande Nere (1498-1526), was buried under the floor of the Medici Chapels together with his wife Maria Salviati (1499-1543). The examination demonstrated that the skeletal remains of Giovanni and Maria did not evidence any traces of autoptic practices (Fornaciari et al., 2013, 2014). The documentary sources are silent about any autopsy or embalming performed on the corpse of Giovanni, while a reference to autopsy was found in a letter in which Cosimo's secretary Campana was asking the major-domo Pierfrancesco

Riccio instructions “about the opening of Maria’s corpse” (Conti, 1893).

Cosimo I (1519-1574), 1<sup>st</sup> Grand Duke of Tuscany, was buried in a lateral chapel of the Basilica of San Lorenzo next to his wife Eleonora from Toledo (1522-1562), and to their sons Giovanni (1543-1562) and Garcia (1547-1562) (Fornaciari et al., 2007).

There is evidence for three attempts at opening the skull of Cosimo. The first two attempts appear to have failed. In the third attempt, the surgeon opened the skull by inserting a large chisel, which damaged the skullcap in four different points, thus causing some large bone breaks (Figs. 1a-b). This evidence would suggest that the craniotomy was attempted without the benefit of an iron rim as a guide.

No traces of cuts at the level of the sternum nor of the ribs were observed. In the written sources the autopsy of Cosimo is justified as follows: “The physicians opened it [the corpse], in order to understand clearly the cause of his disease, and in order to avoid any corrupt smell born in the corpse” (Cantini, 1805).

The skeleton of Eleonora from Toledo, Cosimo’s wife, presented no traces of craniotomy nor of thoracotomy. However, the written sources attest that she was submitted to autopsy (Pieraccini, 1986).

The examination of the skeletal remains of Cosimo and Eleonora’s sons Garcia and Giovanni revealed no traces of craniotomy nor of thoracotomy. The written sources attest that the internal organs of Giovanni were examined (Pieraccini, 1986), but no reference is made to a possible autopsy on the corpse of Garcia.

### *3.2 The family of Francesco I*

Francesco I (1541-1587), 2<sup>nd</sup> Grand Duke of Tuscany, was buried in a lateral chapel next to his wife Giovanna from Austria (1548-1578), to their daughter Anna (1569-1584), and to an unknown child (Med9) (Fornaciari et al., 2007). The skeletal remains of Don Filippino (1577-1582), the seventh son of Francesco I and Giovanna, were identified in the crypt of Giangastone (Vitiello et al., 2015).

The examination of the skeletal remains of Francesco I showed that craniotomy had not been practiced, as demonstrated by the absence of openings in the skull. Autopsy was limited to thoracotomy; in fact, the sternum shows a clean cut, obtained by a bone saw, of the inferior tract of the left lateral border of the **gladiolus** (Fig. 2a). The longitudinal and slightly oblique cut was caused at the moment of opening of the thorax on the left para-sternal line, since it would have been more difficult for the surgeon to work on the right-hand side. A detailed description in Latin of the autopsy of Francesco is reported by the court physicians, who mention the opening of the thorax and of the abdomen, but not of the skull (Pieraccini, 1986).

There was no skeletal evidence of a craniotomy observed for the remains of Giovanna, though there was a cut through the sternum near the left lateral border of the gladiolus (Fig. 2b). The longitudinal and slightly inclined cut was produced at the opening of the thorax with a bone saw on the left para-sternal line, similar to that of Francesco I. A historical report describes a detailed autopsy, aimed at investigating the thoracic and abdominal organs (Pieraccini, 1986).

As for Don Filippino, an accurate horizontal cut obtained with a bone saw, probably using an iron rim as guide, was practiced in his skull (Fig. 2c-d). The use of a metallic rim is evident from the perfect linearity of the craniotomy and from the coincidence of the cuts especially posteriorly, impossible to be obtained with a handmade cut. The presence of the clothes prevented total recovery of the skeletal remains; however, it was possible to examine the ribs and the sternum by *in situ* X-ray, which did not reveal any signs of cuts. The archival documents refer that the corpse of the Prince was opened after death, and craniotomy is also mentioned (Pieraccini, 1986).

The remaining members of Francesco I and Giovanna's family examined for this research included Princess Anna and an unidentified 6-12 month old (Med 9). In both instances, there was no evidence of craniotomy or thoracotomy.

### 3.3 *The family of Ferdinando I*

Ferdinando I (1549-1609), 3<sup>rd</sup> Grand Duke of Tuscany, son of Cosimo I and Eleonora from Toledo, was buried in a lateral chapel next to his wife Cristina from Lorraine (1565-1637), and to their sons Francesco (1594-1614) and Carlo (1596-1666). The seventh child of Ferdinando I and Cristina, Filippo (9 April 1598 - 3 April 1602), was found in Giangastone's crypt (Vitiello et al., 2015).

Ferdinando was submitted to craniotomy: the surgeon cut the soft tissues with a subtle blade, as proven by some horizontal and oblique thin incisions of the parietal and temporal bones. He then opened the skull with an accurate, horizontal cut, which reached the occipital bone at a lower level and needed only a small change of direction (Figs. 3a-b). This accurate horizontal craniotomy was obtained with a bone saw, with no iron rim as guide. No autoptic cuts were observed on the sternum and the ribs. Historical reports attest that Ferdinando was submitted to autopsy, but there is no reference to opening of the skull (Pieraccini, 1986).

Like the other female members of the family, Cristina was not submitted to craniotomy, but only to thoracotomy. The sternum showed two cuts of the left lateral border of the *manubrium* and the **gladiolus** (Fig. 3c); these almost longitudinal cuts, obtained by a bone saw, were produced when opening the thorax on the left para-sternal line, obviously less easy to handle for a surgeon positioned on the right. No written sources mentioning the autopsy were found.

The examination of the skeletal remains of Prince Francesco, fourth child of the Granducal couple, demonstrated that the court surgeon had opened the skull with an accurate, oblique cut, obtained with a bone saw, probably using an iron rim as guide, as the cuts on the lateral sides of the skull are perfectly rejoined in the occipital region (Fig. 3d). The sternal *manubrium* reveals a deep, transversal, slightly inclined incision, produced by a large and very sharp blade. This cut was evidently caused by a large knife transversally sectioning the soft tissues of the anterior wall of the thorax, at the beginning of the autopsy. The written records refer that both the skull and the abdomen were open (Pieraccini, 1986).

The analysis of the skeletal remains of Cardinal Carlo, fifth child of Ferdinando and Cristina, revealed two large transversal cuts on the upper part of the **sternum** (Fig. 4a), evidently produced by a large knife, transversally sectioning the soft tissues of the anterior wall of thorax, at the start of the autopsy. The sternal extremities of the 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup> and 8<sup>th</sup> right ribs, and the 5<sup>th</sup> on the left, appear to be completely sectioned (Fig. 4b). The section of the ribs at the level of the chondro-sternal junction was probably **produced by scissors or pincers**, when the cavity of the thorax was opened. No reports about the autopsy appear in the archival sources.

In the remains of Filippo the mould of the lung, the mediastinum and the xipho-pubic and umbilical-transverse incisions for evisceration were well visible (Fig. 5a). The negative mould of the vertebral column on the back could also be identified easily (Fig. 5b). Palynological analyses of the child cast demonstrate the presence of several pollens to be referred to plants used for embalming; **a prevalence of oak, rockrose and aromatic plants of the Labiatae family, in particular germander, *Phlomis* and sage, was observed** (Giuffra et al., 2011). The documents attest that on the same day of the child's death, the surgeons Pier Rossi, Fonseca and Turini autopsied the little corpse, opening the thoracic and abdominal cavities and examining the internal organs (Pieraccini, 1986).

### *3.4 The illegitimate members of the family*

Anton Francesco Maria (1618-1659) was son of Antonio de' Medici (1576-1621) and Artemisia Tozzi (1643?), and is suspected to be an illegitimate member of the Medici family. In fact, the true lineage of his father has never been clarified (Luti, 2006). Osteoarchaeological examination evidenced that he had been submitted both to craniotomy and thoracotomy. The surgeon cut the soft tissues with a subtle blade, as proven by some horizontal thin incisions of the occipital bones; he then opened the skull with an accurate, oblique cut with a bone saw, which reached the inferior occipital bone (Figs. 6a-b). The sternal extremities of the ribs, from the 2<sup>nd</sup> to the 8<sup>th</sup> rib on the right, the 2<sup>nd</sup>, and from the 4<sup>th</sup> to the 10<sup>th</sup> rib on the left appeared to have been completely sectioned (Fig.



7c), probably **by scissors or pincers**. No reports about the necroscopy are reported in the written sources.

Gian Francesco Maria (1619-1689), son of Don Giovanni de' Medici (1567-1621) and Livia Vernazza (1590-1655), was born from an illegitimate relationship. However, after his father's death, he was brought up at the Medici court in Florence, and given an annuity by the Grand Duke's family. The examination of the skeletal remains of Gian Francesco Maria showed that he had been submitted to craniotomy. The surgeon practised an oblique and incomplete cut, interrupted in the posterior portion of the skull, in correspondence of the occipital bone; the opening of the head was made possible by an irregular breakage ca 3 cm above the lambdoid suture (Figs. 6d-e). The presence of garments and objects belonging to the funerary gear prevented the recovery of the post-cranial skeleton, therefore it was impossible to ascertain whether his thoracic cavity had been opened. No reports about the necroscopy were found in the written sources.

### *3.5 Giangastone and the other children of the family*

Son of Cosimo III and Margherita Luisa of Orléans, ruled from 1723 to 1737, and was the last Grand Duke of the Medici dynasty. The skeletal remains of Giangastone were found in a hidden crypt that had never been explored, his corpse had been wrapped in a large quantity of clothes, which prevented recovery and observation of the postcranial skeleton. On the contrary, the skull was well visible and showed the sign of a craniotomy. The skull had been opened with an accurate horizontal cut reaching the occipital bone, probably by means of an iron rim as guide (Fig. 7a). The archival documents attest that his corpse was submitted to autopsy, and that both the skull and the abdomen had been opened (Pieraccini, 1986).

Exploration of the crypt of Giangastone revealed the burials of 8 infantile members of the family.

The children's remains, mostly skeletonised, were found inside their coffins, or scattered on the floor, or randomly spread over a raised plank, evidently moved by the water as a result of the disastrous flood of the Arno river in 1966. An attempt of identification of the children on the basis

of an anthropological study was proposed, even if some identifications remain uncertain (Vitiello et al., 2015).

Beside Don Filippino and Filippo, mentioned above, another skeleton, still in partial articulation and belonging to a newborn, showed evidence of embalming (Med 40.34). This newborn still presented the endocranial cast (Fig. 7b) and the mould of the thorax. Even in this case, as for Filippo, palynological analyses demonstrated the presence of pollens of plants used for embalming; a strong prevalence of germander, with minor presence of olive, grapevine, pine and chamomile was evidenced (Giuffra et al., 2011). This case is of great interest because it attests that embalming was also practised for the newborns of the family.

The 5 other children of the family (Med 40.22/42, Med 40.29+31, Med 40.40, Med 40.45, Med 40.48) found in the crypt of Giangastone showed no evidences of autoptic practices.

#### **4. Discussion**

The examination of the skeletal remains of the members of the Medici family reveals interesting direct details about the practice of autopsy in 16-18<sup>th</sup> century Florence.

In total, evidence of autopsy, i.e. thoracotomy and/or craniotomy, was found in 13 out of 25 individuals (52%). The procedure was also carried out for the illegitimate members of the family and for very small children, as demonstrated by the case of the newborn, who showed evidence of embalming.

Craniotomy was observed in 8 out of 25 individuals, all of male sex; therefore, from this study it could be inferred that the practice was reserved to males of all ages, including newborns, while it was denied to women. At the end of Middle Ages and in the Renaissance the female bodies played a central role in the history of anatomy. In particular, the corpses of wives and mothers yielded crucial information about the secrets of female bodies, linked to pregnancy and the capacity of give life (Park, 2006). However, there are no references about the consideration of the surgeons about

the brain; therefore the reason for this respect towards female bodies is not clear, but probably was to avoid disfiguring of the head for the funeral exhibition. Craniotomy was performed with a horizontal cut in 4 cases (Cosimo I, Ferdinando I, Don Filippino and Giangastone); an oblique craniotomy was observed in 3 cases (Prince Francesco, Antonio Francesco Maria and Gian Francesco Maria). In the case of the newborn, the opening of the skull was possible without any cuts, since sutures at this age are open; opening of the cranium was attested by the presence of embalming material found inside.

Signs of thoracotomy were present in 7 out of 25 individuals, including both sexes. In the majority of cases the thorax was opened by sectioning the sternum. In three cases, those of Francesco I, Giovanna and Cristina, the cut was longitudinal and was practiced on the sternal body, whereas in two cases, those of Prince Francesco and Cardinal Carlo, the section was obtained through an oblique cut through the manubrium. In Carlo the section of the sternum was also accompanied by incisions in the sternal ends of the ribs; in Antonio Francesco Maria thoracotomy was limited to the section of the ribs. In two children, thoracotomy could be inferred by the presence of embalming substances found in the mould of the thorax. Only two individuals presented signs of both craniotomy and thoracotomy, the illegitimate Antonio Francesco Maria and the newborn.

In some cases the written information that would suggest that individuals were submitted to autoptic practice was not confirmed by the osteoarchaeological findings, since no traces of cuts in the skull nor in the ribs nor sternum were observed. This discrepancy could be explained with the fact that the procedure was performed by opening only the abdomen and by reaching the thoracic organs through the diaphragm, without sectioning any bones. For the same reasons absence of evidence in the other skeletons does not mean evidence of absence: some form of treatment was likely to have been performed, probably not affecting the skeleton, i.e. evisceration through the abdominal cavity.

The Aragonese family represents a useful comparison of the same period, as their members were buried between the second half of the 15<sup>th</sup> and 18<sup>th</sup> centuries. A total of 15 out of the 38 examined

bodies (48.4%), most of which were conserved as mummies, showed evidences of embalming. Craniotomy was observed in 13 individuals; among them, the cut was horizontal in 7 cases, whereas in 6 cases the craniotomy was performed through a hole in the posterior part of the skull. The head was opened also in some children, whereas the female members of the family showed no signs of craniotomy. Thoracotomy, consisting in cuts of the sternum or of the ribs, was observed in 9 individuals; in 5 other mummified members of the Aragonese family, opening of the corpses is attested by an abdominal incision from the xyphoid process to the pubis, which demonstrates that the thoracic cavity was eviscerated through the diaphragm without involving the skeletal apparatus (Fornaciari, 2006). Therefore, the procedure followed by the physicians for the Aragonese nobles and kings is very similar to that observed for the Medici family, with the sole exception of the craniotomy practiced through a hole in the occipital bone.

Interesting considerations can be made about the reasons for these autopsies among the members of the Medici family. During the Renaissance and the Early Modern Age opening of a corpse performed privately on request of the family should be distinguished from the public dissections and anatomical research. The subjects of the autopsies requested by the families were not criminals, condemned or poor patients of hospitals: these were the categories that provided corpses for teaching and for anatomical research. Instead, they belonged to the upper or aristocratic classes and were patients of scholarly doctors or lettered surgeons; in several cases the physicians and surgeons who practised the autopsy had treated the deceased in life (Siraisi, 2001).

Historical sources attest that autopsies in the Renaissance period were carried out also for medico-legal purposes. Sporadic cases of “forensic” autopsies on human bodies in the Western world have been recorded since the 14<sup>th</sup> century (Busacchi, 1965; Park, 1994). In the city of Florence anatomical dissection was regulated by precise rules contained in the *Statuti* of 1387 (Nardi, 1956). Autoptic practice was already mentioned in 1399 in the *Tractatus de nobilitate legume et medicinae*, composed by Coluccio Salutati, Florentine secretary and humanist (Costa and Weber, 1963). Evidences of autopsies performed by doctors on their private patients started to emerge in

the 15<sup>th</sup> century. These autopsies were requested by the families who could afford the expenses, in order to investigate the possible presence of hereditary diseases and to predispose a possible prevention and cure (Park, 1994).

The diffusion of this practice in Florence is also attested by the work of Antonio Benivieni (1443-1502), who is considered the father of pathological anatomy. His work *De abditis nonnullis ac mirandis morborum et sanationum causis*, published posthumous in 1507, illustrated a large series of cases for which autopsy is fundamental to discover the causes of death or to study the anatomical and physiological changes determined by diseases. The work testifies the diffusion of autoptic practice in Florence during the 15<sup>th</sup> century (Costa and Weber, 1963).

In the case of Cosimo I, explicit reference to a medico-legal purpose of the autopsy, aimed at investigating the causes of death, can be inferred in documentary sources. Another reference is reported in a letter of June 9, 1547 when the courtier Don Pedro de Toledo brings Cosimo I and Eleonora the news of the death of their son Pedricco (August 7, 1546 – June 9, 1547). Cosimo orders an autopsy of the child's body: “He [Cosimo] ordered that the beautiful little corpse were opened so that they could see how it was inside” (Vol. 1173, folio 212).

The other important reason for the practice of autopsy was the preparation of the funerals of the elitarian members at least until the 17<sup>th</sup> century. Since aristocratic, and in particular royal burials, required long preparation times in the Middle Ages and in the early Modern period, embalming was often a necessity to prevent putrefaction before burial. As embalming required particular skills and expensive materials, it also became a status symbol for the elite (Korpiola and Lathinen, 2015). Furthermore, the corpse of a ruler exhibited a strong symbolic power, as it transcends its own materiality, bringing together community and political values; it became a means to the successors to legitimate and retain their power long after death (Huntington and Metcalf, 1985). Therefore, keeping the body even for a long period of time before celebrating the funeral represented a dynastic and political necessity.

At the beginning of their rule the Medici were still a family of bankers, to whom Charles V attributed the title of Dukes in 1531. From that moment onwards the process of legitimation of their power was inspired to the imperial model. Embalming and dressing of the corpses were two important religious practices which made the funerary ritual of the Medici one of the main instruments of sovereignty. These operations were simulacra of sacrality, in an attempt to emulate the model of the Empire. For the funerals of Cosimo I in 1574, the source of inspiration was represented by the funerary ceremony celebrated in Brussels in 1558 in honour of Charles V, whose body was embalmed (Fantoni, 2012).

Embalming and autopsy were particularly linked; most likely the surgeons who were asked to embalm the body of important personages in this time took advantage of the opportunity to observe internal organs in order to understand the cause of death (Park, 2006). Therefore, it can be supposed that after death the corpses of the members of the Medici family were firstly submitted to autopsy in order to examine internal organs and to determine the causes of death, and immediately after were submitted to the postmortem processing for embalming. It should be considered that it is not possible to differentiate the skeletal manifestations of autopsy versus procedure for embalming, as the craniotomies and thoracotomies were used for both purposes. Variation in treatment of individuals evidenced by examination of the skeletal remains of the Medici should be attributed to different technique of different court surgeons.

Some traces of embalming substances were preserved in the cast of the four-year-old Filippo (Med 40.2) and of the newborn (Med 40.34), in which a prevalence of aromatic plants was detected (Giuffra et al., 2011). Unfortunately, during the previous anthropological investigations of the Medici in the 19<sup>th</sup>-20<sup>th</sup> centuries, all the soft tissues were removed, preventing the observation of further traces of embalming and the sampling of possible substances used to treat the bodies. After removal, the internal organs of the members of the Medici family were conserved and usually deposited in jars buried separately from the body (Lippi, 2006).

It is difficult to reconstruct the procedures followed by the physicians to perform autopsy, as detailed written accounts during the Renaissance are rare. The surgeons probably followed the procedure described by Mondino de' Liuzzi in his fundamental *Anathomia*, intended as a practical “manual” that remained the reference text until the 16<sup>th</sup> century. Dissection consisted in dividing the human body into three distinct parts: the head, chest and abdomen. The abdomen had to be opened first, because it contained the least noble and most putrescible organs; the chest followed, and finally the head, which contains higher and more complex anatomical structures (Crivellato and Ribatti, 2006). A graphic representation of the opening of the cranium was described in the *De humani corporis fabrica* (1543) by Andreas Vesalius. This protocol is also mentioned in a later anatomical treatise, as testified by the work of Dionis (1708) at the beginning of the 18<sup>th</sup> century. In this text a detailed description of the procedure for the opening of the skull is reported: after removal of the scalp, the cut was performed with a sawbone, starting from the frontal bone, proceeding on one of the temporal bones and then on the other side; finally, the corpse was turned so that the surgeon could cut the occipital bone.

This procedure seems to have been applied to the craniotomies of the male members of the Medici family. Some cases reveal the action of rather unskilled surgeons, as demonstrated by breakages in the skull bones or by several cuts demonstrating different attempts to open the skull. As for thoracotomy, the evidences from the Medici family, consisting in the section of the sternum and the ribs, represent a rare direct finding referable to the opening of the thoracic cavity in this period.

## **5. Conclusions**

The osteoarchaeological study of the skeletal remains of some members of the Medici family exhumed in the Basilica of San Lorenzo in Florence allowed a detailed direct analysis of the autoptic practices reserved to aristocratic personages of the 16-18<sup>th</sup> centuries. The examination of the skeletons revealed evident signs of autopsy, such as horizontal and oblique craniotomies, longitudinal and transversal cuts of the **sternum**, and sectioning of the sternal extremities of the ribs.

In this group women were treated differently to men at autopsy, as only men underwent craniotomy; autopsy and embalming were carried out also for the illegitimate members of the family and for subadults, as demonstrated by the two children showing evidences of vegetal substances in the thoracic cavity used for embalming.

With regard to the reasons for the autopsies, during the Renaissance and the Early Modern Age opening of a corpse performed privately and on request of high social status families was practised for medico-legal purposes. Furthermore, autopsy was carried out to allow embalming of the bodies, which was a diffused custom typical of the elite classes, related to the need for complex funerary ceremonies of the ruling dynasties and to the necessity to legitimize power.

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## Legend to the figures

Figure 1 Skull of Cosimo I showing craniotomy: lateral view (a); frontal view (b)

Figure 2 Sternum of Francesco I (a) and Giovanna (b) with vertical cuts (black arrows); frontal (c) and lateral view of the skull of don Filippino showing craniotomy (d)

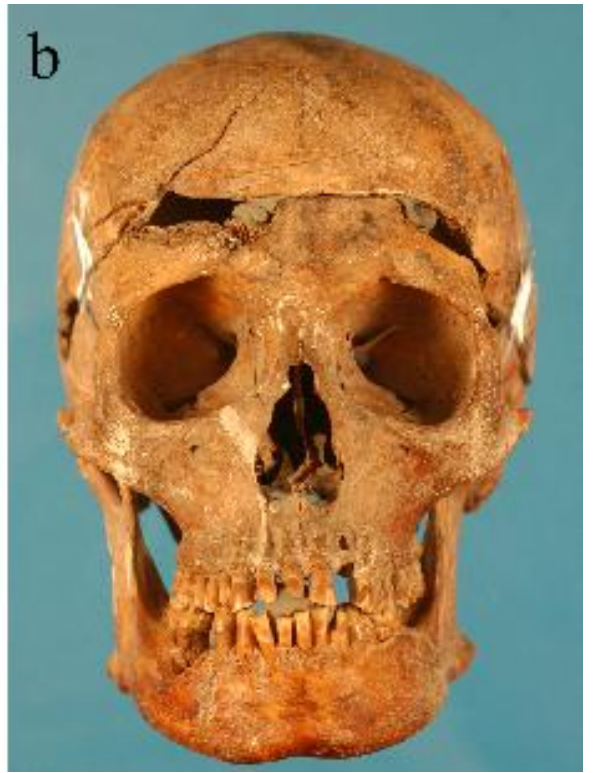
Figure 3 Skull of Ferdinando I showing craniotomy: frontal view (a); lateral view (b); sternum of Cristina with two vertical cuts (black arrows) (c); lateral view of the skull of Prince Francesco with oblique craniotomy (d)

Figure 4 Cardinal Carlo: sternum with horizontal cuts (a); section of the distal end of the ribs **in detail** (b)

Figure 5 Thoracic cast of Filippo (Med 40.2): anterior view with the mould of the lungs (black arrows), the mediastinum (white arrow) and the xipho-pubic and umbilical-transverse incisions (grey arrows) for evisceration (a); posterior view with the mould of the vertebral column (b)

Figure 6 Anton Francesco Maria: frontal (a) and lateral (b) view of the skull showing craniotomy; section on the distal end of the ribs (c); skull of Gian Francesco Maria showing craniotomy: lateral view (d); frontal view (e);

Figure 7 Skull of Giangastone still *in situ*: the craniotomy under the crown is visible (a); skull of the newborn (Med 40.34) with endocranial cast (black arrow) (b)

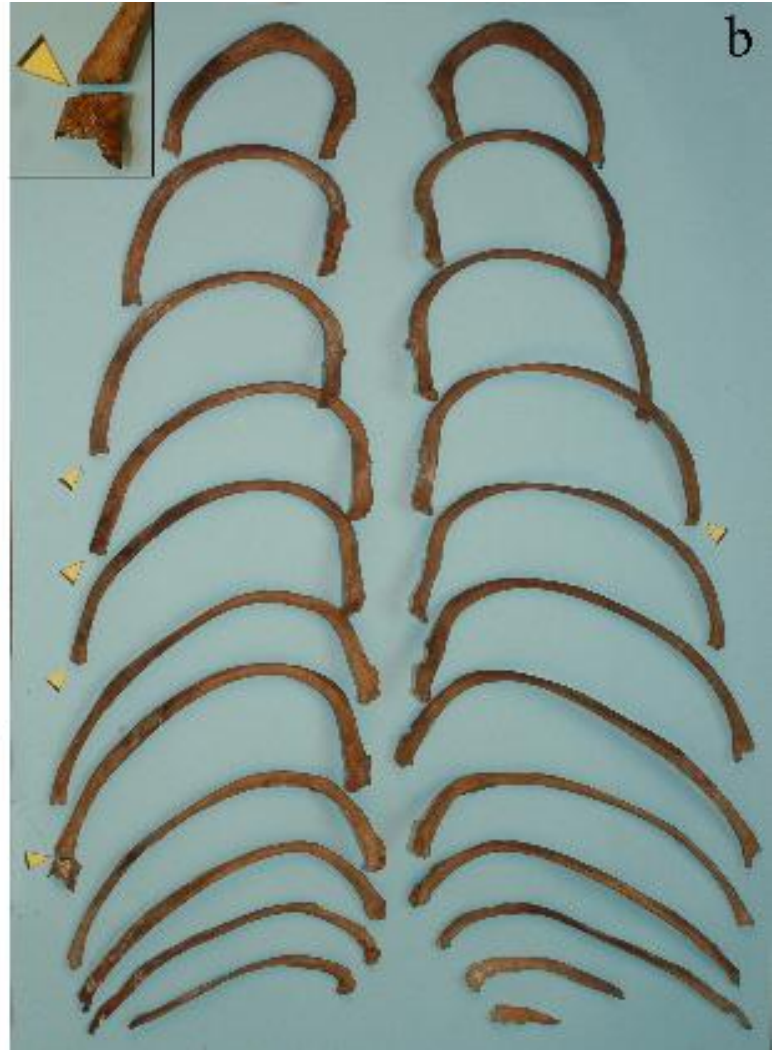








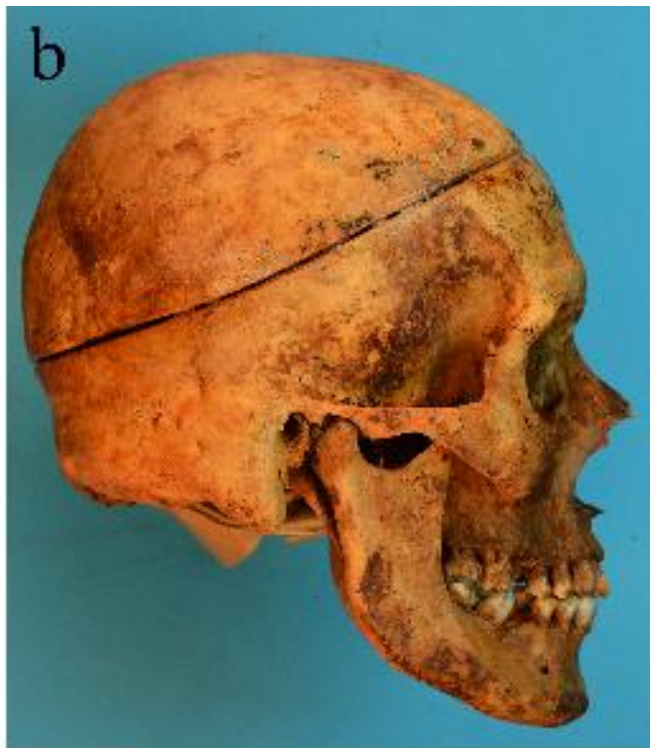
















Name	Date	Sex	age at death	Title	Autopsy (archive)	Craniotomy	Thoracotomy
Giovanni dalle Bande Nere	1498-1526	M	28	-	-	-	-
Maria Salviati	1499-1543	F	44	-	+	-	-
Cosimo I	1519-1574	M	55	Grand Duke	+	+	-
Eleonora of Toledo	1522-1562	F	40	Grand Duchess	+	-	-
Garcia	1547-1562	M	15	Prince	-	-	-
Giovanni	1543-1562	M	19	Cardinal	+	-	-
Francesco I	1541-1587	M	46	Grand Duke	+	-	+
Giovanna from Austria	1548-1578	F	30	Grand Duchess	+	-	+
Anna	1569-1584	F	15	Princess	-	-	-
Anonymous child (Med9)	?	?	6-12 months	?	-	-	-
Don Filippino Med40.39	1577-1582	M	15	Prince	+	+	-
Ferdinando I	1549-1609	M	60	Grand Duke	+	+	-
Cristina from Lorraine	1565-1636	F	71	Grand Duchess	+	-	+
Francesco	1594-1614	M	20	Prince	+	+	+
Carlo	1595-1666	M	71	Cardinal	+	-	+
Filippo (Med40.2)	1598-1602	M	4	Prince	+	-	+
Anton Francesco Maria	1618-1659	M	41	Illegitimate	-	+	+
Gian Francesco Maria	1619-1689	M	70	Illegitimate	-	+	?
Giangastone	1671-1737	M	66	Grand Duke	+	+	?
Anonymous child (Med40.34)	?	?	newborn	?	-	+	+
Anna (Med 40.22/42)	1552-1553	F	1	Princess	-	-	-
Anonymous child (Med40.29+31)	?	?	6-12 months	?	-	-	-
Lucrezia (Med40.40)	1572-1574	F	22 months	Princess	-	-	-
Anonymous child (Med40.45)	?	?	newborn	?	-	-	-
Anonymous child (Med40.48)	?	?	6-12 months	?	-	-	-
					<b>13/25 (52%)</b>	<b>8/25 (32%)</b>	<b>8/25 (32%)</b>

Table 1 Summary of autoptic records, craniotomies and thoracotomies in the Medici family