

Differentiating between rhinosinusitis and mastoiditis surgery from postmortem medical training: a study of two identified skulls and hospital records from early 20th century Coimbra, Portugal

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Abstract

Differentiating between medical procedures performed antemortem, perimortem or postmortem in skeletal remains can be a major challenge. This work aims to present evidence of procedures to treat rhinosinusitis (RS) and mastoiditis, suggest criteria for the diagnosis of frontal sinus disease, and frame the individuals described in their medical historical context. In the International Exchange collection, the skull (878) of a 24-year-old male, who died in 1933 due to frontal sinusitis and meningitis, presents evidence of a trepanation above the right frontonasal suture, and micro/macroporosity on the superciliary arches. The available Coimbra University Hospitals archives (1913–1939) reported that 46 females and 59 males (aged 15 months–84 y.o., $x = 35.33$) underwent surgery to treat RS, primarily by trepanation (94.3%). In a search for similar evidence in the collection, the skull of a 42-year-old female (85), who died in 1927 due to sarcoma in the abdomen, shows four quadrangular holes located above the right supraorbital notch, right and left maxilla, and left mastoid process. The number/location of the holes and cut marks point to postmortem medical training (possible dissection). This paper discusses the value of information from historical contexts to differentiate between surgery and medical training in the paleopathological record.

Keywords: Trepanation; perimortem; dissection; autopsy; porosity; paleopathology

Introduction

Rhinosinusitis (RS) is a group of diseases defined by inflammation of the mucosa of the nose and paranasal sinuses and, depending on the duration of the symptoms, can be defined as acute (<12 weeks) or chronic (≥ 12 weeks) (Fokkens et al., 2012; Jackman and Kennedy, 2006; Magrysi' et al., 2011). Currently, RS is one of the diseases that most commonly affects the respiratory tract (Roberts, 2007; Slavin et al., 2005), and the action of viruses, bacteria and fungi play an important role in its etiology, with exposures to poor air quality in the environment, ciliary impairment, and allergy being the most common factors associated with RS (Dykewicz and Hamilos, 2010; Fokkens et al., 2012; Magrysi' et al., 2011). Nevertheless, its true prevalence is unclear, since not all individuals seek care, and because there is a deficit of epidemiological studies exploring its prevalence (File, 2006; Fokkens et al., 2012). RS symptoms can be disabling and

lead to significant impairment of quality of life. Major signs and symptoms associated with the diagnosis of chronic RS are facial congestion, pressure and pain, reduction or loss in sense of smell, nasal polyps, nasal obstruction and discharge, and mucosal changes within the osteomeatal complex and/or sinuses (e.g. Caroline et al., 2011; Clement, 2006; Fokkens et al., 2012; Schalek, 2011). RS may include several complications, such as mucocoele formation, orbital cellulitis and abscess, meningitis, intracranial abscess, thrombophlebitis and cavernous sinus thrombosis or perivascular spread of infection (e.g. Madani and Beale, 2009).

Studies in past populations have demonstrated the existence of sinonasal maxillary bone changes with quite diverse frequencies (4%–73.7%) (e.g. Panhuysen et al., 1997; Roberts, 2007). Panhuysen et al. (1997) studied three medieval groups of skeletons from the Netherlands and found no significant differences in maxillary RS between rural and urban populations. Roberts (2007) compared data from three continents and found, with few exceptions, a lower susceptibility to maxillary RS in hunter-gatherers, people who lived in a rural environment, or who had a high status. To the authors' knowledge, trepanation of the maxillary sinuses is unknown amongst the evidence of surgical treatment in bioarchaeological contexts, while few surgical procedures are reported on frontal antra (Table 1).

Table 1: Reports of trepanation to frontal sinuses and mastoid processes in paleopathology (ordered by period of time).

Reference	Location	Chronology	Individuals
<i>Frontal sinuses</i>			
Zias and Pomeranz (1992)	Israel	5500 y.o.	One individual ^a
Armentano et al. (1999)	Spain	Chalcolithic/Bronze age	One young female
Burton (1920)	Peru	1200 to 2000 y.o. (?)	Three individuals ^a
Campillo et al. (1999)	Spain	11th to 16th century AD	One young adult, one undetermined
<i>Mastoid processes</i>			
Boljunčić and Hat (2015)	Croatia	11th century AD	One adult male
Vercelotti et al. (2010)	Italy	Late 19th/20th century	Two individuals ^a
Vercelotti et al. (2010)	USA	20th century	Possibly five individuals ^a

Mastoiditis is a term used for the presence of inflammation of both the mucous membrane in the pneumatized mastoid cells and the underlying bone tissue (Flohr and Schultz, 2009a, 2009b; Palma et al., 2014). It can be defined as acute or chronic, and is a consequence of otitis media, typically caused by the invasion of bacteria through the Eustachian tube into the tympanic cavity (Flohr and Schultz, 2009a, 2009b; Palma et al., 2014). Flohr and Schultz (2009a) identified bone alterations associated with mastoiditis in 83.4% of human skeletal remains from two early medieval German cemeteries, but with the introduction of antibiotic therapy, mastoiditis became a rare consequence of otitis media in the industrialized world, although it is still common in developing countries (e.g. Tarantino et al., 2002; Vassbotn et al., 2002).

Several studies have described osseous changes associated with ear infection in past populations (Flohr and Schultz, 2009a, 2009b; Mann et al., 1994; Mays and Holst, 2006), essentially, distinct plate- like osseous proliferations attached to the walls of the pneumatized cells of the inner part of the mastoid process; pin-like or spicular structures; and complete filling in of the pneumatized cells with bone, or fine net-like bone formation (Flohr and Schultz, 2009a, 2009b). Upper respiratory tract infections are known to play a role as a causative/complicating

factor of otitis media in clinical literature, and the risk for otitis media may be reduced when exposure to viral respiratory infections is avoided (e.g. Chonmaitree et al., 2008; Nokso-Koivisto et al., 2015; Revai et al., 2007). Unfortunately, this possible relationship is unknown in past populations, due to the lack of studies. Knowledge of surgery to relieve mastoid process infection in the past is also rare. Despite documentation of mastoidectomies in clinical studies since the 16th century (Bento and Fonseca, 2013), only a few examples have been described in paleopathological literature (Table 1). The reasons why this is a reality are not very clear but the need for specific anatomical and surgical knowledge in the past, poor preservation of the frontal and maxillary bones and mastoid processes in archaeological contexts, or the lack of interest of anthropologists to investigate these particular cases in identified samples may be pointed out as possibilities.

Distinguishing among medical procedures performed ante-mortem, perimortem, or postmortem using dry bones can be very difficult, and this is frequently highlighted in forensic pathological studies on trauma (Cappella et al., 2014; Fleming-Farrell et al., 2013; SWGANATH, 2011; Ubelaker, 2015; Wheatley, 2008). In fact, in the last few years the 'perimortem concept' has been discussed within the anthropological sciences as determined on the basis of evidence of the biomechanical characteristics of the plastic response of fresh or green bone or through the detection of specific mechanisms causing injuries (blunt or sharp force), not taking into account the death event itself (SWGANATH, 2011; Ubelaker, 2015). Although evidence of surgery is well documented in paleopathological studies (e.g. Carty, 2013; Powers, 2005; Santos and Suby, 2015), it can be difficult to accurately diagnose when performed close to the death of a patient (e.g. Dittmar and Mitchell, 2015;

Santos and Suby, 2015) before bone start remodeling, and thus may be confused with postmortem medical examinations such as autopsy, dissection, and prosection. To distinguish between these procedures can also be challenging, because all of them take place after the death of the individual. Autopsy refers to an examination whose purpose is to determine the cause of death, while the primary aim of dissection is to facilitate the anatomical study of the human body by students (Bugaj et al., 2013; Nystrom, 2011). Dissection is distinguished from prosection, the latter of which being performed by an experienced anatomist while the student learns by observing (Yeager, 1996). Postmortem medical examinations have been reported mostly in Europe (e.g. Boston and Webb, 2012; Bugaj et al., 2013; Dittmar and Mitchell, 2015; Fornaciari et al., 2008) and in the United States (e.g. Nystrom, 2011).

This research aims to present evidence of medical procedures during the first half of the 20th century in Coimbra (Portugal), suggest lesions that can identify possible frontal sinus disease, and frame the individuals studied within their medical historical context.

Material and methods

The individuals studied belong to the International Exchange Skull collection curated by the University of Coimbra. This osteological collection is composed of 1142 well preserved skulls, representing 578 females and 564 males, with ages at death ranging from 6 to 109 years old ($x = 46.22$). All died in Coimbra between 1904 and 1937, were buried at the Municipal Cemetery

of Conchada, and have documented identifications (sex, age at death, birthplace, occupation, address, and cause of death) (Lopes, 2014; Rocha, 1995; Santos, 2000).

The applied methodology included several steps. Firstly, signs of medical procedures on the frontal and maxillary bones and the mastoid processes were macroscopically explored, and evidence of trepanation and cut marks caused by surgical instruments was recorded. The dimensions of all cut marks were measured with the use of a sliding caliper. Evidence for the four types of bone response (osteoblastic, osteoclastic, line of demarcation, and sequestration) described by Barbian and Sledzik (2008) for cranial trauma was also macroscopically explored, with the assumption that the bone response would be similar for both antemortem medical procedures and trauma. In addition, considerations outlined by SWGANTH (2011) and Ubelaker (2015) for perimortem identification were taken into account. Finally, the method developed by Dittmar and Mitchell (2015) was considered for better distinguishing human dissection and autopsy. The skulls were observed using strong illumination with a magnifying glass, allowing a more accurate differential diagnosis to be made among antemortem, perimortem and postmortem medical procedures.

A videoscope (Cartull Professional, external diameter of 4.9 mm) was used to look for inflammation within the maxillary and frontal sinuses. Inflammation on the maxillary sinuses was scored using the criteria of Sundman and Kjellström (2013); the extent and severity of the bone changes within the maxillary sinuses were scored as follows: type 0 (no alterations), type 1 (isolated alteration), type 2 (alterations isolated to half of the sinus), and type 3 (more than half of the sinus has alterations). Additionally, when different bony alterations (scored as 'pitting', 'spicules', 'remodeled spicules', 'white pitted bone' and 'other') were observed in the same sinus they were also scored according to their extent and severity from type 1 to type 3. Evidence for fistulae connecting the dental alveoli to the maxillary sinus was carefully considered as the possible cause of dental induced RS.

The reports from the Coimbra University Hospitals were searched to check if the individuals under analysis had undergone surgery, and to evaluate the statistics of RS and mastoiditis surgeries published for the period between 1913 and 1939 (Hospitais da Universidade de Coimbra, 1931, 1934, 1935, 1936, 1938, 1939, 1941). All data collected was analyzed with Microsoft Excel 2010 and IBM SPSS Statistics 21.

Results

Identified skulls observation

Of the 1142 observed skulls of the International Exchange Collection, numbers 878 and 85 present evidence of surgical procedures for rhinosinusitis (RS) and mastoiditis. Individual 878 was a 24-year-old telegraph operator who, according to his obituary records, died due to frontal sinusitis and meningitis on June 30th 1933 at the Military Hospital of Coimbra. He was buried on the day after his death at the Municipal Cemetery of Conchada. His skull shows an irregular rounded hole (10 mm of maximum diameter) superior to the right frontonasal suture, and a curved incision along the inner third of the supraorbital ridge through the eyebrow (from the

right supraorbital notch to the area immediately superior to the nasal bones). The upper left margins of the hole present five concave cuts with sharp beveled edges, while the lower left parts are partially broken postmortem probably due to its fragility while being handled (Fig. 1A). Moreover, micro (<1 mm) and macro- pores (>1 mm) are observable on both superciliary arches (with a maximum extension of ca. 40 mm), and are more intense over the glabella and on the right superciliary arch (Fig. 1B). Macroscopically there is no evidence of new bone formation or osteoclastic resorption on the margins of the lesion or within the right frontal sinus, but bone destruction is observable in the latter, while the left could not be observed. Endoscopic inspection of the endocranium showed that inflammatory response was absent, but its presence was confirmed within both maxillary sinuses, in the form of type 3 spicules and white pitted bone. Oroantral fistulae were absent.

Individual 85 was a 42-year-old woman who received a daily wage for her work, usually in agriculture, who died on September 30th 1927 at the Coimbra University Hospitals (CUH), due to sarcoma in the abdomen. She underwent an exploratory laparotomy, and no other surgical operations or diseases were recorded in her patient file during the 10 days of hospitalization. She was buried 6 days after death at the Municipal Cemetery of Conchada. The skull shows four quadrangular intersecting cuts with sharp edges (Fig. 2A) located in the right superciliary arch/frontal sinus (7 × 5.5 mm) (Fig. 2B), right (5 × 6.5 mm) and left (7 × 8.5 mm) anterior maxillae (Figs. 2C and 2D), and left mastoid process (9 × 7 mm) (Fig. 2E). The holes located in the maxillae are asymmetrical: the right one is located just next to the piriform aperture, the bony inlet of the nose, while the left one is located more posterior and inferiorly, over the canine fossa. The hole on the frontal bone presents small cut marks inferiorly, and on its right side, while the mastoid process presents cut marks above and on the right side of the trepanation; in both maxillae there are no visible cut marks. Both maxillary sinuses show type 3 spicules of new bone, confirming the presence of severe inflammation on both sides. Fistulas between dental alveoli and maxillary sinuses were absent.

Surgeries for RS and mastoiditis at the CUH

In order to historically frame these lesions, the available Coimbra University Hospitals archives were consulted. For a period of 27 years (1913–1939), the Newsletter of the CUH reported 179 patients (aged from 15 months to 73 years, $x^- = 36.16$) who had undergone surgery to treat RS (Fig. 3). Eighty one were females (aged from 15 months to 73 years old, $x^- = 36.95$) and 98 were males (aged from 6 to 84 years old, $x^- = 35.53$); trepanation was reported to be the surgical procedure applied to 91.1% (163/179) of the patients.

One hundred (100/179, 55.9%) patients underwent surgery to maxillary sinus disease, seventy (70/179, 39.1%) to frontal sinuses, six (6/179, 3.4%) to frontal and maxillary sinuses, one (1/179, 0.6%) to maxillary and ethmoidal sinuses, and two (2/179, 1.1%) are unknown. The duration of hospitalization of those patients range from few hours (specific number not specified in the records) to 375 days ($x^- = 41.15$). One hundred and thirty four (134/179, 74.9%) left the CUH listed as cured, thirty-nine (39/179, 21.8%) as improved, three (3/179, 1.7%) died, one (1/179, 0.6%) left the hospital in the same state, and for two (2/179, 1.1%) individuals this information was not reported.

For the same period of time 205 patients underwent mastoidectomy (aged from 4 months to 87 years old, $x = 23.97$), 88 of whom were females (aged from 18 months to 67 years old, $x = 23.43$) and 117 males (aged between 4 months and 87 years old, $x = 24.38$). Patients were hospitalized from a few hours (specific number not specified in the records) to 322 days ($x = 28.32$). One hundred and sixty five (165/205, 80.5%) of the patients were listed as cured, thirty (30/205, 14.6%) as improved, eight (8/205, 3.9%) died, and two (2/205, 1%) left the CUH in the same health at admission.

Discussion

At the beginning of the 20th century the medical treatment for individuals with less severe rhinosinusitis included inhalations of menthol alcohol vapors, catheterization, nasal washes, and aspiration of the purulent material (Rodrigues, 1906). Nevertheless, when these treatments were unsuccessful, surgical drainage was indicated (Rodrigues, 1906), and it was the only reliable relief in an attempt to avoid further complications in the era before antibiotics (Lund, 2002).

Frontal RS was surgically treated at the Coimbra University Hospitals by simple trepanation (or Ogston-Luc surgery), frontoorbital trepanation (Kilian surgery), or orbital trepanation (Jacques surgery) (Bissaia-Barreto, 1922). The 24 years-old man (878) studied in this paper underwent surgery of the right frontal sinus, the second most common location for surgery to RS at the Coimbra University Hospitals between 1913 and 1939 (39.1%), with a survival rate of 97.3% (174/179), while 1.7% (3/179) of the patients died. However, for the individuals who left the hospital classified as 'cured', at least two had the same surgical procedure again, with a time difference between operation of 165 and 1209 days. The male individual (878) died at the Military Hospital and, unfortunately, the patients' records are unavailable, which precludes confirming if he underwent surgery or which technique was used. However, the incision along the inner third of the supraorbital ridge is the corresponding anatomical area for surgical drainage of the frontal sinus, the so-called 'simple trepanation' or 'Ogston-Luc surgery' (Jacobs, 1997; Wright and Smith, 1914). This surgery was described at the end of the 19th by Alexander Ogston and Henri Luc, but its link with a high failure rate due to the frontonasal communication closure, and the small size of the trepanation, which led to poor visualization in larger sinuses, were recognized as shortcomings (Jacobs, 1997; Ramadan, 2005). A concave, sharp edged gouge and a mallet were most probably the instruments used to perforate into the inner right frontal sinus, and the five concave cuts observable in the upper and left margins of the hole are indicative of this action. Furthermore, the presence of extreme bony alterations in the form of spicules and white pitted bone within both maxillary sinuses may be indicative of the presence of a wider inflammatory process on this individual. Although the few published paleopathological studies on frontal RS point out that its diagnosis is based on the evidence of porosity and/or bone apposition within the frontal sinuses (e.g. Liebe-Harkort, 2012), the presence of asymmetrical micro and macro porosity on the outer cortical surface of the sinuses and bone destruction within those anatomical structures may be references for scoring the possible presence of frontal RS in paleopathology. Although porosity can normally be present on the external surface of both frontal sinuses, asymmetric porotic reaction may suggest the

presence of unilateral sinus disease. The presence of bone destruction within the same frontal sinus seems to confirm the diagnosis, and the absence of new bone formation or osteoclastic resorption on the margins of the lesion may indicate that the individual died at the time of, or within a few days after, the surgery. The three individuals who died after RS surgery at the CUH between 1913 and 1939 were hospitalized one, eleven, and forty- eight days after the procedure, and underwent surgery to the right maxillary sinus, left frontal sinus and left maxillary sinus, respectively. As Nerlich et al. (2005) have shown in autopsies of recently trepanned skulls for medical reasons, the absence of osseous reaction may be found in individuals who died during surgery up until at least ten days post-operatively. Additionally, in a sample of 127 crania, Barbian and Sledzik (2008) stated that the earliest observed osseous response to cranial fracture occurred 5 days later, but the authors stated that, in most of the cases, none of the four types of bone response they considered (osteoblastic, osteoclastic, line of demarcation, and sequestration) are discernible during the first week post-fracture. However, in this study neither plastic response nor differences in coloration of the bone (both characteristic of perimortem force bony alterations) were identified in the area of surgical procedure. Moreover, the differential diagnoses for the cause of these alterations should include Pott's puffy tumor, characterized by osteomyelitis of the frontal bone, which erodes through the wall of the frontal bone leading to subperiosteal abscess (e.g. Jafri and Farooq, 2015).



Fig. 1. a. Individual 878 (24 year old man): trepanation superior to the right frontonasal suture, affecting the outer cortical surface of the right frontal sinus. Note the five concave bevel cuts in the upper and left margins of the hole and no evidence of healing. b. Close-up. Note the extensive asymmetrical micro and macroporosity on both superciliary arches.

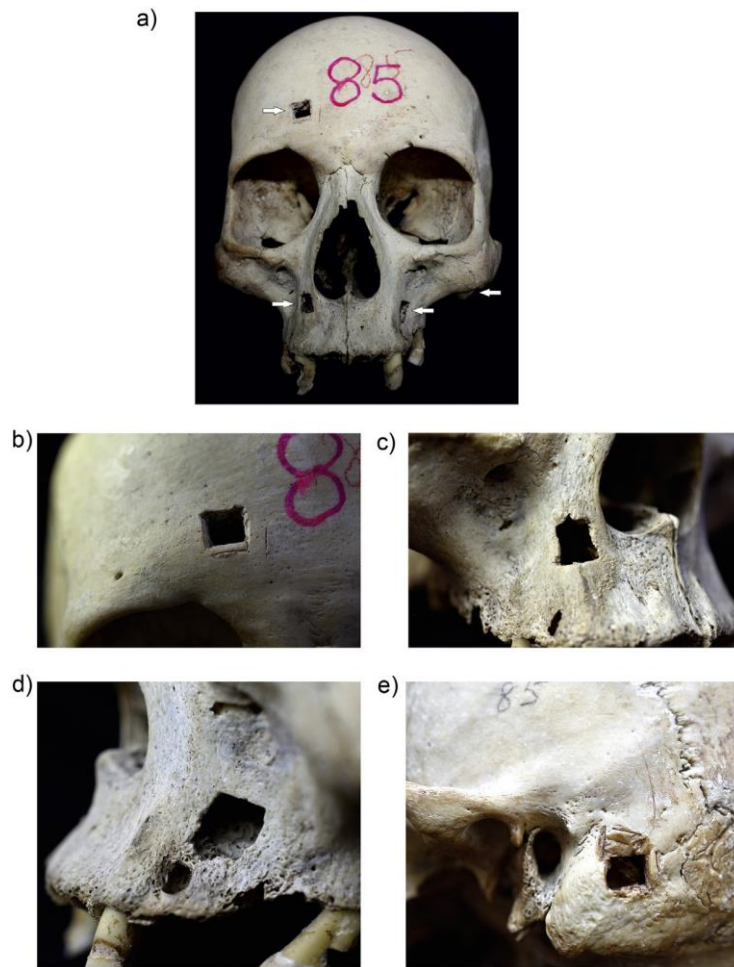


Fig. 2. A. Cranium of the individual 85, a 42-year-old woman, with evidence of four trepanations (arrows). b. Trepanation on the right frontal sinus, with evidence of several cut marks. c. Trepanation on the right anterior maxilla. d. Trepanation on the left anterior maxilla. e. Trepanation on the left mastoid process with several cut marks to remove the scalp.

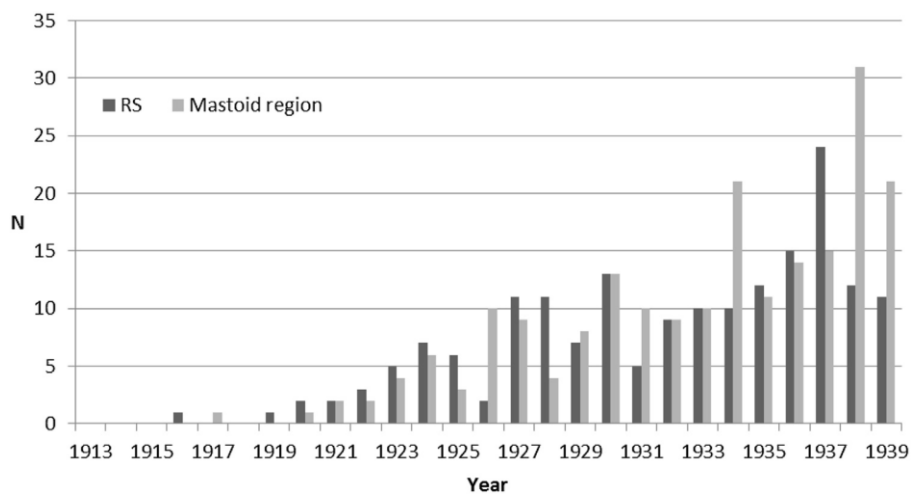


Fig. 3. Rhinosinusitis (RS) and mastoiditis surgeries in the Coimbra University Hospitals between 1913 and 1939.

Regarding the 42 years-old woman (85), data in her file states that two days before her death she had undergone an exploratory laparotomy, which was diagnosed as an 'inoperable abdomen sarcoma with starting point in the right ovary' (Hospitais da Universidade de Coimbra, 1927). No other health problems were reported during the ten days of hospitalization. However, her skull presents four different trepanations, and, in the CUH archives, there is no reference to any patients who underwent surgery to the frontal and maxillary sinuses and the mastoid process at the same time. For each patient surgery is described for RS (confirming the possibility of simultaneous surgery to both frontal and maxillary sinus) or mastoiditis, but never to both conditions. Despite the fact that the skull of this woman shows evidence of RS within both maxillary sinuses, all these anatomical observations seem to reveal a procedure that was clearly not therapeutic in origin, and is more likely to be related to the study of morbid anatomy. The presence of multiple surgical procedures in the same individual seems to reveal evidence of dissection, as noted in other osteological assemblages (e.g. Chamberlain, 2012; Kausmally, 2012). Moreover, this woman was buried six days after her death. In the individuals from the International Exchange collection the number of days between death and burial vary between 0 and 16, with 68% of burials occurring the day after death (Lopes, 2014). According to the abovementioned, it seems highly probable that this individual (85) was dissected or prosected, while the male (878) must have undergone surgery to relieve the infection and to drain the pus from the right frontal sinus.

Although paranasal sinus infection was described by Hippocrates in the 5th century BC, it was only in the 17th century that the British surgeon Nathaniel Highmore described surgical procedures for maxillary RS, recognizing its association with dental pathology, and referring to the relief that alveolar suppuration produced when related to dental infection (Lund, 2002). The anatomist Emile Zuckerkandl described the treatment to maxillary RS by perforating the middle meatus at the end of the 19th century (Lund, 2002). Several other procedures for treatment of maxillary RS have been used since then, and the Caldwell-Luc surgical procedure, performed through the canine fossa in the anterior maxillary wall, was one of the most used approaches at the beginning of the 20th century (Lund, 2002; Nogueira Júnior et al., 2007). It was described by George Walter Caldwell and Henri Luc (Nogueira Júnior et al., 2007), and it is likely that this was the surgical approach that was being taught to students in the dissection of the maxillary sinuses of individual 85, as described by Bissaia-Barreto (1922).

Dittmar and Mitchell (2015) identified knife cuts from defleshing without craniotomy as an indicator of a dissection, once they are inconsistent with the expected tool mark patterns of an autopsy, where the scalp is removed only when a craniotomy is performed. The cut marks of the individual 85 were identified below and on the left side of the trepanation on the right frontal sinus, and above and on the left side of the left mastoid process. In both instances these cuts seem to have been made during the first step of dissection, to cut the scalp to access the frontal bone and the mastoid region.

At the beginning of the 20th century the teaching of medicine in Coimbra was developed at the CUH, which started to work as the hospital of the Faculty of Medicine (Pina, 2010). In this context, the lack of cadavers for anatomical studies was a reality, as in other countries (e.g., introduction of the 1832 British Anatomy Act legally allowed access to cadavers for anatomical teaching [Mitchell, 2012]). The publication of the Ordinance Number 40, on August 22, 1913,

tried to fill that void in the Portuguese law (Pontinha and Soeiro, 2014), stating that “... the bodies of the deceased in hospitals, nursing homes, and care homes are available to the faculties of medicine to their studies, if, within twelve hours after the death, were unclaimed by their families to proceed to its burial” (Ministério da Justic, a, 1999). This was probably the case for this widow (85), who lived around 40 km from Coimbra, and, at the hospital admission, was classified as a 3rd class pensioner, meaning that she did not have to pay for her stay in the CUH (Santos, 1999). The use of cadavers of the poor for dissection was a reality at least in the United States (e.g. Nystrom, 2011) and England (e.g. Mitchell et al., 2011) during the 19th century, and this could have also been the reality at the CUH, after the publication of the Ordinance 40. Nevertheless, dissection was already a common practice in the 1920s at the CUH, with surgeon Bissaia-Barreto (1922) reporting the dissection of about 200 cadavers to test several procedures in the anatomical theater during the winter semester of 1921.

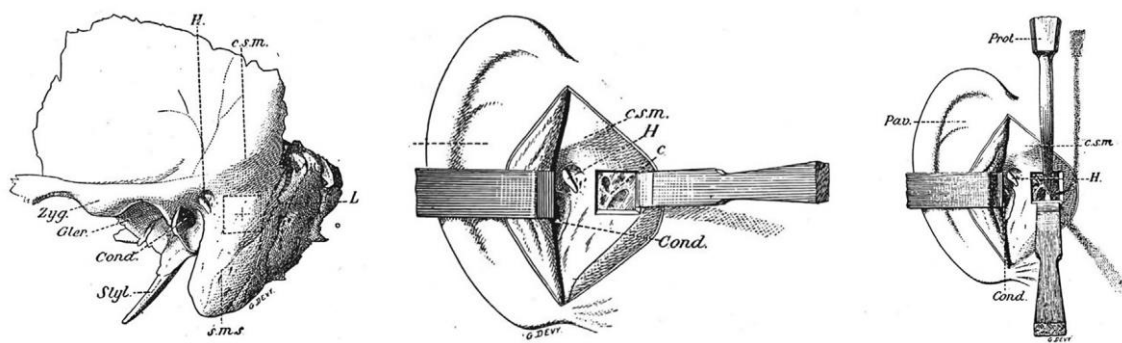


Fig. 4. Indications for mastoidectomy presented by Monod and Vanverts (1902:803-805) at the beginning of the 20th century. The method, technique, and probably the tools are similar to those applied in the dissection of the 42-year-old woman (85).

In addition, antrostomy and mastoidectomy were surgical procedures taught in “Surgery technic and surgical therapeutic” classes in 1922, with precise indications referring to symptoms, surgery and surgical instruments (Bissaia-Barreto, 1922). Jean-Louis Petit is reported to be the first to develop a successful operation on the mastoid process to evacuate pus in 1774, while William Wilde was the first to establish surgical recommendations to the postauricular incision to access this anatomical structure in 1853 (Moberly and Fritsch, 2010; Nogueira Júnior et al., 2007; Sunder et al., 2006). This procedure was improved in 1873 by Hermann Schwartze with the description of the ‘simple mastoidectomy’ (or antrostomy), the first systematic description of the operation (Moberly and Fritsch, 2010; Monod and Vanverts, 1902; Sunder et al., 2006). In this regard, the location and size of the hole in the mastoid process of individual 85 may have been an approach to practicing this type of surgery (Fig. 4). The four quadrangular intersecting cuts seem to have been opened with a chisel, a short-bladed hand tool with a straight, beveled cutting edge and a plain handle which was struck with a mallet. The use of these instruments for mastoidectomies was recommended for the adequate removal of the bone, and for proper inspection and drainage of the antrum without the loss of the existing ear capacity (Monod and Vanverts, 1902; Mudry, 2009; Sunder et al., 2006).

Clinically, higher frequencies of mastoiditis are associated with the first months of life (e.g. Ladomenou et al., 2010; Sakran et al., 2006). At the CUH the mean age of the patients was 23.97 years, with 1.5% under one year old, and 33.7% between 1 and 12 years.

Conclusions

This study presents evidence of surgical procedures evident on the skulls of two individuals dating from the first half of the 20th century. According to the Coimbra University Hospitals (CUH) records, infection in the paranasal sinuses before the use of antibiotics was a serious problem, leading to the treatment of the most severe clinical cases with surgery. Individuals from both sexes and all ages were affected by RS and mastoiditis, with the onset of the mastoid process infection at a younger age than in RS. Patients were hospitalized for long periods even after successful surgery. These long term diseases may leave bone lesions visible in dry bones, such as in individual 878. His skull presents asymmetrical micro and macroporosity in the superciliary arches and bone destruction within the right frontal sinus. These lesions could be useful for future detection of sinus inflammation via paleopathological analysis. This young male, who most probably underwent surgery a few days before death, did not show any signs of bone remodeling of the outer edges of the trepanation.

The current study has shown that the number of surgical procedures increased as the techniques became more efficient. As stated in the CUH records, between 1913 and 1939 successful surgeries for RS were estimated at 81% and for mastoiditis in 73%. These surgical procedures were taught at the CUH, once cadavers were reportedly used for medical training as was probably the case of the female individual (85).

This work has provided valuable skeletal data set within its historical context to enable differentiation between lesions caused by surgery and medical training in the paleopathological record.

Acknowledgments

The authors thank the help from Alfredo Rasteiro, Cassandra DeGalia, Douglas Ubelaker, João Patrício, Kelly Blevins, Piers Mitchell, and Teresa Alcobia, and also from the Biblioteca das Ciências da Saúde, and Arquivo and Department of Life Sciences, all at the University of Coimbra. Our acknowledgments go also to the anonymous reviewers and to the Deputy Editor for the help in improving the manuscript. This work had the support of Fundação para a Ciência e Tecnologia (FCT – Fellowship SFRH/BD/102980/2014) and CIAS (Pest-UID/ANT/0283/2013).

References

- Armentano, N., Malgosa, A., Campillo, D., 1999. A case of frontal sinusitis from the Bronze Age site of Can Filuà (Barcelona). *Int. J. Osteoarchaeol.* 9, 438–442. doi:10.1002/(SICI)1099-1212(199911/12)9:6<438::AID-OA510>3.0.CO;2-N
- Barbian, L.T., Sledzik, P.S., 2008. Healing Following Cranial Trauma. *J. Forensic Sci.* 53, 263–268. doi:10.1111/j.1556-4029.2007.00651.x
- Bento, R.F., De Oliveira Fonseca, A.C., 2013. A brief history of mastoidectomy. *Int. Arch. Otorhinolaryngol.* 17, 168–178. doi:10.7162/S1809-97772013000200009
- Bissaia-Barreto, 1922. O ensino da técnica operatória e patologia cirúrgica em Coimbra (920-921). Imprensa da Universidade, Coimbra.
- Boljunčić, J., Hat, J., 2015. Mastoid trepanation in a deceased from medieval Croatia: a case report. *Coll. Antropol.* 39, 209–14.
- Boston, C., Webb, W., 2012. Early Medical Training and Treatment in Oxford: A Consideration of the Archaeological and Historical Evidence, in: Mitchell, P. (Ed.), *Anatomical Dissection in Enlightenment England and Beyond: Autopsy, Pathology and Display*. Ashgate Publishing Limited, Farnham, pp. 43–67.
- Bugaj, U., Novak, M., Trzeciński, M., 2013. Skeletal evidence of a post-mortem examination from the 18th/19th century Radom, central Poland. *Int. J. Paleopathol.* 3, 310–314.
- Burton, F.A., 1920. Prehistoric trephining of the frontal sinus. *Cal. State J. Med.* 18, 321–4.
- Campillo, D., Safont, S., Malgosa, A., Puchalt, F.J., 1999. Four trepanned skull from 5th and 16th century in Spain. Surgery or ritual? *Cuad. Valencia. Hist. Med. Cienc.* 261–284.
- Cappella, A., Amadasi, A., Castoldi, E., Mazzarelli, D., Gaudio, D., Cattaneo, C., 2014. The Difficult Task of Assessing Perimortem and Postmortem Fractures on the Skeleton: A Blind Text on 210 Fractures of Known Origin. *J. Forensic Sci.* 59, 1598–1601. doi:10.1111/1556-4029.12539
- Caroline, H., Franceschi, D., Philippe, R., 2011. Chronic Rhinosinusitis and Olfactory Dysfunction, in: Marseglia, G.L., Caimmi, D.P. (Eds.), *Peculiar Aspects of Rhinosinusitis*. InTech, Ryjeka, pp. 39–52.
- Carty, N., 2013. Evidence for Cranial Trauma and Treatment in Medieval Kildare. *J. Kildare Archaeol. Soc.* 10, 46–76.
- Chamberlain, A.T., 2012. Morbid osteology: evidence for autopsies, dissection and surgical training from the Newcastle Infirmary burial ground, in: Mitchell, P.D. (Ed.), *Anatomical Dissection in Enlightenment England and beyond: Autopsy, Pathology, and Display*. Ashgate Publishing Limited, Farnham, pp. 11–22.

Chonmaitree, T., Revai, K., Grady, J.J., Clos, A., Patel, J.A., Nair, S., Fan, J., Henrickson, K.J., 2008. Viral upper respiratory tract infection and otitis media complication in young children. *Clin. Infect. Dis.* 46, 815–23. doi:10.1086/528685

Clement, P.A.R., 2006. Classifications of rhinosinusitis, in: Brook, I. (Ed.), *Sinusitis: From Microbiology to Management*. Taylor & Francis Group, New York, pp. 15–38.

Dittmar, J.M., Mitchell, P.D., 2015. A new method for identifying and differentiating human dissection and autopsy in archaeological human skeletal remains. *J. Archaeol. Sci. Reports* 3, 73–79. doi:10.1016/j.jasrep.2015.05.019

Dykewicz, M.S., Hamilos, D.L., 2010. Rhinitis and sinusitis. *J. Allergy Clin. Immunol.* 125, S103–S115. doi:http://dx.doi.org/10.1016/j.jaci.2009.12.989

File Jr., T.M., 2006. Sinusitis: epidemiology, in: Brook, I. (Ed.), *Sinusitis: From Microbiology to Management*. Taylor & Francis Group, New York, pp. 1–14.

Fleming-Farrell, D., Michailidis, K., Karantanas, A., Roberts, N., Kranioti, E.F., 2013. Virtual assessment of perimortem and postmortem blunt force cranial trauma, *Forensic Science International*. doi:10.1016/j.forsciint.2013.03.032

Flohr, S., Schultz, M., 2009a. Mastoiditis--paleopathological evidence of a rarely reported disease. *Am. J. Phys. Anthropol.* 138, 266–73. doi:10.1002/ajpa.20924

Flohr, S., Schultz, M., 2009b. Osseous changes due to mastoiditis in human skeletal remains. *Int. J. Osteoarchaeol.* 19, 99–106. doi:10.1002/oa.961

Fokkens, W.J., Lund, V.J., Mullol, J., Bachert, C., Alobid, I., Baroody, F., Cohen, N., Cervin, A., Douglas, R., Gevaert, P., Georgalas, C., Goossens, H., Harvey, R., Hellings, P., Hopkins, C., Jones, N., Joos, G., Kalogjera, L., Kern, B., Kowalski, M., Price, D., Riechelmann, H., Schlosser, R., Senior, B., Thomas, M., Toskala, E., Voegels, R., Wang, D.Y., Wormald, P.J., 2012. European Position Paper on Rhinosinusitis and Nasal Polyps 2012. *Rhinol. Suppl.* 3 p preceding table of contents, 1-298.

Fornaciari, G., Giuffra, V., Giusini, S., Fornaciari, A., Marchesini, M., Vitiello, A., 2008. Autopsy and embalming of the Medici Grand Dukes of Florence (16th-18th centuries), in: Atoche, P., Rodriguez, C., Ramirez, A. (Eds.), *Mummies and Science: World Mummies Research. Proceedings of the VI World Congress on Mummy Studies (Teguise, Lanzarote)*. Academia Canaria de la Historia, Ayuntamiento de Teguise, Cabildo Insular de Lanzarote, Caja Canarias, Fundación Canaria Mapfre Guanarteme, Universidad de las Palmas de Gran Canaria, Santa Cruz de Tenerife, pp. 325–331.

Hospitais da Universidade de Coimbra, 1941. *Boletim dos Hospitais da Universidade de Coimbra (g)*. Imprensa da Universidade, Coimbra.

Hospitais da Universidade de Coimbra, 1939. *Boletim dos Hospitais da Universidade de Coimbra (f)*. Imprensa da Universidade, Coimbra.

Hospitais da Universidade de Coimbra, 1938. Boletim dos Hospitais da Universidade de Coimbra (e). Imprensa da Universidade, Coimbra.

Hospitais da Universidade de Coimbra, 1936. Boletim dos Hospitais da Universidade de Coimbra (d). Imprensa da Universidade, Coimbra.

Hospitais da Universidade de Coimbra, 1935. Boletim dos Hospitais da Universidade de Coimbra (c). Imprensa da Universidade, Coimbra.

Hospitais da Universidade de Coimbra, 1934. Boletim dos Hospitais da Universidade de Coimbra (b). Imprensa da Universidade, Coimbra.

Hospitais da Universidade de Coimbra, 1931. Boletim dos Hospitais da Universidade de Coimbra (a). Imprensa da Universidade, Coimbra.

Hospitais da Universidade de Coimbra, 1927. Papeleta de doente no430 [manuscript].

Jackman, J.H., Kennedy, R.J., 2006. Pathophysiology of sinusitis, in: Brook, I. (Ed.), Sinusitis: From Microbiology to Management. Infectious Disease and Therapy. Taylor & Francis Group, New York, pp. 109–134.

Jacobs, J.B., 1997. 100 years of frontal sinus surgery. *Laryngoscope* 107, 1–36.

Jafri, L., Farooq, O., 2015. Pott's puffy tumor. *Pediatr. Neurol.* 52, 250–1. doi:10.1016/j.pediatrneurol.2014.08.024

Kausmally, T., 2012. William Hewson and the Craven Street Anatomy School, in: Mitchell, P.D. (Ed.), *Anatomical Dissection in Enlightenment England and Beyond: Autopsy, Pathology and Display*. Ashgate Publishing Limited, Farnham, pp. 69–76.

Ladomenou, F., Kafatos, A., Tselentis, Y., Galanakis, E., 2010. Predisposing factors for acute otitis media in infancy. *J. Infect.* 61, 49–53. doi:10.1016/j.jinf.2010.03.034

Liebe-Harkort, C., 2012. Cribra orbitalia, sinusitis and linear enamel hypoplasia in Swedish Roman Iron Age adults and subadults. *Int. J. Osteoarchaeol.* 22, 387–397. doi:10.1002/oa.1209

Lopes, C., 2014. As mil caras de uma doença - sífilis na sociedade Coimbrã no início do século XX. PhD thesis in Anthropology presented to the University of Coimbra.

Lund, V., 2002. The evolution of surgery on the maxillary sinus for chronic rhinosinusitis. *Laryngoscope* 112, 415–9. doi:10.1097/00005537-200203000-00001

Madani, G., Beale, T.J., 2009. Sinonasal inflammatory disease. *Semin Ultrasound CT MR* 30, 17–24.

Magryś, A., Paluch-Oleś, J., Koziół-Montewka, M., 2011. Microbiology aspects of rhinosinusitis, in: Marseglia, G.L., Caimmi, D.P. (Eds.), *Peculiar Aspects of Rhinosinusitis*. InTech, Rijeka, pp. 27–38. doi:10.5772/1307

Mann, R.W., Owsley, D.W., Reinhard, K.J., 1994. Otitis Media, Mastoiditis, and Infracranial Lesions In Two Plains Indian Children 131–146.

Mays, S.A., 2006. A possible case of surgical treatment of cranial blunt force injury from medieval England. *Int. J. Osteoarchaeol.* 16, 95–103. doi:10.1002/oa.806

Mays, S., Holst, M., 2006. Palaeo-otology of cholesteatoma. *Int. J. Osteoarchaeol.* 16, 1–15. doi:10.1002/oa.801

Ministério da Justiça, 1999. Decreto-Lei no 274/99 de 22 de junho. Diário da República, Portugal.

Mitchell, P.D., 2012. There's more to dissection than Burke and Hare: unknowns in the teaching of anatomy and pathology from the enlightenment to the early twentieth century in England, in: Mitchell, P. (Ed.), *Anatomical Dissection in Enlightenment Britain and Beyond: Autopsy, Pathology and Display*. Ashgate Publishing Limited, Farnham, pp. 1–9.

Mitchell, P.D., Boston, C., Chamberlain, A.T., Chaplin, S., Chauhan, V., Evans, J., Fowler, L., Powers, N., Walker, D., Webb, H., Witkin, A., 2011. The study of anatomy in England from 1700 to the early 20th century. *J. Anat.* 219, 91–9. doi:10.1111/j.1469-7580.2011.01381.x

Moberly, A.C., Fritsch, M.H., 2010. The evolution of mastoidectomy and tympanoplasty. *Laryngoscope* 120 Suppl, S213. doi:10.1002/lary.21680

Monod, C., Vanverts, J.L., 1902. *Traité de technique opératoire*. Libraires de l'Académie de Médecine, Paris.

Mudry, A., 2009. History of instruments used for mastoidectomy. *J. Laryngol. Otol.* 123, 583–9. doi:10.1017/S0022215109004484

Nerlich, A.G., Peschel, O., Zink, A., Rösing, F.W., 2005. The Pathology of Trepanation: Differential Diagnosis, Healing and Dry Bone Appearance in Modern Cases, in: Arnott, R., Finger, S., Smith, C.U.M. (Eds.), *Trepanation. History, Discovery, Theory*. Swets & Zeitlinger Publishers, Lisse, pp. 43–51.

Nogueira Júnior, J.F., Hermann, D.R., Américo, R. dos R., Barauna Filho, I.S., Stamm, A.E.C., Pignatari, S.S.N., 2007. Breve história da otorrinolaringologia: otologia, laringologia e rinologia. *Rev. Bras. Otorrinolaringol.* 73, 693–703. doi:10.1590/S0034-72992007000500017

Nokso-Koivisto, J., Marom, T., Chonmaitree, T., 2015. Importance of viruses in acute otitis media. *Curr. Opin. Pediatr.* 27, 110–5. doi:10.1097/MOP.000000000000184

Nystrom, K.C., 2011. Postmortem examinations and the embodiment of inequality in 19th century United States. *Int. J. Paleopathol.* 1, 164–172. doi:10.1016/j.ijpp.2012.02.003

Palma, S., Bovo, R., Benatti, A., Aimoni, C., Rosignoli, M., Libanore, M., Martini, A., 2014. Mastoiditis in adults: a 19-year retrospective study. *Eur. Arch. Oto-Rhino-Laryngology* 271, 925–931. doi:10.1007/s00405-013-2454-8

Panhuysen, R.G.A.M., Coened, V., Bruintjes, T.D., 1997. Chronic maxillary sinusitis in Medieval Maastricht, The Netherlands. *Int. J. Osteoarchaeol.* 7, 610–614. doi:10.1002/(SICI)1099-1212(199711/12)7:6<610::AID-OA366>3.0.CO;2-Q

Pina, M.E., 2010. As faculdades de medicina na I República, in: Garnel, M.R.L. (Ed.), *Medicina na 1a República : Catálogo Exposição Centenário da República*. Imprensa Nacional - Casa da Moeda, Lisboa, pp. 30–37.

Pontinha, C.M., Soeiro, C., 2014. A dissecação como ferramenta pedagógica no ensino da Anatomia em Portugal. *Interface - Comun. Saúde, Educ.* 18, 165–176. doi:10.1590/1807-57622014.0558

Powers, N., 2005. Cranial trauma and treatment: a case study from the medieval cemetery of St. Mary Spital, London. *Int. J. Osteoarchaeol.* 15, 1–14. doi:10.1002/oa.733

Ramadan, H.H., 2005. History of frontal sinus surgery, in: Kountakis, S.E., Senior, B.A., Draf, W. (Eds.), *The Frontal Sinus*. Springer-Verlag, Berlin/Heidelberg, pp. 1–6. doi:10.1007/3-540-27607-6

Revai, K., Dobbs, L.A., Nair, S., Patel, J.A., Grady, J.J., Chonmaitree, T., 2007. Incidence of Acute Otitis Media and Sinusitis Complicating Upper Respiratory Tract Infection: The Effect of Age. *Pediatrics* 119.

Roberts, C.A., 2007. A bioarcheological study of maxillary sinusitis. *Am. J. Phys. Anthropol.* 133, 792–807. doi:10.1002/ajpa.20601

Rocha, M.A., 1995. Les collections ostéologiques humaines identifiées du Musée Anthropologique de l'Université de Coimbra. *Antropol. Port.* 13, 7–38.

Rodrigues, M.H. de C., 1906. Indicações das intervenções cirurgicas nas sinusites frontaes. *Escola Medico-Cirurgica de Lisboa*.

Sakran, W., Makary, H., Colodner, R., Ashkenazi, D., Rakover, Y., Halevy, R., Koren, A., 2006. Acute otitis media in infants less than three months of age: clinical presentation, etiology and concomitant diseases. *Int. J. Pediatr. Otorhinolaryngol.* 70, 613–7. doi:10.1016/j.ijporl.2005.08.003

Santos, A.L., 2000. A skeletal picture of tuberculosis: macroscopic, radiological, biomolecular, and historical evidence from the Coimbra identified skeletal collection. University of Coimbra.

Santos, A.L., 1999. TB files: new Hospital data (1910-1936) on the Coimbra Identified Skeletal Collection. International congress the evolution and paleoepidemiology of tuberculosis (Szeged, Hungria, 4-7 de Setembro de 1997). In:

Pálfi, G. et al. (Eds.), in: Pálfi, G., Dutour, O., Deák, J., Hutás, I. (Eds.), *Tuberculosis Past and Present*. Golden Book Publisher Ltd, Tuberculosis Foundation, Szeged, pp. 127–134.

Santos, A.L., Suby, J.A., 2015. Skeletal and Surgical Evidence for Acute Osteomyelitis in Non-Adult Individuals. *Int. J. Osteoarchaeol.* 25, 110–118. doi:10.1002/oa.2276

Schalek, P., 2011. Rhinosinusitis - Its impact on quality of life, in: Marseglia, G.L., Caimmi, D.P. (Eds.), *Peculiar Aspects of Rhinosinusitis*. InTech, Ryjeka, pp. 3–26. doi:10.5772/1307

Slavin, R.G., Spector, S.L., Bernstein, I.L., Kaliner, M.A., Kennedy, D.W., Virant, F.S., Wald, E.R., Khan, D.A., Blessing-Moore, J., Lang, D.M., Nicklas, R.A., Oppenheimer, J.J., Portnoy, J.M., Schuller, D.E., Tilles, S.A., Borish, L., Nathan, R.A., Smart, B.A., Vandewalker, M.L., 2005. The diagnosis and management of sinusitis: a practice parameter update. *J. Allergy Clin. Immunol.* 116, S13-47.

Sunder, S., Jackler, R.K., Blevins, N.H., 2006. Virtuosity with the Mallet and Gouge: the brilliant triumph of the “modern” mastoid operation. *Otolaryngol. Clin. North Am.* 39, 1191–210. doi:10.1016/j.otc.2006.08.014

Sundman, E.A., Kjellström, A., 2013. Chronic Maxillary Sinusitis in Medieval Sigtuna, Sweden: A Study of Sinus Health and Effects on Bone Preservation. *Int. J. Osteoarchaeol.* 23, 447–458. doi:10.1002/oa.1268

SWGANTH - Scientific Working Group for Forensic Anthropology, 2011. Trauma Analysis [WWW Document]. URL <http://swganth.startlogic.com/Trauma Rev0.pdf> (accessed 10.10.16).

Tarantino, V., D’Agostino, R., Taborelli, G., Melagrana, A., Porcu, A., Stura, M., 2002. Acute mastoiditis: a 10 year retrospective study. *Int. J. Pediatr. Otorhinolaryngol.* 66, 143–8.

Ubelaker, D.H., 2015. The Concept of Perimortem in Forensic Science, in: Gerdau-Radonić, K., McSweeney, K. (Eds.), *Trends in Biological Anthropology*. Oxbow Books, Oxford, pp. 95–99.

Vassbotn, F.S., Klausen, O.G., Lind, O., Moller, P., 2002. Acute mastoiditis in a Norwegian population: a 20 year retrospective study. *Int. J. Pediatr. Otorhinolaryngol.* 62, 237–42.

Vercelotti, G., Williams, L.L., Stout, S.D., 2010. Two possible cases of mastoidectomy from a recent Italian ossuary (Chiavari, GE). *Paleopathol. Newsl.* 13–18.

Wheatley, B.P., 2008. Perimortem or Postmortem Bone Fractures? An Experimental Study of Fracture Patterns in Deer Femora. *J. Forensic Sci.* 53, 69–72. doi:10.1111/j.1556-4029.2008.00593.x

Wright, J., Smith, H., 1914. A text-book of the diseases of the nose and throat. Lea & Febiger, Philadelphia and New York.

Yeager, V.L., 1996. Learning gross anatomy: dissection and prosection. *Clin. Anat.* 9, 57–9. doi:10.1002/(SICI)1098-2353(1996)9:1<57::AID-CA12>3.0.CO;2-9

Zias, J., Pomeranz, S., 1992. Serial craniectomies for intracranial infection 5.5 millennia ago. *Int. J. Osteoarchaeol.* 2, 183–186. doi:10.1002/oa.1390020210