Case Report

Metastatic Prostate Carcinoma in an Early 18th-Century South German Abbot—Interdisciplinary Research Reveals Clues to His Final Disease History

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Abstract: This interdisciplinary investigation of the human remains of Balduin Helm, one of the most important abbots of the Fürstenfeld monastery, provides novel information on this historic individual. This is particularly interesting since Balduin, during the early 18th century, was involved in the renovation of this large Bavarian monastery. Metastatic prostate cancer was found as evidenced by multiple mixed osteolytic–osteoblastic bone lesions in all available vertebral bodies, fragments of both os coxae, and isolated metastases in skull bones. Distribution, radio- and histomorphology, and especially the immunohistochemical detection of prostate-specific antigens in those metastases definitively confirm this diagnosis. Further investigation, especially by stable isotope analysis, showed a balanced high-level diet with considerable contribution from animal protein and significant freshwater fish. These additional findings suggest a significant radiocarbon reservoir effect as an explanation for a “too old” radiocarbon date. Finally, the obviously high-level protein diet may have contributed to the tumorigenesis which caused the death of the abbot at an advanced age.

Keywords: cancer; skeleton; stable isotopes; radiocarbon; immunohistochemistry

1. Introduction

The interdisciplinary investigation of human remains offers a unique opportunity to identify specific information about the life and disease in historic individuals. These data are of even greater value when the individual is known so that bioarchaeological data may be correlated with biographic information. Besides this, the identification of specific diseases, such as malignant tumours, offers new insight, not only into an individual’s medical history but also into specialised medical disciplines, such as paleo-oncology.

Oncological diseases are widespread in modern times but relatively rare in studies of the osseous remains of ancient populations [1–4]. There are several reasons which include the low level of tumour detection in dry bone, the incomplete preservation of historic skeletons, lower life expectancy in previous populations than today, and, perhaps, reduced environmental factors for tumorigenesis. While the exact influence of these factors on any real tumour rate remains unknown, every well-documented case of a malignant skeletal tumour, both of primary or secondary (metastatic) cause, is of interest [2,3]. This holds particularly true in those cases where an historic individual can be identified. The identification of malignant tumoral growth in an historic person is of particular interest,
since the diagnosis of a malignancy may be correlated with its potential impact on the life and living conditions in a past setting. To date, few such examples of palaeopathologically identified malignant tumours in specific persons exist [5–8]. This report adds to the literature with particular emphasis on the potential influence of metastatic cancer on the life of a South German abbot of the early 18th century who played an important role in regional history and provides some insight into his living conditions before death.

2. Material and Methods

2.1. The Individual’s History

Balduin Helm (1645–1720 CE) was an abbot of one of the most eminent monasteries of Southern Bavaria, the monastery of Fürstenfeld located close to the small town of Fürstenfeldbruck, which is about 25 km from the Bavarian capital city of Munich. The abbey was founded in 1263 by the Bavarian Duke Ludwig II, who had initially designated the monastery as the burial place for his family and had gifted the convent with a large land and property holding [9–11].

Following serious decay during the Thirty Years’ War in 1632, the monastery returned to some of its previous economic wealth during the post-war decades such that, by the end of the 17th century, it was decided to rebuild the whole monastery. The church was considerably enlarged and decorated in the in-vogue baroque style. This was started under the leadership of Abbot Balduin Helm.

Balduin Helm was born in Munich in 1645 with the Christian names Christoph Ferdinad. He was the son of the Munich court musician Elias Helm and his wife Anna Maria [11]. According to the baptismal register, he was the youngest son with two elder brothers and two sisters, one of each becoming a monk and a nun, respectively. He was later named Balduin. In 1663 CE, following an extended school education, he entered the monastery at the age of 18 years. This was followed by 3 years of studying theology at the University of Dillingen (Bavaria). In 1669 CE, he not only received his final consecration, but he also graduated as Doctor of Theology [11].

Following his return to the monastery, he served as parochial curate between 1671 and 1690 in the parish of St. Magdalena in Bruck (which is a part of Fürstenfeldbruck) [11]. These services were interrupted by periods of residence in the monastery. While serving in the monastery, he also was engaged in administrative work, mainly as the secretary of the abbot Martin Dallmayr. In 1690, abbot Martin Dallmayr unexpectedly died, and the convent unanimously elected Balduin Helm to replace him [10].

During his appointment, he was described as being “calm, steady, humble, tolerant and of superior character associated with ample learnedness”. There exists one painting in which Abbot Balduin has been identified with him as a member of an important ceremony (Figure 1). Beyond his work as an abbot, Balduin authored several theological oeuvres which were widely viewed. Additionally, he was frequently invited to perform church services in Munich. Apart from the theological services, he was, by virtue of his ecclesiastical duties, a member of the Bavarian Diet. All these obligations required frequent travelling. A compilation of his travel itinerary shows a list of 75 journeys in 15 years of duty [11].

The most important event during Balduin’s abbacy was the renovation and reconstruction of the monastery and particularly the new church. Balduin planned the erection of an up-to-date building of enormous dimensions. The economic conditions favoured his plans since the monastery had considerable revenues from several endowments that were obliged to pay taxes to the monastery [9].

The construction work started soon after Balduin’s election in 1691 and lasted until 1701 when numerous offices and service buildings were finished. The renovation of the church, however, though already started, remained unfinished at that time. Despite this, an enormous amount of 120,000 florins had been spent (equivalent to about EUR 12 million today). But the political conditions had dramatically changed. The War of the Spanish Succession (1701–1714) had begun, and the Bavarian Elector Maximilian II. Emmanuel (1662–1726) had been defeated by the Holy Roman Emperor forcing him to flee from his
home state Bavaria. Since the Elector had protected the monastery, and, in particular, supported Abbot Balduin, the loss of this support led to the latter’s resignation on 29 May 1705 [11].

The church was not finished until 1741 (Figures 2 and 3), a date that Abbot Balduin did not live to see [9]. He died on 8 May 1720, having spent another 15 years as a titular abbot in Fürstenfeld abbey being mainly devoted to theological studies. During this period, Balduin authored five tomes on theological issues [11]. He lived withdrawn from all official duties. No report exists about his physical abilities or any ill health.

Abbot Balduin initially was buried in the monastery’s cemetery. It is mentioned that his grave was decorated with a large tombstone [11]. This was necessary due to the construction of the new church. The crypt was not available for burials between around 1700 and 1740 AD. Only three abbots died during this time, including Abbot Balduin [10]. There is evidence that they were initially buried in special graves in the cemetery. After the dissolution of the monastery in 1803, a commission was appointed by Bavarian King Ludwig I in 1847 to transfer them to the renovated crypt [9]. Accordingly, the skeletal remains of Abbot Balduin were removed from his tomb and transferred into a large clay pot (Figure 4A). This clay pot containing the mortal remains of Abbot Balduin was sealed by the Royal Commission, meaning that it is highly likely that the human remains in the pot are those of Balduin Helm. In 2019, his skeletal remains were inspected and removed for a very short time for scientific analysis by the authoring team at the request of the local parish (Figure 4B).
Figure 2. Fürstenfeld monastery in 1701. This lithography by Michael Wenig shows a sketch of the planned new church; the surrounding service and office buildings had already been erected under Balduin Helm’s leadership (Bay. Vermessungsamt, München, with permission).

Figure 3. Fürstenfeld monastery in 1748 (Kath. Kirchenstiftung St. Magdalena Fürstenfeldbruck, with permission).
2.2. Methods for the Analysis of the Skeletal Remains

All material that was contained in the pot was removed and sorted. Besides the human remains, the pot contained several distorted and corroded metal objects, most likely to be clasps. Wood fragments were identified as remnants of a wooden coffin. The bones were found to comprise major parts of a skeleton including the cranium and mandible, most of the long bones, fragments of both os coxae, several vertebral bodies, and several small bones of the feet. There were only three small pieces of mid-shaft ribs. Some of those bones had minor soil residues on the surface which were partly of a reddish colour.

All bones were slightly cleaned, registered, and evaluated according to the presence of the skeletal elements (termed “representativity”) and the condition of the bone matrix (“preservation”). For standardisation, a previously developed and applied scheme was used. This covers 42 regions of the human skeleton and evaluates the presence of the respective skeletal material (0–42 points) and the condition of the bone (0–max. 126 points) with low figures indicating an absent or very fragmented skeleton and extremely poorly conserved bone matrix, respectively [12]. In contrast, high figures indicate the presence of all/most skeletal elements and good/excellent bone preservation, respectively. This system has previously been successfully applied to other small skeletal series [13].

Furthermore, the anthropological investigation was designed to obtain specific information about the sex and age of the individual. Therefore, various approaches were pursued which followed established protocols [14–17]: the identification of sex typical morphological criteria was determined in the cranium and ischiadic bone as far as possible [15]. Since part of the bones (especially the ischiadic bones) were fragmented, thereby limiting the diagnostic power, we additionally determined femoral and humeral head diameters as previously suggested as supplementary information [18]. The analysis of individual age covered the evaluation of the fusion of cranial sutures [19] and morphology of the pubic symphysis [16,17]. Since ischiadic bones were of limited value, we added a supplementary study of cancellous bone from several long bones [20]. Finally, the body height was estimated from long bone measurements wherever possible also using standard protocols [21]. This protocol was applied to both humeri (with the formula: \(BH = (H1/10) + 2.71 + 81.33\)) and radii (with the formula: \(BH = (R1/10) + 2.968 + 97.09\)). This method is well established for historic white male populations, particularly in Central Europe. The resulting values were pooled and then the arithmetic mean determined. Subsequently, all bones were

Figure 4. The clay pot containing the skeletal remains of Abbot Balduin Helm: (A) left: external appearance; (B) right: view into the content of the pot (images: A. Nerlich).
subjected to a CT scan (Siemens Somatom, Quebec City, QC, Canada, 120V, slice thickness 0.6 cm; [22]).

Finally, some small tissue samples were obtained for radiocarbon dating and stable isotope analysis, as well as selected bone tissue histomorphology analysis. For radiocarbon and stable isotope analysis, the tissue samples were taken from the compact bone of the left femur diaphysis. The extraction of collagen and stable isotope analyses of the ratios of carbon, nitrogen, sulphur, and hydrogen isotopes followed the usual protocols [23]. The radiocarbon dating was performed on the femoral collagen following established extraction protocols [24]. Thereby, 3.2 mg material was analysed by accelerator mass spectrometry (AMS) at the Leibniz-Laboratory for Radiometric Dating and Isotope Research, Kiel University (Kiel, Germany) (AMS Type HVE 3MV Tandetron 4130), using the calibration data by Reimers et al. [25].

For the preparation of the histological analyses, the bone samples were rehydrated, fixed, decalcified, and embedded into paraffin wax as previously described [23]; the latter also included immunohistochemical investigations as described [26]. These included parallel negative and positive tests with pre-immune serum and appropriate tissue samples from recent clinical cases [26].

3. Results
3.1. The Anthropological Evaluation of the Skeletal Remains

Within the clay pot, an incomplete skeleton was found of an advanced-aged male individual; several skeletal elements were absent (Figure 5). The estimation of the skeleton’s completeness was 17 points out of 42 possible points (40.5%), and the value for bone structure was 58 out of 72 possible points (80.6%). In summary, roughly half of an adult skeleton was preserved, and the bone matrix was fairly well preserved.

With respect to the sex assessment, the skull was meaningful; the prominent mastoids indicated a male individual (4 points [14]; see Figure 6F). However, the other cranial criteria were less clear with only slightly prominent supraorbital ridges (3 points) and an indifferent form of eye sockets (3 points) and the chin (3 points). The occipital muscular insertion zone was only partly preserved with some prominent bone formation (3–4 points). In total, the skull criteria suggested a male individual although not with very pronounced criteria. Unfortunately, the right ischiadic bone was partly destroyed and therefore was of only limited value for sex determination. Especially the sciatic notch was only partially preserved. The angle measured 61° which would be in favour of a male individual (Figure 6D). Furthermore, the transverse diameter of the left femoral head measured 45.8 mm and a vertical diameter of 44.9 mm; the right humeral head was 45.6 mm (transverse) and 45.2 mm (vertical) and the left humoral head 45.3 mm (transverse) and 45.1 mm (vertical). These values also suggest a male individual [27,28].
Figure 6. Cont.
Figure 6. The skull of Balduin Helm. (A) The frontal view of the cranium showing the complete loss of all maxillary teeth. (B) The view at the skull base showing some post-mortem defects and some minor soil residues. (C) The view at the mandibula with only one retained tooth. Numerous frontal teeth must have been lost intra vitam since the dental alveoli are already closed. (D) The view at the skull surface: all sutures are closed. (E) The lateral view of Balduin’s skull. (F) The detail of the lateral view showing a prominent mastoid (circle) suggesting male sex. (G) Although the right os ischium with the sciatic notch (arrow) is partly destroyed, it is more in favour of a male than a female individual (images: A. Nerlich).

With respect to the individual’s age, we first resorted to cranial criteria [15,17,19]. The complete closure of all cranial sutures including the lateral anterior and the coronal indicated an age of more than 51.5/56.2 years, respectively; the lateral-anterior suture at 15 points suggested 56.2 ± 8.5 1SD, and the complete skull at 21 points suggested 51.5 ± 12.6 1SD) thereby confirming advanced age. A subsequent analysis of the morphology of the pubic symphysis showed a very flat surface without retained grooves. Taking the various previously applied ranking systems into account (five phases in [15], ten phases in [29], and six phases in [16,17]), the following relevant criteria could be evaluated: the shape of the face appeared as irregular with some pitting, the superior apex was flat and had a smooth appearance, the ventral and dorsal margins showed some pitting, and some erosions of these margins stretched over several centimetres in length. Taking the most recent classification into account [16] revealed a phase VI which indicated an individual age of 61.2 ± 12.2 (1SD) and a 95% range between 34 and 86 years.

Finally, we estimated the spongy bone structure of long bones [20] showing the rarefaction of spongy bone to stage 4 which covered a control age group of 56.0 ± 13 (1SD) and an age range between 32 and 86 years.

In summary, age estimation suggested an individual of 60 years of age or more. Since almost all teeth were lost, this feature is also consistent with advanced age (see Figure 6B,C).
With respect to the bone length measurements of intact long bones (left humerus and both radii), we determined a body height of 167 cm ± 2 cm (mean ± 1 SD). The muscle insertion zones in all long bones were not significantly prominent and therefore suggested low physical activity profiles.

3.2. Palaeopathological Analysis

The most prominent finding was the presence of numerous small mixed osteolytic–osteoblastic lesions affecting several bones. This was seen in all available vertebral bodies, the fragments of both os coxae, and occasional lytic lesions in the inner table of the cranium (Figure 7). Besides the bone defects, a tiny network of a newly formed bone matrix can be seen. Furthermore, a section through a lumbar vertebral body showed a central irregular osteolysis of a few millimetres’ diameter with considerable osteoblastic bone reaction at the margins in terms of both irregularly layered and partly spiculated new bone of woven type which partly reached the outer bone surface (Figure 7C). Here, the osteoblastic component of new bone formation dominated. The cranium showed few and mainly osteolytic defects (maximum 1 cm in size) that were primarily affecting the inner cranial bone table (Figure 7D). All these lesions occurred geographically in shape with patchy distribution in the vertebrae and the osa coxae.

Beyond these clearly pathological features, the only minor additional pathology was the lost teeth. On visual inspection, there were no signs of trauma, no evidence for metabolic deficiency (e.g., vitamin deficiency), and the available joints did not show any significant wear or tear such as seen in chronic biomechanical overload, e.g., by specific activities such as dominant-handed work load.

Figure 7. Bone defects in skeletal elements: (A) The superior surface of a fragment of a thoracic vertebral body with significant osteolytic defects with minor osteoblastic reaction. (B) Also, a superior view of a fragment of a lumbar vertebral body with mainly osteoplastic reaction. (C) Cut surface through the vertebral body of B showing central osteolysis with peripheral major new bone formation (arrows). (D) An osteolytic defect in the inner table of the skull (arrows) (C/D: bars = 1 cm) (images: A. Nerlich).

3.3. CT Scans

The scanning of all available bones confirmed the macroscopic observations. All preserved vertebral bodies and the fragments of both os coxae showed widespread mixed osteolytic–osteoblastic bone defects with some dominance of osteoblastic bone formation. These comprised regions of dense new bone formation in an irregular, patchy
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The scanning of all available bones confirmed the macroscopic observations. All preserved vertebral bodies and the fragments of both ossa coxae showed widespread mixed osteolytic–osteoblastic bone defects with some dominance of osteoblastic bone formation. These comprised regions of dense new bone formation in an irregular, patchy distribution pattern with focal small osteolytic defects of less than 1 cm in size (mostly only a few millimetres in size). While some of these lesions reached the bone surface, no major periosteal spicula or peri-/parosteal bone formation was seen. In total, this pattern is highly suggestive of multiple osseous metastases (Figure 8A,B). Additionally, isolated, mostly osteolytic lesions were seen in the skull, mainly lacking the osteoblastic component (Figure 8C). In addition, the CT scans showed additional metastatic infiltration in the mandibular part of the left temporo-mandibular joint which was macroscopically unremarkable (Figure 8D). In contrast, long bones and the few small bones of the feet remain free of abnormal lesions. In general, the mineralisation of the skeleton was fairly well preserved with no signs of significant generalised osteopenia.

In the jaws, the CT scans also confirmed the presence of old-healed tooth loss in the whole maxilla and several more recent ante-mortem tooth losses in the central mandible with still partly preserved dental alveoli. Only the tooth of region 47 was present (Figure 9A). In the paranasal sinuses, the scans show almost complete filling by external soil material (Figure 9A). Finally, the distal right radius shows an oblique bone bar in the distal metaphysis (Figure 9B).
Figure 8. CT scans of the osteolytic–osteoblastic lesions of the skeleton: (A) Sagittal reconstruction through several vertebral bodies showing the extensive mixed osteolytic–osteoblastic bone reaction (arrows). (B) Paracoronal reconstruction through the right pelvic bone fragment also showing extensive mixed bone infiltration (arrows). (C) Parasagittal reconstruction through the cranium with a circumscribed osteolysis, mainly of the inner skull bone table (arrows). (D) Axial reconstruction through the skull showing an additional presumed metastasis in the left temporomandibular joint (circle); note the soil residues in the maxillary sinus (arrows) (images: S. Panzer).
3.4. Radiocarbon Determination and Stable Isotope Testing

A sample from the right femur was used for radiocarbon and stable isotope analysis. The calibrated $^{14}$C value matched with two time periods (Figure 10) which covered the time frames (95% probability) of 1509–1594 CE and 1618–1661 CE. These ranges have to be adjusted for the effect of metabolism in the cortical femoral bone of approximately 29-32 years [30,31]. Both ranges do not match with Abbot Balduin’s known date of death (1720CE) and have to be considered in combination with stable isotope values and the general discussions below.

Figure 9. Further CT scan features: (A) Coronal reconstruction through the skull showing soil in the paranasal sinuses (arrow). Note the single preserved tooth in region 47 (circle). (B) The coronal reconstruction of the right radius showing an oblique bone bar in the distal radial metaphysis (circle) (images: S. Panzer).
Figure 10. The calibrated radiocarbon date profile of a femur sample (radiocarbon date profile [25]).

For the stable isotope values, sufficient bone collagen was extracted with a yield of 16.5%. The ratio of carbon to nitrogen (C:N ratio) ranges at 3.14 and indicated excellent collagen quality. The detailed results were as follows:

\[
\begin{align*}
\delta^{13}C \left[\%_{\text{V-PDB}}\right] & : -20.0 \\
\delta^{15}N \left[\%_{\text{AIR}}\right] & : 12.5 \\
\delta^{34}S \left[\%_{\text{V-CDT}}\right] & : 6.6 \\
\delta^{2}H \left[\%_{\text{V-SMOW}}\right] & : -2.3
\end{align*}
\]

Accordingly, Abbot Balduin’s diet mainly contained food products based on C3 plants. The nitrogen value indicates a considerable proportion of animal protein, both from terrestrial animals and also freshwater fish. There was no evidence for marine fish consumption. A further evaluation is given below.

3.5. Bone Histology and Immunohistochemistry

Bone material was taken from one of the macroscopically and radiologically suspicious mixed osteolytic–osteoblastic lesions of a vertebral body. Following fixation and decalcification, histological sections were routinely stained. The resulting pattern shows appositional irregular woven bone trabeculae (Figure 11A) which is consistent with an osteoblastic bone reaction. Subsequent sections were stained immunohistochemically using monospecific antibodies against a surface protein which is highly selective for prostate-specific antigens (PSAs). Small residues in the marrow cavities showed positive staining consistent with the prostatic origin of the tumour infiltration (Figure 11B). Pre-immune serum controls were entirely negative.
Figure 11. The histomorphology of tumour tissue found in a vertebral body: (A) Routine staining (H&E stain) showing irregular newly built woven tumour bone (arrows) enclosing small residues of tumour tissue in the marrow (bar = 20 µm). (B) The immunohistochemical detection of PSAs (red colour; circles) indicating a prostate metastasis (images: A. Nerlich).

4. Discussion

This paper describes the interdisciplinary findings in an aged male skeleton of an historic person. Abbot Balduin was a prominent leader of one of the most important monasteries in late 17th- to early 18th-century Bavaria; accordingly, he can be regarded as an eminent local person. The detection of numerous osseous metastases, mainly in his axial skeleton, and the immunohistochemically verified origin of prostate carcinoma make this case interesting both for the history of early modern era and for paleo-oncology.

4.1. The Authentication of the Skeletal Material

The skeletal material found in the clay pot contained nearly half of the skeleton of an advanced-aged male. Although the state of preservation limited the evaluation of certain criteria, the anthropological findings at the skull and femoral/humeral heads are in favour of a male individual with a not very pronounced expression of gender criteria. However, in the context of this individual, a high-ranked abbot buried in a specifically labelled burial context in a male monastery’s cemetery, there is no real doubt as to the individual’s sex which is also confirmed by the palaeopathological findings of prostate cancer, since Skene gland adenocarcinoma of women (the equivalent to male prostate cancer) has yet to be reported in not many more than 20 cases worldwide [32]!
As to the individual’s age, the findings confirmed an age of significantly more than 55 years, ranging up to 80 years. The written information indicated that Abbot Balduin died at the age of 75 years which is in keeping with the skeletal findings. Further information reported that the body of Abbot Balduin obviously had first been buried in a tomb in the monastery’s cemetery [11]. As stated above, his remains were officially translated into the renovated crypt [9]. The clay pot of Abbot Balduin’s remains accordingly was sealed by this Royal Commission, so the human remains within the pot are those of Balduin Helm with very high probability. According to this translation, considerable soil material was found, for instance, in the paranasal sinuses, with the staining of the bone surface from red bricks, as well as small fragments of wood from the coffin. This is consistent with a previous burial in a cemetery with a subsequent exhumation of the remains into a pot and transference to the crypt.

The discrepancy in the radiocarbon data suggests that these remains were of a skeleton that predeceased Abbot Balduin’s death by a number of decades. Taking the calibrated 14C values into account, the date ranges can be considered between 1509 and 1594 CE and 1618 and 1661 CE.

Taking these significant differences between the known time of death and the radiocarbon dating into account, two facts have to be regarded: Firstly, there exists a mean lag time of collagen turnover, i.e., the average residence time of the carbon in the collagen. It includes both carbon that has been in the collagen for some time and carbon that has only recently been incorporated into the collagen. In the femur of adults, the annual collagen remodelling is around 2–3% [33] which means that complete collagen turnover ranges at about 50 years. Previous studies indicate that 29–32 years is a reasonable period for the lag time between the radiocarbon age and the actual time of death of Abbot Balduin [30,31]. Accordingly, the aforementioned radiocarbon date has to be corrected by this period. This, however, does not explain the large presumed difference of between 59 and up to 200 years.

The second possible influence may come from the so-called radiocarbon reservoir effect (RRE) which comes from the aquatic food chain, when “old” carbon from calcareous sediments may be incorporated into the body tissues of the consumer [34,35]. There exists a well-known example for a significant freshwater RRE: the radiocarbon dating of Queen Editha, wife of Emperor Otto II (ca. 910–946 CE), showed calibrated radiocarbon data that were 115 years older compared to her actual time of death—most probably as a result of a freshwater RRE [36,37]. For Queen Editha, a protein proportion of fish of 18 and 9% of the total protein in the diet was estimated (depending on variable repeated determinations), corresponding to a reservoir effect of around 170 and 80 years, respectively [37]. A radiocarbon reservoir effect has been documented in several lakes, and its effect is highly variable. It may result in a time lag of around 1000 years as in Lake Tegernsee (Bavaria) [38]. This means that the consumption of fish from waters in the foothills of the Alps may have a considerable influence on the radiocarbon age and leading to an erroneous older 14C dating. For Abbot Balduin, a 15% share of fish protein in the diet (due to the typical Benedictine monastic rules: every Friday + periods of fasting) would cause a shift in the age at death of around 150 years, given an RRE of inland fish of around 1000 years. Taking into account a lag time of 29–32 years for the femoral collagen [30,31], we can expect a shift in the age at death of 179/182 years under these conditions. Considering the RRE and the mean lag time factor mentioned above, the calibrated time periods of our radiocarbon dating (both 1509–1594 AD and 1618–1661 AD) fit well with the time of death of Abbot Balduin—depending on the amount of freshwater fish consumed. Based on the high nitrogen isotope value, we can almost certainly assume a not insignificant proportion of fish in his diet.

Unfortunately, there is no information on where the Fürstenfeld monastery received their fish supply. Also, as yet, there do not exist radiocarbon reservoir effect data on nearby lakes, such as Lake Ammersee, or other smaller lakes or fish ponds. The sulphur isotope value excludes major marine fish consumption which might have occurred as with dried fish (stockfish or dried cod).
In summary, we have firm indicators that the human remains are those of Abbot Balduin Helm and that the result of radiocarbon dating was influenced by a freshwater reservoir effect that can be assumed for the fish from the limestone-rich waters of the Alpine foothills.

4.2. Metastatic Carcinoma

The most prominent pathological findings were multiple mixed osteolytic–osteoblastic tumoral lesions in the axial parts of the skeleton comprising all of the few available intervertebral bodies and pelvic bone fragments and a few lesions in the skull, whereas none were found in all available long bones. Taking the potential differential diagnoses of those multiple lesions into account, we can exclude benign tumours but also tumour-like lesions (e.g., secondary hyperparathyroidism, etc.) on the basis of the multiplicity of lesions and the osteo-aggressive pattern [39]. Similarly, multiple tumour-like infectious manifestations (tuberculosis, leprosy, syphilis) can be ruled out due to the radiological pattern and the distribution of the lesions. Primary malignant bone tumours (osteoclast- or histiocytic tumours) are usually uni- or oligofocal; multiple myeloma does not present with an osteoblastic reaction. Taking these considerations into account, the most likely diagnosis is therefore metastatic carcinoma [2–5,7,8] which accounts for more than 90% of all tumoral bone lesions [39].

Among metastatic carcinomas of different origin, both the macro-/micro- and radiomorphological pattern have to be considered. Mixed osteoblastic–osteolytic metastases may occur in a whole variety of tumour types, primarily including lung cancer, renal cancer, and, in males, prostate cancer, while most other primary tumours produce mainly osteolytic lesions and/or usually also affect long bones (e.g., gastrointestinal, liver, and bladder cancer). Accordingly, the primary tumours with the highest probability for the pattern in the present case are lung and prostate cancer. The final diagnosis in our case was ultimately established by the immunohistochemical detection of a prostate-specific antigen in the tumour residues in the lesions such as previously shown both by chemical (7) and immunohistochemical techniques (4) in historical samples. Accordingly, the diagnosis of a metastatic prostate cancer was established.

Prostatic carcinoma is the most common malignant tumour in modern elderly males [40]. This diagnosis also clarified Balduin Helm’s cause of death, namely cachexia from disseminated metastatic prostate carcinoma. Assuming a similar clinical course to modern populations in historic ones, and the absence of effective therapies, it can be assumed that the time course for the malignancy was at least several months to many years [40]. The extensive involvement of the vertebra and pelvic bones must have almost certainly led to significant pain symptoms in the later stages, with the final one being a wasting disorder [41]. With respect to the extensive loss of teeth, despite a presumed healthy diet, it may be speculated that the premature loss of teeth due to extensive periodontitis may have contributed to an enhanced cancer risk as previous data particularly suggest increase prostate cancer rates in long-term periodontitis [42,43]. Finally, the loss of almost all the remaining teeth not long before death may have come from an extended moribund phase in the diseased.

4.3. Further Pathological Findings

Besides the multiple metastases and the tooth loss, this investigation showed only a few additional disorders; most cases of intra vitam tooth loss in historic populations is due to poor dental health, e.g., extensive chronic periodontitis or the lack of dental hygiene [12], but it remains unproven in this case.

There was no evidence for bony trauma either macroscopically or on CT scanning. The right radius showed an oblique hyperdense bone line, which is an unusual finding and is also called a reinforcement bar. The pathogenesis is uncertain. It is considered to be similar to a Harris growth arrest line although this is typically perpendicular to the bone cortex and associated with illness in children. When found in the elderly, it is usually associated with chronic osteopenia [44,45]. Here, the reduction in size and lost trabeculae
reveals the bone bar which is presumed to develop due to bone remodelling in response to mechanical stresses (Wolff’s Law [46]).

Finally, we have no evidence for further osteopathy and no sign of significant wear or tear of joint surfaces in keeping with the abbot not having heavy physical duties.

### 4.4. Balduin’s Diet and Nutrition

There was good evidence that Abbot Balduin’s diet contained considerable amounts of freshwater fish, presumably from local waters. The isotope data provided further information that showed, in general, he ate well. Although there are no directly comparable data from the Fürstenfeld monastery or a nearby contemporary site, there do exist data on contemporaneous or socially comparable individuals in the literature. There are skeletal remains from a non-monastic cemetery of the monastery of Herrenchiemsee (a convent on an island of Lake Chiemsee, Bavaria; [47]), several provosts and clerics of Waldhausen monastery (Upper Austria; including the so-called “Luftgelschter Pfarrer” [48,49]), and finally contemporaneous aristocrats from Sulzbürg (the Counts of Wolfstein, [50]). These show comparable levels of isotope values and thus a very high-quality nutrient supply (see Figure 12). The carbon isotope value also indicates a diet based on C3 plants as is common in Southern Germany and a high content of animal protein.

In summary, it can be assumed that the abbot had a high-quality diet in adequate amounts. Since the stable isotope values are the accumulated results over a long period of time (around 30 years), any final wasting secondary to the malignant tumour cannot be expected to show up in those data.

![Figure 12](image: Ch. Lehn).

### 4.5. The Scenario of the Life of Abbot Balduin

Figure 12. Cont.
4.5. The Scenario of the Life of Abbot Balduin

Combining historical information and biomedical data supplements the biography of this individual. The diagnosis of a metastatic prostate carcinoma adds to paleo-oncological knowledge [1–5]. Therefore, Balduin Helm’s life can be summarised as that he was born in a middle-class family of the mid-17th century. Early in his life, he decided to enter the monastery of Fürstenfeld, one of the most important in Central Bavaria at that time. There, he rapidly advanced by virtue of his ecclesiastical activities to the position of abbot at a time when not only the scars of the Thirty Years’ War had healed, but monasteries regained economic activity and gained considerable wealth. In this position, he initiated the complete rebuilding of the monastery. Political interference by the upcoming War of the Spanish Succession, and the temporary flight of the Bavarian Elector to the Spanish Netherlands, interrupted his career and, in 1705, very abruptly ended his service as an abbot. His final 15 years were spent with him living quietly in the monastery.

He was, by virtue of his high social rank by becoming an abbot, very well supplied with food likely to comprise entrails, meat, fish, and also alcohol. In excess, these can be unhealthy. Otherwise, during the first decades of his life, he did not suffer from obvious major disorder, at least that manifested in his skeleton, except for the complete loss of the teeth of the maxilla and several teeth of the mandible. This, however, was quite a frequent occurrence in advanced-aged individuals at this time and included monastic communities, probably due to poor dental health care and the lack of oral hygiene [12]. Beyond this, his most important health problem was the development of prostatic cancer which may have affected him symptomatically in his very final years or even only for his final months of life. This final period must have been difficult for him, despite all possible support in the well-supplied monastery. It can be assumed that he suffered from significant back pain from bone metastases, a frequent complication of spread to the vertebrae and pelvis [51].
In addition, he seemed to have lost most of his remaining frontal teeth, possibly from periodontitis, which frequently occurs in the wasting-associated complications of untreated or poorly managed cancer patients in the modern era [41].

Finally, this is not only an interesting interdisciplinary biography of a high-ranked 17th-century individual but also a further case of historical metastatic cancer. In this regard, the observation continues previous discussions about the presence and absence of cancer in human history. In this case, the relative longevity of this otherwise very well-resourced person may have contributed to his cancer risk. This supports the previous notion that the relatively low numbers of documented cancer cases in history may have mainly been influenced by the short life expectancy [41]. A further interesting aspect of the present case is that the high level of protein-rich nourishment may have even increased his individual cancer risk [40]. In this respect, it is interesting that a recent study showed that, even with the temporal increase in adult human lifespan, the increase in malignant neoplasms of bone between the medieval and industrial time periods was still statistically significant [51]. The authors concluded that an augmented exposure to carcinogens and pollution during the Industrial Revolution had a stronger effect on an individual’s susceptibility to developing a malignant disease of bone than simply the extension of the lifespan. Accordingly, this question requires several more comparable cases than ours in order to clarify all arguments.


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