The embalmed heart of Richard the Lionheart (1199 A.D.): a biological and anthropological analysis

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During the Middle Ages, the partition of the cadaver of the elite members was a current practice, with highly technical treatment given to symbolic organs such as the heart. Considered mostly from a theoretical point of view, this notion of dilaceratio corporis has never been biologically explored. To assess the exact kind of embalming reserved to the heart, we performed a full biomedical analysis of the mummified heart of the English King Richard I (1199 A.D.). Here we show among other aspects, that the organ has been embalmed using substances inspired by Biblical texts and practical necessities of desiccation. We found that the heart was deposed in linen, associated with myrtle, daisy, mint, frankincense, creosote, mercury and, possibly, lime. Furthermore, the goal of using such preservation materials was to allow long-term conservation of the tissues, and good-smelling similar to the one of the Christ (comparable to the odor of sanctity).

Richard I, King of England (nicknamed “Richard the Lionheart” because of his reputation as a courageous warrior and military leader) has been a central Christian commander during the 3rd Crusade after the departure of Philippe-Auguste, King of France, fighting against his Muslim counterpart, Saladin (1189–1192). He died in Châlus (close to Limoges, in the Centre of France) on the 6th of April 1199, 12 days after a wound he suffered at the left shoulder close to the cervical vertebra from a French arbalest while fighting without any chain mail1. Cause of death was reasonably gangrene and/or septicaemia, even if some fantasized about a poisoning caused by toxics deposed on the arable’s arrow2.

According to the common medieval practices, a partition of the cadaver was performed, the internal abdominal and thoracic organs (entrails) were placed within a coffin in Châlus, the heart was embalmed separately and deposed in the church of Notre-Dame in Rouen (head of the English occupation of Normandy territories at that period), and the rest of the body was inhumed at Fontevraud Abbey, close to his father the King Henri II (and later to his mother Eleanor of Aquitaine)1. The partition of the body was widespread among the aristocracy that time3; indeed, 16 years before his death, his brother Henri au court mantel had received a double grave: entrails, eyes and brain were deposed in Grandmont, while the rest of the embalmed body was inhumed in the church of Notre-Dame in Rouen1.

An intact 12.2 × 23 × 17 cm lead box containing the remains of Richard’s heart – a brown-whitish powder – was discovered on the 31st of July 1838 by the local historian Achille Deville close to the funeral effigy of Richard I during excavations of the Rouen cathedral1. The sealed box was engraved with a funerary inscription (HIC IACET COR RICARDI REGIS ANGLORUM, i.e. “Here is the heart of Richard, King of England”) whose characters were typical of the 12th–13th century AD. (Fig. 1a)1.

In order to better know the context of the death and post-mortem treatment of the organ, we submitted samples of the embalmed heart to a complete biomedical analysis (chemistry, palinology, anthropology, paleopathology,
microscopy, etc.). Following the will of cultural authorities, for whom the authenticity of the remains was everything but dubious, no genetic analysis was carried out. 14C dating was not performed for the following reason: the presence of balm, oil and organic embalming residues may have been at the origin of a huge contamination of the sample and aberrant carbon dating result despite successive solvent extractions, impossible on such a tiny quantity of material.

**Results**

Preliminary examination under binocular lenses showed the presence of tiny remains of textiles made of linen (a thin equilibrated cloth of 50 threads per centimetre in both directions: chain and weft). Simple threads with a moderate Z torsion (Fig. 2a) were compatible with a 12th–13th c. A.D. and European origin.

The optical analysis of the brown-whitish powder showed the presence of numerous vegetal structures, altered cell structures, mineral and crystal formations. No clearly identifiable tissue was visible (heart tissue, e.g. muscle fibres, for example), but the human muscle nature of the altered cell structures was confirmed by a slight to moderate positive signal using antibodies anti-myoglobin (human, MG1) and anti-myosin (human, MY32).

The optical and scanning electron microscopic analysis showed the presence of various pollen grains (Table 1): myrtle, daisy, mint (Fig. 2b), pine, oak, poplar, plantain, bell-flower. Numerous isolated bacteria (Bacillus sp.) and fungi (Aspergillus sp.) were observed, but of post-mortem origin (Fig. 2c and 2d), therefore not related to the cause nor to the manner of death of Richard I. No one parasite was identifiable.

Elemental analyses revealed large amounts of lead and tin, and traces of copper, mercury, and antimony (Table 2)\textsuperscript{11}. Calcium may have been added during the embalming process, as the very slight amount of associated aluminium would eliminate an environmental origin (i.e. a soil contamination)\textsuperscript{11}: indeed, lime (calcium oxide or hydroxide) is known as disinfectant and desiccant\textsuperscript{12}, and such properties justify its use during an embalming, in association with other products, including plants.

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**Figure 1** | The heart box of Richard I (photo credit: Musée départemental des Antiquités © Yohann Deslandes/CG76) (A). Actual aspect of the crystal box containing the remains of the mummified heart of Richard I (picture by Philippe Charlier) (B).

**Figure 2** | Detail of the textile fragments and whitish organic powder under binocular lenses (picture by Joël Poupon) (A). Surface view and optical section of a pollen of Mentha sp. Lamiaceae under optical microscope (magnification x1000) (picture by Speranta-Maria Popescu) (B). Detail of a group of bacteria (Bacillus sp.) within the embalming matter of the mummified heart (SEM, magnification x4840) (picture by Raphael Weil) (C). General view of the post-mortem development of fungi (Aspergillus sp.) within the embalming matter of the mummified heart (SEM, magnification x50) (picture by Raphael Weil) (D).
of chemical products obtained by the distillation of a tar that remains characteristic of wood-tar product, creosote type. Creosote is the portion dimethoxy phenol derivatives). This family of substances is char-
mainly guaiacol, 4-ethyl guaiacol, 4-vinyl guaiacol, cresol and 2,6-
detected, associated with several phenolic derivative compounds
urated oleic acid have also been found; these compounds are present with even number of carbon atoms from C16 to C24 and the unsat-
identify triterpenoid compounds with ursane and oleanane type

Burseraceae
natural gum-resins from the
boswellic acids were identified. These molecules are characteristic of
From these compounds
penoid compounds with ursane and oleanane type structure (Fig. 4).

Discussion
The elemental analyses of the white powder found a huge quantity of lead15 from the Middle Ages16. Iron may also be attributed to iron hardware of the reliquary. On the contrary, mercury is attested in embalming both in literature and in Medieval and Renaissance mumification practices; for example, Guglielmo di Salico in his Chirurgia (1275 ca) and the French surgeons Henri de Mondeville (La chirurgie, 1306–1320) and Guy de Chauliac (La grande chirurgie, 1363) refer to the use of “quicksilver” in the post-mortem treatment of bodies; more, mercury was found in the burial of Jean de Lancaestre, duke of Bedford (died 1435) in the Rouen cathedral17, and in the burials of the French Queen Anne de Bretagne (died 1514) and the French King Charles VII (died 1461) in the St Denis basilica18. In 1866, at the first opening of the grave of the Duke of Bedford, metallic mercury was found in great quantity (11.25% of the mass, i.e. 112,500 \(\mu g\)). Non-metallic mercury was not determined. Fifty-two years later, a new and more complete analysis performed by Le Roy showed that total mercury represented 8.03% (80,300 \(\mu g\)) of the solid mass, and metallic mercury only 4.08% (40,800 \(\mu g\)), the rest (3.85% or 38,500 \(\mu g\)) being in a combined form17. Then, more than fifty years after, 36% of the metallic mercury had disappeared. After several experiments, Le Roy concluded that mercury must have been employed as an emulsion of metallic mercury in a balsamic-like substance17. The amount of mercury found in Richard’s heart (150 \(\mu g\)), even if considerably less than the levels observed in the rest of the Duke of Bedford, may indicate the use of another mercury compound such as mercury chloride (calomel); it cannot be considered in any case as originating from lead impurities, as it is never retrieved in ancient lead17.

Pollen grains recorded in the heart powder may originate from embalming products and/or airborne contamination. The interpretation of such results needs a comparison with Medieval and

| Identified taxa (family, genus and species when possible) | Number of pollen grains | State of preservation of pollen grains | Period of pollination of referred plants | Present-day geographic distribution of referred plants |
|----------------------------------------------------------|-------------------------|---------------------------------------|----------------------------------------|-----------------------------------------------------|
| Pinus, Pinaceae                                           | 4                       | Poor                                  | May-June                               | Pinus silvestris (Scots pine), only one specie spontaneous in the north-western Massif Central |
| Quercus ilex (holm oak), Fagaceae                        | 1                       | Moderate                              | April-May                               | Common in the Mediterranean region, but also distributed in Western France up to Brittany |
| Plantago (plantain), Plantaginaceae                       | 1                       | Moderate                              | > April                                 | Plantago species widely distributed in Western France |
| Campanulaceae                                            | 1                       | Good                                  | > April                                 | Several genera (Campanula i.e. bellflower, Jasione, Phyteuma, etc.) widely distributed in France |
| Myrtus communis (myrtle), Myrtaceae                       | 3                       | Good                                  | May-July                                | Sweet-smelling plant endemic of the Mediterranean region |
| Asteraceae Asteroidae (chrysanthemums, maybe the species Leucanthemum vulgare (daisy) according to the small size of the pollen grains (< 20 \(\mu m\)) | 2                       | Good                                  | May-August                              | Widely distributed in France |
| Lamiaceae (Mentha (mint), according to the ornamentation of exine) | 1                       | Good                                  | July-October                            | Mentha (mint) displays several species living in Western France such as M. silvestris (sweet-smelling plant; blooming July-September), M. viridis (August-October), M. aquatica (July-September), M. arvensis (strong-smelling plant: July-October), and M. Pulegium (strong-smelling plant: July-October) |
| Populus (poplar), Salicaceae                              | 1                       | Good                                  | March-April                             | Three species of Populus (P. alba, P. tremula, P. nigra) widely distributed in France |

Table 2 | Results of elemental analyses on the white powder from the heart of Richard I

| Weight (mg) | Pb (\(\mu g\)/g) | Sn (\(\mu g\)/g) | Sb (\(\mu g\)/g) | Cu (\(\mu g\)/g) | Bi (\(\mu g\)/g) | Hg (\(\mu g\)/g) | Fe (\(\mu g\)/g) | Ca (\(\mu g\)/g) | Al (\(\mu g\)/g) |
|-------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 0.75        | 183,148        | 4,280          | 22             | 102            | 13             | 150            | 3,580          | 59,420         | 700            |
Renaissance literature about plants and vegetable substances used during the embalming process, but also with the period and localization of the preparation of the cadaver of King Richard I. Some pollen grains must undoubtedly be considered as originating from embalming products (myrtle, daisy, mint), whose pollination occurs long before/after Spring; they also may have been stored before their use during the embalming process (that occurred short after the 6th of April 1199). It is noteworthy that their state of preservation is better than the other recorded pollen grains (Table 1): pine, Holm oak, plantain. That may indicate some transport by air and the resulting oxidation. They are hence considered as contaminated external material, excluding their use during the embalming process, as pine resin is also a substance attested in embalming, for example in the treatise *La practica in arte chirurgica copiosa* by Giovanni da Vigo (1450–1525). Two other pollen grains, even if we consider them as external contaminations, are well preserved: poplar (characterised by a fragile pollen) and bellflower. Poplar and bellflower were blooming at the time of the death and embalming of the King. Accordingly, we interpret their presence in a so good preservation state in relation with the short time-interval between their pollination and contamination of the heart contain, and probably their nearby distribution (*i.e.* short transport and weak risk of oxidation).

Molecular analyses showed the presence of frankincense (corresponding to the white matter) and wood tar product, creosote type (corresponding to the dark one). Frankincense was a non-negligible part of all embalming process during medieval times, as this symbolic substance appeared at both extremities of the Christ life: presented by the Biblical Magi at His birth, and used during His external embalming after the Passion.

The goal of using such materials was to allow long-term conservation of the tissues, and good-smelling close to the one of Christ (comparable to the odour of sanctity). Comparable examples from

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**Figure 3** | Chromatogram from the direct desorption of the white matter sample (A) and dark matter sample (B) from the heart's fragment of King Richard the Lionheart.

**Figure 4** | Oleanane type structure (alpha-boswellic acid) and its mass-spectra.
later periods (13th to 19th c.) have been described, particularly in Italy: Cangrande della Scala (1291–1329)3–12,15, members of the Medici family in Florence13, the Aragonese mummmies in San Domenico Maggiore, Naples14–15, the Blessed Christine of Spoleto (1432–1458)16, Salimbene Capacci (1433–1497) and his wife Margherita Sozzini (died in 1511)17, late Medieval and Renaissance Saints18, etc. Comparable substances and plants known as filling materials of these mummmies have been described (mint, rose powder, myrtle, etc.), but the case of Richard I may represent the oldest physical example of their use during an embalming process. Daisy and incense (oliban) have not yet been described in other cases of mummmified corpse or anatomical fragment.

In addition, it is important to mention that even if the heart was completely pulverized at the time of our examination (and of its discovery in the 19th c.), it does not mean that the embalming was not successful, just that the equilibrium was lost between the mummmified organ and its direct environment due to the alteration of the metal box and water infiltrations from the ground.

The use of such conservation products above-mentioned, reveals the influence of cooking and pharmacy for the embalming of viscera, and particularly the heart. Indeed, the first embalmers (12th c. AD) were cooks, i.e. those who were used to open the meat and cut the offal, but also had access to herbs, spices and other odoriferous substances29. Then it was the turn of apothecaries and afterwards, chemists30, using plants, sometimes exotic and disinfectant solutions proved to be efficient for the medium and long-term conservation of human cadavers after their opening by surgeons and barbers9.

This embalming process in the case of King Richard was, first of all, necessary for practical reasons: the organs were treated because the King's body had to reach the definitive burial (Rouen) which was far from the death place (Châlus): almost 530 kilometres. Other reasons, political this time, could have motivated this partition of the body, such as the appropriation of a territory using physical parts of the King30–32. In the case of the controversial life of Richard I, it is equally possible that the post-mortem treatment of the organs (and particularly the heart), inspired by biblical spices, was necessary in order to accelerate his religious apotheosis. Indeed, as stated by a 13th century bishop of Rochester14,15, Richard the Lionheart spent 33 years in Purgatory as expiation for his sins, and ascended to Heaven only in March 1323.

With embalming, symbolically, the deceased is identified as the Christ whose body was scented with spices by Joseph of Arimathea before being placed in his tomb. This study conducted on the mummmified heart of Richard the Lionheart (died 1199) made it possible to ascertain that the organ has been filled or covered with a mix of vegetal and mineral material. Since the studied organ was entirely turned into powder, we ignore if an opening of the heart occurred prior to any embalming, and the exact aspect of the embalming material (liquid and/or salts).

This embalming method is of great importance, as we do not have any procedure or surgical treatise known for this period (end of the 12th c. AD) describing the methodology and/or composition of the embalming material.

Methods

We sampled this highly fragmented mummmified heart in 2012 (a total of 2 grams from an amount of almost 80 grams, now conserved in a crystal box: Fig. 1b). A preliminary macroscopic examination completed with binocular lenses (magnification ×20 and ×40) was carried out. Further analyses were then performed.

An optical microscope analysis of six samples from the white and black powders was carried out as follows: after a short rehydration and decalcification of 30 minutes in a solution of 10% NaCl diluted in pure water plus 100 mL of 100% acetic acid, 200 mL from the supernatant were sampled. This liquid was then centrifuged (1000 turns per minute for 10 minutes) in order to obtain one spot per slide (Superfrost). A total of four slides were obtained, two coloured by the technique of Hematein-Eosin-Saffran (HES), two for further cyto-chemistry analysis (respectively Biogenex® antibodies anti-myosin (human) MG1 and anti-myoglobin (human) MY32): antigen retrieval was performed according to the laboratory recommendations for primary antibodies, then slides were washed in de-ionised water, neutralized of endogenous peroxidase using peroxide block for 5 minutes, washed in TBS for 2 × 5 minutes, incubated with protein block for 5 minutes, washed in TBS for 2 × 5 minutes, incubated with optimally diluted primary antibodies according to the laboratory recommendations, washed in TBS for 2 × 5 minutes, incubated with post-primary block for 30 minutes, washed in TBS for 2 × 5 minutes, incubated with Novolink® polymer for 30 minutes, washed in TBS for 2 × 5 minutes with gentle rocking. The developed peroxidase activity with DAB working solution, dehydrated, washed in water, counterstained with hematein, washed in water for 5 minutes, dehydrated, cleared and mounted.

A palynological analysis was performed on only one available sample made of 0.5 gram of the white powder prepared as follows: attack by KOH 5% without heating in order to destroy vegetal tissues without affecting pollen grains. After centrifugation and rinsing, the final dried residue has been diluted within glycerol providing a total volume of 100 μL, being separated into two parts of 50 μL each put between slides and cover glasses. The two slides have been completely examined at optical microscope (x250) and provided a total of 14 pollen grains only (Table 1). Each pollen grain was observed at magnifications >1000 for the detailed examination of its morphology and its identification. Identification of pollen grains mainly refers to the personal bank of modern pollen grains (pollen slides and photographs) of one of us (S.M.P.) and to the Reille’s Atlases2–6. Information on plant systematic, distribution and flowering refers to the Coste’s Flora27.

A scanning electron microscopy analysis was performed on two samples from the white powder, for both of them, morphology observations and chemical analyses were made (Zeiss® Supra 55 vp with an energy-dispersive X-ray spectrometer Bruker® SDD detector). The field-effect “gun” microscope (FE-SEM) operates at 0.5–30 kV. High-resolution observations were obtained by 2 secondary electron detectors and a software program in order to analyze the surface structure of the samples. The electron images were obtained with a Hitachi TM3000 scanning electron microscope coupled to an Oxford X-Max detection system and a SuperCam® EDS detector.

A peculiar analysis was performed on one sample from the white powder. SPME (Solid Phase MicroExtraction) has been used to trap organic volatile compounds from the samples and gas chromatography/mass spectrometry (GC/MS) analysis has been carried out in order to identify them. Samples have also been directly placed in a glass liner into the injector of the chromatograph and organic components have been directly desorbed at 300 °C during five minutes (detail of equipment: GC/MS Agilent 6890 fitted with the Mass spectrometer 5973 mounted with an adapted purge and trap technique; Gerstel® Combipal with the CIS4 injector).

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