

SUMMARY OF DOCTORAL THESIS

PALEORADIOLOGY: NON-INVASIVE METHODOLOGICAL POSSIBILITIES IN HISTORICAL ANTHROPOLOGY

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**SZEGED
2015**

INTRODUCTION

The primary resources of bioarcheological, historical anthropological and paleopathological research are human remains. In these fields of science, skeletons and artificially or naturally mummified individuals or body parts provide the most amount of information on the people of past populations, their diseases, infecting agents, nutritional and other habits. Paleoradiological examinations facilitate an extraordinary insight into the body or the bone structure without any damage affecting the investigated specimen. Radiological evaluation of changes in the internal structure of bones is primarily used in bioarcheology to estimate age at death or to study the development of bones, and it also has an important role the differential diagnostics of disease symptoms in paleopathology. Beside systematizing and refining paleoradiological methods, my doctoral thesis is also intended to demonstrate the practical application of these investigation techniques. In the course of my research projects I have examined numerous human skeletons and artificially or naturally mummified human remains.

My physical anthropology research projects were intended to follow interdisciplinary approaches: my doctoral thesis is based on bioarcheological investigations, but it utilizes information and methodology from several other fields of science like medicine, social sciences, arts and humanities. Human remains act as 'biodocuments' in bioarcheology; the applied paleoradiological methods, however, provide a comprehensive investigation possibility

in structural mapping of the remains, data recording, evaluation and verification.

RESEARCH AIMS AND APPLIED METHODS

The aims of my doctoral research project may be summarized as follows:

- Overview of paleoradiological methods used in bioarcheology and paleopathology, refinement of technical possibilities, verification of imaging techniques, recommendations for further later studies.
- Development and refinement of age estimation and diagnostical possibilities.
- Radiological study of human osteological remains, artificially and naturally mummified remains.
- Historical anthropological case studies: paleoradiological and interdisciplinary research of famous historical personalities and holy relics.

In the course of my research I have utilized the following paleoradiological tools, methods:

- Conventional radiography
- Computed tomography (CT)
- Digital volume tomography (DVT)
- Nano CT

Along with paleoradiological examinations I have explored the historical context of certain findings; sometimes even the life history of the individual was recovered facilitated by historical resources. Synthesizing the results of different methods in my case studies I have attempted to obtain a better understanding of the history of the period in question through the physical anthropology, the mortuary settings and the life history of the individual.

RESULTS

The first group of my results concerns methodological verification of paleoradiological techniques. In the course of my doctoral research I have also aimed at verification, systematic overview and description of methodological possibilities applied in paleoradiology. The main observations concerning image taking techniques I made during the conventional radiography examination of several hundreds of human remains helped me to develop finer typical images that are easier to evaluate or at least images with better approximation to this aim. Based on this experience I put down methodological recommendations in my thesis. I have continuously tested the set-ups and technical values (kV, mAs) I was aiming for. I have summarized the results and arranged them in tables for easier understanding. Also concerning mummy studies, I have managed to propose a practical protocol for conventional radiography and CT examinations as well that I have also presented in tables.

The second group of results of my doctoral research project concerns the application of the paleoradiological experience I gathered to

facilitate complex anthropological and radiological description of human remains of historical populations. Remains of famous historical personalities and holy relics were included in these studies, thus additional information available on the remains (eg. historical, curricular information or works of cultural history) facilitated interdisciplinary approaches to be applied in these projects.

I coordinated a research group in 2007 conducting paleoradiological and paleopathological investigations of Pál Széchényi's mummy in Nagycenk. Our primary goals were to decide whether the mummification process occurred because of artificial or natural reasons, whether the death of the archbishop was caused by arsenic poisoning in 1710 or not, and to diagnose possible pathological symptoms in the body. The examinations were conducted using non-invasive methods including multislice CT and conventional radiography, energy-dispersive X-ray spectroscopy (EDX) and X-ray fluorescence (XRF) element analyses. On the basis of the results we can state that the body of Pál Széchényi was artificially mummified: CT slices of the pelvic region clearly demonstrate the presence of a material used to fill up the cavities of the body. Some bones in several spine regions and in the pectoral girdle have been moved out of their anatomical positions probably attributed to recurring disturbance of the burial. Longitudinal ligaments along the spine show advanced stage ossification furnishing radiological signs of the chronic osteological condition DISH (diffuse idiopathic skeletal hyperostosis). CT examination of the skull was conducted applying

slice thickness smaller than 1 mm, thus copies of the 3D printed skull reconstruction were accurate and detailed enough for anthropological examinations and further graphical face reconstruction.

According to our paleopathological results, the death of the Archbishop Pál was not caused by arsenic poisoning, but most possibly by cardiovascular disease. Both the endoscopic examination and the analysis of CT scans proved that evisceration was not performed through the ventral aspect of the abdominal wall, but through a longitudinal cut on the left side of the mummy reaching from the armpit to the pelvis. Our research concerning the body of Pál Széchenyi prove that artificial mummification was applied in preparation of the remains of some high-ranking nobilities at least for temporary purposes. The main reason behind this custom may be time-consuming organization of an adequately representative funerary ceremony – eg. between the death and the funeral of Pál Széchenyi one month has passed – and body somehow had to preserved in a good condition to the time of the ceremony.

The next case study introduced in my doctoral thesis is the comparative analysis of earlier investigations conducted on the Holy Right Hand. Formerly there have been only three instances when the mummified right hand of king St. István has been made accessible for scientific investigations. At the first occasion in 1951 Ádám Bochkor medical specialist examined the remains because mold became visible in the surface. He published a short report about the

results in 1960. Four researchers were granted access to the remains in 1988 lead by János Szentágothai and János Nemeskéri, and in 1999 Miklós Réthelyi and Lajos Patonay were invited to conduct medical and anthropological studies on the Holy Right Hand. With permissions from Cardinal Péter Erdő, Archbishop of Esztergom, professor Réthelyi and director Patonay I could analyze the records of the 1988 and 1999 examinations.

I have concluded that the results of examinations conducted by different scholars in different periods diverge from each other in several points, and their conclusions are also not concordant, eg. they do not agree on artificial or natural mummification of the remains. There is apparent difference between the osteometrical data of the 1988 and the 1999 surveys. Higher accuracy and replicability of the 1999 data were facilitated by paleoradiological method used for the first time in the research history of the Holy Right Hand in those times. The radiographs did not indicate signs of *arthrosis* or *osteoporosis*, other paleopathological changes were also not present on the bones. Contours of articular surfaces were sharply delineated and intact, narrowing of the synovial cavity probably occurred because of dehydration.

Having reviewed the research archives of the Holy Right Hand, concerning mummification it can be concluded that *post mortem* embalming was very likely, and it might have affected the whole body, not just the upper limb.

I have organized the complex investigation of the head reliquary and the skull relic of our king St. László housed in the Héderváry Chapel of the Basilica of Győr. This project has been a very important case study in the course of my research. Primarily the anthropological and paleoradiological investigation of the cranium is connected to my doctoral research topic.

The skull of king St. László is well preserved, but the mandible is missing. It features hypermasculine anthropological traits. Sex, age at death, several characteristic and the observed taphonomical alterations testified the genuineness of the skull. The paleoradiological examinations mainly found *post mortem* bone loss in several areas of the skull relic, eg. along the right *sutura squamosa* a *post mortem* comminuted fracture is seen affecting the *os frontale* and the *os temporale* too. In the basal left part of *os occipitale* at the dorsal rim of *foramen magnum* signs of *post mortem* intervention are present. Radiographic and CT images helped to determine the dental status of the royal relic. The laminar or fine globular objects with the density of limestone found in the *canalis caroticus* during the paleoradiological examinations may refer to atherosclerosis of the *arteria carotis interna*. Further peculiarity is the fungal hypha mass found in the left maxillary sinus probably containing metal or lime that became visible in the CT scans. *Pre-* or *post mortem* origin of the lesions cannot be unequivocally stated.

During the last case study, I have conducted the paleoradiological and anthropological examination of the remains of early Christian

martyrs St. Augustine and St. Christine. Meanwhile we could also study body preparation techniques of the Baroque era.

In 2012 the remains were subjected to paleoradiological condition assessment. Two years later, as the actual restoration works took on, we had the possibility to conduct an anthropological investigation. We could make anthropological/anatomical observations complemented by new radiological records and images. The anthropological observations proved our earlier assumption based on the former radiological examination that the skeletons were assembled from several individuals' remains. We found bones at least from three individuals. St. Augustine's skeleton contained an animal bone instead of the left *radius*. During the preparation of the relics, anatomically incorrect items might have been frequently applied and sides were also often switched. Especially in case of hands and feet– and also with the ribs of St. Christine - bones were substituted with other materials. Phalanges were replaced by paper rolls covered with a lime-like material giving a rather specious radiological image that could have been easily mistaken for porotic bone.

Scientific investigation and restoration of holy relics demands cooperation between specialists of different scientific fields. Anthropological and radiological results provide essential help for planning and conducting the restoration process. During our case study we could examine and evaluate the relics of the early Christian martyrs with non-invasive techniques, and we provided important

new data to specialists of several other fields involved in the investigations.

CONCLUSION

My research results confirmed that paleoradiology is a useful examination approach in bioarcheology and historical anthropology, especially in mummy studies: paleoradiology furnishes important data to the understanding of past populations or the life history of deceased individuals. The non-invasive technology facilitates insight into the remains of the body and the bone structure. Next to anthropological age estimation and paleopathological diagnostics, it is also possible to take measurements of bones to tenth of a millimeter accuracy, providing bases for development of new anthropometrical techniques. CT data provide basis for virtual 3D reconstruction and printing of any skeletal element or mummified body part, which is of crucial importance in case of skulls and facial reconstructions.

The paleoradiological investigations in the case studies of my dissertation yielded a lot of new results with importance not only in physical anthropology but also in historical fields. Replicability of these results may refine hypotheses concerning the life of historical personalities and fate of their dead bodies. This is well demonstrated in mummy studies. The case of Archbishop Pál Széchenyi proves that embalming was an established practice in the Baroque era in

case of funerals of high-ranking priests and noblemen. Embalming being involved in medieval royal mortuary practices may be very likely on the basis of research results concerning the Holy Right Hand, but it may also be proposed in case of the skull relic of St. László. Paleoradiological examinations of the relics of two early Christian martyrs provided novel anthropological knowledge and important cultural and historical data.

Paleoradiological results of the last century in Hungary and especially the research in the last decades drew attention to the strong need for a national paleoradiological center or platform servicing anthropological, paleopathological, archeological and historical research projects that would dramatically increase the efficiency and productivity of these interdisciplinary research initiatives.

PUBLICATIONS IN INDEXED JOURNALS IN CONNECTION
WITH THE TOPIC OF THE DOCTORAL THESIS:

Kristóf LA, Kovács M, Baksa G, Bereczki Zs, Patonay L, Szatmári F, Pálfi Gy, Pohárnok L (2015): Condition assessment of two early Christian martyrs', St. Christine's and St. Augustine's relics with paleoradiological methods in Hungary, *Journal of Cultural Heritage* 16: 249–253.

Coqueugniot H, Dutailly B, Desbarats P, Boulestin B, Pap I, Szikossy I, Baker O, Montandon M, Panuel M, Karlinger K, Kovács B, **Kristóf LA**, Pálfi Gy, Dutour O (2015): Three-dimensional imaging of past skeletal TB: from lesion to process. *Tuberculosis* 95: S73–S79.

Pálfi Gy, Maixner F, Maczel M, Molnár E, Pósa A, **Kristóf LA**, Marcsik A, Balázs J, Masson M, Paja L, Palkó A, Szentgyörgyi R, Nerlich A, Zink A, Dutour O (2015): Unusual spinal tuberculosis in an Avar Age skeleton (Csongrád-Felgyő, Űrmös tanya, Hungary): a morphological and biomolecular study. *Tuberculosis* 95: S29–S34.

Cumulative impact factor: 7.695

FURTHER PUBLICATIONS IN CONNETION WITH THE TOPIC
OF THE DOCTORAL THESIS:

As a first author:

- Kristóf LA** (2003): Hagyományos röntgenvizsgálatok a történeti antropológiában, in Penksza K, Korsós Z, Pap I (edd.): *III. Kárpát-medencei Biológiai Szimpózium*, Budapest, 2003: 305–308.
- Kristóf LA**, Barta MH, Petrik A, Pap I, Pálfi Gy, Fornet B, Forrai G (2004): „Belelátni a múltba”. Módszertani lehetőségek a paleoradiológiában. *Magyar Radiológia* 78(1): 24–31.
- Kristóf LA**, Riedl E, Laki A, Pap I, Barta MH, Polányi A, Pálfi Gy, Tóth E, Szikossy I, Kustár Á, Forrai G (2008): Radiology in the historic anthropology. In Atoche Peña P, Rodríguez Martín C, Ma. Ramírez Rodríguez Á (edd.): *Mummies and Science. World Mummies Research. Proceedings of the VI World Congress on Mummy Studies* (Teguiise, Lanzarote, 20th February, 2007) Santa Cruz de Tenerife, 2008: 453–461.
- Kristóf LA**, Tóth G, Riedl E, Végvári Zs, Pohárnok L, Kustár Á (2008): Mummies and face reconstruction. The skull CT examination and 3D printing of baroness Antonia Tauber's and the archbishop of Kalocsa, Pál Széchényi's mummies. In Lajos Borbás (ed.): *Proceedings of the Third Hungarian Conference on Biomechanics...* Budapest, 2008: 133–138.
- Kristóf LA**, Pohárnok L, Kerényi T, Tóth V, Istók R, Tóth G, Hargittai P, Fornet B, Pálfi Gy (2010): Paleoradiológia és múmiakutatás. A nagycenki múmia interdiszciplináris vizsgálata és 3D koponyamásolatának nyomtatása CT-adatok alapján. *Magyar Radiológia Online* 1(4): 6–16.
http://www.radiologia.hu/uploads/doc/3030_MRO_2010_04_02.pdf (2013. 11. 28.).
- Kristóf LA**, Kovács M, Tóth G, Pohárnok L (2012): Széchényi Pál múmiájának paleoradiológiai vizsgálata. In **Kristóf LA**, Tóth Vilmos (edd.): *Széchényi Pál érsek emlékezete. Adalékok az életüthoz és a nagycenki múmia vizsgálatának eredményei*. Győr, 2012: 116–125.
- Kristóf LA** (2012): Testek a múltból. Három 18. századi apáca múmiájának vizsgálata, In Kristóf LA, Tóth V (edd.): *Széchényi*

- Pál érsek emlékezete. Adalékok az életúthoz és a nagycenki múmia vizsgálatának eredményei.* Győr, 2012: 154–169.
- Kristóf LA**, Kovács M, Baksa G, Patonay L, Szatmári F, Pálfi Gy, Pohárnok L (2014): Mosonmagyaróváron található két ókeresztény vértanú szent maradványának paleoradiológiai vizsgálata. *Magyar Radiológia Online* 5(8).
http://www.radiologia.hu/szakma/mro/cikk/mosonmagyarovaron_talalhato_ket_okereszteny_vertanu_szent_maradvanyainak_pal_eoradiologiai_vizsgalata.html (2014.10.28.)
- Kristóf LA**, Tóth V (edd.): *Széchenyi Pál érsek emlékezete. Adalékok az életúthoz és a nagycenki múmia vizsgálatának eredményei.* Második, bővített kiadás, Győr, 2015.
- As a co-author:
- Bernert Zs, Szikossy I, Pap I, **Kristóf LA**, Barta M, Pálfi Gy (2001): Prévalence de fractures dans deux séries anthropologiques hongroises. In Bérato J (ed.): *Centre Archéologique du Var 2001*. Toulon, 2001: 49–51.
- Fóthi E, Pap I, **Kristóf LA**, Barta M, Maczel M, Pálfi Gy (2001): A propos d'un nouveau cas paléopathologique de lèpre en Hongrie. In Bérato J (ed.): *Centre Archéologique du Var 2001*. Toulon, 2001: 52–54.
- Évinger S, Bernert Zs, Józsa L, **Kristóf LA** (2003): Two cases of joint disease from the Avar Age, Hungary. *Anthropologie (Brno)* 41(1-2): 79–85.
- Istók R, Glasz T, **Kristóf LA**, Tóth V, Hargittai P, Kerényi T (2015): Széchenyi Pál múmiájának paleopatológiai vizsgálata. Adalékok a mumifikálás gyakorlathoz a barokk kori Magyarországon. In **Kristóf LA**, Tóth V (edd.): *Széchenyi Pál érsek emlékezete. Adalékok az életúthoz és a nagycenki múmia vizsgálatának eredményei.* Második, bővített kiadás. Győr, 2015: 158–165.
- Molnár E, Falk Gy, Pálfi Gy, **Kristóf LA** (2012): Antropológiai vizsgálat Széchenyi Pál háromdimenziós, nyomtatott koponyamásolatain. In **Kristóf LA**, Tóth V (edd.): *Széchenyi Pál érsek emlékezete. Adalékok az életúthoz és a nagycenki múmia vizsgálatának eredményei.* Győr, 2012: 142–149.
- Szikossy I, Kustár Á, Guba Zs, **Kristóf LA**, Pap I (2010): Naturally mummified corpses from the Dominican Church in Vác,

- Hungary. In Wieczorek A, Rosendahl W (edd.): *Mummies of the world*. Munich-Berlin-London-New York, 2010: 160–171.
- Kustár Á, Pap I, Végvári Zs, **Kristóf LA**, Pálfi Gy, Karlinger K, Kovács B, Szikossy I (2011): Use of 3D virtual reconstruction for pathological investigation and facial reconstruction of an 18th century mummified nun from Hungary. In Gill-Frerking H, Rosendahl W, Zink A (edd.): *Yearbook of Mummy Studies I*, München, 2011: 83–93.

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Coauthor's declaration

I, undersigned Dr. György Pálfi, PhD, hereby certify that I am familiar with the PhD thesis of the applicant Ms. Lilla Alida KRISTOF (University of Szeged) entitled '*Paleoradiology: Non-invasive Methodological Approach in Historical Anthropology*'.

Regarding our jointly obtained results that form part of this PhD dissertation, I declare the followings:

The applicant's contribution was prominent in obtaining the following results:

Paleoradiological interpretation of the X-ray and CT examinations of a 7-8th century (Avar age) spine (Pott's disease), from the Collection of the Department of Biological Anthropology, University of Szeged.

I did not and will not use these results in getting an academic research degree.

Regarding our joint results referred to in this thesis, the following one was obtained as the result of joint contribution by the applicant and myself:

Pálfi György, Maixner Frank, Maczel Márta, Molnár Erika, Pósa Annamária, **Kristóf Lilla Alida**, Marcsik Antónia, Balázs János, Masson Muriel, Paja László, Palkó András, Szentgyörgyi Réka, Nerlich Andreas, Zink Albert, Dutour Olivier: Unusual spinal tuberculosis in an Avar Age skeleton (Csongrád-Felgyő, Űrmös tanya, Hungary): a morphological and biomolecular study. *Tuberculosis* 95 (2015). S29–S34. p.

I attest that the above statement is true and valid to the best of my knowledge.

Szeged, September 30th 2015.




Dr. György Pálfi, PhD, Head of Department)



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de BORDEAUX

PESSAC, 30th September 2015

Coauthor's declaration

I hereby certify that I am familiar with the PhD thesis of the applicant Ms Lilla Alida KRISTOF (University of Szeged) entitled "*Paleoradiology: Non-invasive Methodological Approach in Historical Anthropology*".

Regarding our jointly obtained results that form part of this PhD dissertation, I declare the followings:

The applicant's contribution was prominent in obtaining the following results:
Paleoradiological study - CT examination - of a 18th century mummy from the Vác Mummy Collection.

I did not and will not use these results in getting an academic research degree.

Regarding our joint results referred to in this thesis, the following one was obtained as the result of joint contribution by the applicant and myself:

Coqueugniot H      , Dutailly Bruno, Desbarats Pascal, Boulestin Bruno, Pap Ildik  , Szikossy Ildik  , Baker Oussama, Montandon Michel, Panuel Michel, Kartinger Kinga, Kov     Bal    , Krist     Lilla Alida, P     Gy      , Dutour Oliver: Three-dimensional imaging of past skeletal TB: from lesion to process. *Tuberculosis* 95, 2015: 573-579.

H       Coqueugniot
DR CNRS, HDR