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RESEARCH ARTICLE

Novel multidisciplinary approach detects multiple individuals within the same Late Bronze–Early Iron Age cremation graves

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Abstract

Cremation graves appear in different forms and shapes, from urns to simple pits and from single to plural graves. The challenging nature of highly fragmented cremated human remains renders the identification of multiple individuals within the same cremation grave rather complex. Osteological analyses alone are often insufficient to detect the presence of bone fragments from different individuals as they are small and diagnostic elements are often missing, although, detection of nonadult bone fragments within adult bone assemblages (or the other way around) points to the presence of at least two individuals—one adult and one nonadult—within the same grave. The combination of osteological analyses, radiocarbon dating, and strontium isotope ratios has proven to be particularly powerful. At different Belgian Metal Age sites, this novel multi-disciplinary approach enabled to identify the presence of bone fragments belonging to up to three different individuals within the same cremation grave who were cremated up to several centuries apart. Whether the presence of these two or three individuals in the same grave is intentional (e.g. curation) or not requires more in-depth analyses. This study shows the high level of complexity of cremation burial (intentionally or not) and shows the necessity to carry out all analytical measurements (i.e. radiocarbon dating, infrared, elemental and isotope analyses) on the same bone fragment to ensure the results are related to the same individual.

Introduction

Throughout Northwestern Europe, from the Neolithic to the Early Middle Ages, two main funerary rituals took place: cremation and inhumation (Capuzzo et al. 2020, 2023; Rebay-Salisbury 2017). They sometimes co-occurred or happened successively within the same region, or even on the same burial ground (e.g. Lippok 2020; Snoeck et al. 2016, 2020; van den Broeke 2014; Veselka et al. 2021a). The reasons behind the choice of one ritual instead of the other are still poorly understood and widely debated (e.g. Lippok 2020;

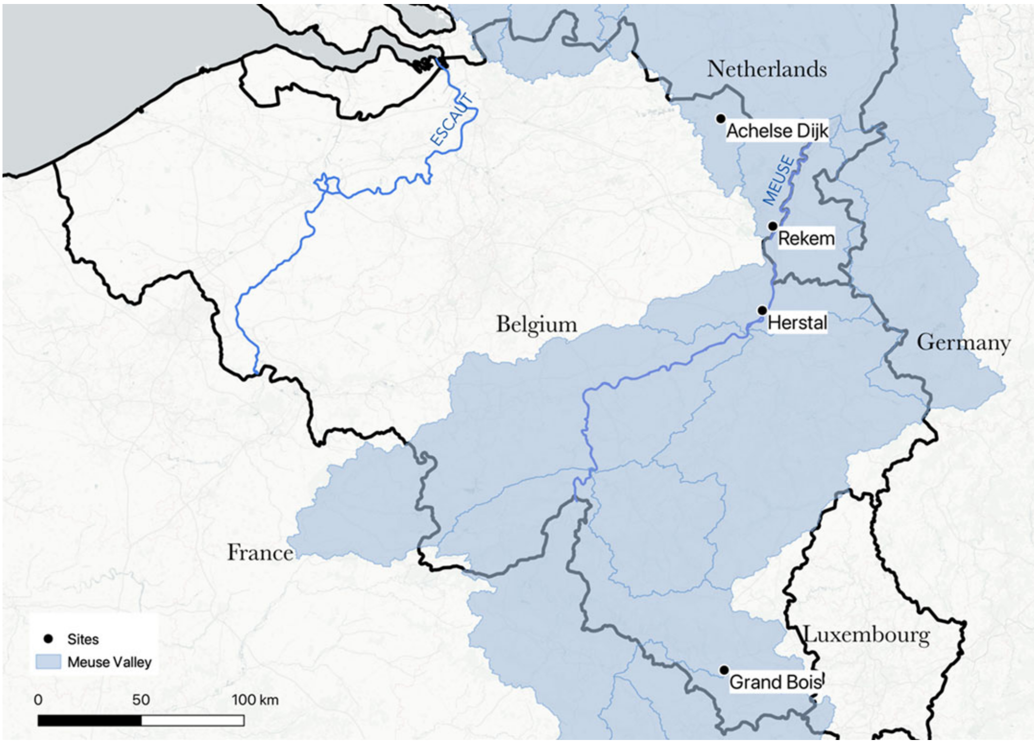

Figure 1. *The location of the studied LBA–EIA sites in the Meuse Valley, Belgium.*

Rebay-Salisbury 2017). The study of cremated remains is rendered even more complex due to the highly fragmented nature and often incompleteness of the human remains found in such burials. Indeed, cremation was the main funerary practice in the Belgian Meuse valley during the Late Bronze (LBA)–Early Iron Age (EIA) and due to the fragmentary aspect of the human remains, cremation graves were either not studied or the older studies provide limited information, highlighting the need for new and in-depth research (De Mulder 2011; Sabaux et al. 2021; Stamataki et al. 2021).

With just osteological analysis of the bone material within a cremation deposit, it is not possible to ensure that all the human bone fragments in the grave belong to a single individual. Even if ageing and sexing methods have been adjusted and adapted to cremated remains in the past years (e.g. Hlad et al. 2021; Veselka et al. 2021b), the Minimum Number of Individuals (MNI) is still commonly based on the presence of multiple unique skeletal elements and differences in bone robusticity (e.g. adult vs. nonadult) (Albanese et al. 2005; Cavazzuti et al. 2019; Gejvall 1963; Gonçalves 2011; Gonçalves et al. 2013; Osipov et al. 2013; Thompson 2002; Van Vark et al. 1996). However, those elements are often absent making the MNI of cremation deposits imprecise.

In the early 2000s, it has been shown that reliable radiocarbon dates could be obtained from fully calcined bones (Lanting et al. 2001; Van Strydonck et al. 2010; 2005). In addition, it was also demonstrated that calcined bone provides a reliable substrate for strontium isotopes ($^{87}Sr/^{86}Sr$) analysis in archaeological contexts (Snoeck et al. 2015, 2018) and strontium isotope analyses are now widely applied across Europe (Snoeck et al. 2022). A recent study in Belgium on the LBA site of Herstal “Pré Wigier” (Figure 1) combining $^{87}Sr/^{86}Sr$ with radiocarbon dating highlighted higher MNI in two of the graves than defined by the osteological study alone (Sabaux et al. 2021). In grave 4, two individuals were identified by combining $^{87}Sr/^{86}Sr$ and radiocarbon dating while only one was determined by osteological analysis. Similarly, in grave 6, two individuals were determined osteologically, but the combination of radiocarbon dates and $^{87}Sr/^{86}Sr$ showed that at least three individuals were present. Some of the calcined diaphyses found in these two graves had indeed quite

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Table 1. *Typology and description of each deposit per grave*

Graves	Grave typology	Deposit A	Deposit B
Herstal 4	A	Bones in the urn	Bones in an accessory vase in the urn
Herstal 6	B	Bones and charcoal in the urn	Bones and charcoal in the pit, under the urn
Achelse Dijk 9	C	Bone pack in the pit	Bone pack in the pit
Grand Bois 23	H	Bones in the urn 1	Bones in the urn 2 (+ fragments of bones dispersed on the pyre)
Grand Bois 41	H	Bones and charcoal in the urn	Bones dispersed in the pit
Rekem 85-143	A	Bones in the urn	Bones and charcoal in an accessory vase in the urn

different $^{87}Sr/^{86}Sr$ (> 0.0010) and thus unlikely belong to the same individual. Furthermore, they returned radiocarbon dates up to more than a century apart. These three individuals from Grave 6 of Herstal were all nonadults, while in general, nonadults are associated with adults in LBA–EIA plural burials (Larentis 2023; Sørensen and Rebay-Salisbury 2023). The presence of different individuals belonging to different time periods within a single cremation deposit raises the issue of intentionality and potentially of bone curation (Booth and Brück 2020; Brück and Booth 2022; Rebay-Salisbury 2018).

The aim of this paper is twofold: first, understand if the phenomenon of multiple deposits containing bones belonging to different chronological events in a single cremation grave appears elsewhere in the Meuse valley, Belgium, or if it is unique to Herstal. Second, demonstrate how combining osteological analyses with radiocarbon dates and $^{87}Sr/^{86}Sr$ improves the assessment of the MNI in cremated graves and how the method can be used on a larger scale. This study also highlights the importance of carrying out $^{87}Sr/^{86}Sr$ analyses and radiocarbon dating on the same bone fragments to enable direct comparison of the $^{87}Sr/^{86}Sr$ results and the radiocarbon dates.

Material and methods

For this research, graves 4 and 6 of Herstal "Pré Wigier" studied in Sabaux et al. (2021) were reanalyzed, additional samples were taken from grave 4, and four graves with separate bone deposits from three additional sites from the Meuse Basin were included (Figure 1; Table 1). Herstal, near Liège, was excavated between 1965 and 1966 and presents 21 graves from the LBA to the EIA transition (Sabaux et al. 2021). Grave 6 consisted of a small pack of bones on which an urn containing bones and charcoal was deposited (Alenus-Lecerf 1974). Grave 4 contained an urn filled with cremated remains and in which an accessory vase also containing several bone fragments was buried (Alenus-Lecerf 1974). The site of "Grand Bois", near the village of Saint-Vincent, located in the province of Luxembourg, was excavated from 1882 to 1964 during several excavation campaigns. In this LBA–EIA site, at least 88 tumuli with cremation graves were found. Two of those graves, 23 and 41, present double bone deposits. Grave 23 contained two urns with cremated bones and few other bone fragments were present on the surface of the pyre (Mariën 1964). According to the author, the urns were placed in the grave simultaneously. Grave 41 contained an urn filled with cremated bones and charcoal in and around it. The urn was deposited on the pyre and was covered by a tumulus of 4 m diameter. Several cremated bone fragments were still scattered on this pyre (Mariën 1964). Grave 9 from the LBA site of "Achelse Dijk" in Neerpelt, in the Limburg province, was excavated in 1962–64. The cremation deposit seems to be a block of bones divided into two deposits (9t4 and 9u4) (Roosens et al. 1975). The last analyzed grave, 85-143, belongs to the site of Rekem "Hangveld", also in the Limburg province.

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This BA–Iron Age (IA) cemetery contains more than 236 cremation deposits and was excavated in the 20th century. Grave 85-143 presents a biconical urn filled with cremated bones and few fragments of charcoal (Temmerman 2007; Van Impe 1980).

The methods for typology, osteoarchaeological analysis, $^{87}Sr/^{86}Sr$ analyses and radiocarbon dating used in the study are fully described in Sabaux et al. (2021) and can be found in SI. The six cremation graves were characterized using the archaeological reports of the sites and the typological classification of De Mulder (2011). De Mulder's funerary urn typology (2011) has been created to describe the cremation burials in the Scheldt valley and was successfully applied to the study of Herstal (Sabaux et al. 2021). Since those six graves had two bone deposits each (A and B), both deposits were sampled. In total, between two and sixteen bone fragments were taken per grave for $^{87}Sr/^{86}Sr$ analyses. All $^{87}Sr/^{86}Sr$ were carried out at the Université Libre de Bruxelles (ULB) and the Vrije Universiteit Brussel (VUB) following Snoeck et al. (2015). In total, 62 calcined bone fragments from the six graves were used (19 samples from Sabaux et al. (2021) plus 43 additional samples. From each cremation deposit, if available, diaphyseal, rib, and cranial fragments were selected to take bone turnover into account as ribs have a faster remodelling rate than diaphysis (Clarke 2008; Fahy et al. 2017). A difference in strontium isotope ratios between two diaphysis or two rib samples ($\Delta^{87}Sr/^{86}Sr$) larger than 0.0010 is taken here as a threshold to consider two diaphysis or two rib fragments to belong to two distinct individuals. Nevertheless, this value has to be taken with cautions as Sr turnover rates in bone are still poorly understood and the variations between bones of the same individual also depends on the variability in $^{87}Sr/^{86}Sr$ of the different foods available to a particular individual.

Radiocarbon dates were performed on 19 calcined bone fragments selected amongst those used for $^{87}Sr/^{86}Sr$ analyses (i.e. $^{87}Sr/^{86}Sr$ and radiocarbon dates were obtained from the same bone fragments). The radiocarbon dating procedure followed the Royal Institute for Cultural Heritage (KIK-IRPA, Brussels, Belgium) protocol (Boudin et al. 2015; Van Strydonck et al. 2005, 2009; Wojcieszak et al. 2020). In total, the radiocarbon dates of 26 calcined bone fragments (7 dates from Sabaux et al. 2021 and 19 additional dates) from six different graves (Herstal 4 and 6, Achelse Dijk 9, Grand Bois 23 and 41, Rekem 85-143) were calibrated using the software OxCal 4.4 (Bronk Ramsey 2009) and the IntCal20 calibration curve (Reimer et al. 2020). Multiple radiocarbon measurements from the same graves were statistically tested for contemporaneity using the R_Combine tool in OxCal 4.4, providing information on the consistency of the time series via a χ^2-test (Ward and Wilson 1978).

Results

To categorize the different graves, the main deposit (deposit A) of each grave was compared to De Mulder's typology (Table 1). Graves 4 and 6 of Herstal were characterized respectively as type A: urn graves containing burnt bone material and possible grave goods and type B: urn containing burnt bones and pyre remains, such as charcoal (Sabaux et al. 2021). Achelse Dijk is defined based on the archaeological survey from the report as a type C, as "bone pack grave", bundled burnt bone material suggestive of the use of an organic container, while graves 23 and 41 of Grand Bois are type H, bone selected and deposited in an urn on the pyre location, according to their description. The grave 85-143 is defined as a type A (Temmerman 2007).

The total weight of the cremations varies between 28.3 and 1172.0 grams, and 4 out of 6 graves contained animal bones (Table 2). The osteological results of Herstal identified a MNI of one individual in grave 4 and two individuals in grave 6 based on the presence of two right petrous part and differences in dental age (Sabaux et al. 2021). For Grand Bois 23, one adult of more than 18 years based on the vertebral rims fusion is identified and for 41, one nonadult between 13 and 18 years old based on the unfused coracoid process of the scapula. The individual of grave 9 from Achelse Dijk could not be identified due to the small amount and high fragmentary state of the bone material. Rekem 85-143 might present two individuals: one adult between 19 and 40 years and another of unknown age according to

Table 2. *Osteological results*

Graves	MNI	Sex	Age general	Age (years)	Animal bone	Total weight (g)	Weight A (g)	Weight B (g)
Herstal 4*	1	M	Adult	19–40	No	28.3	8.5	17.8
Herstal 6*	2	NA	2 Non-adults	0–6/7–12	Yes	155.9	103.3	52.6
Achelse Dijk 9	1	I	I	I	No	223.6	76.5	147.1
Grand Bois 23	1	I	Adult	18+	Yes	898.9	852.4	46.5
Grand Bois 41	1	NA	Non-adult	13–18	Yes	750.3	516.0	234.3
Rekem 85-143	1 or 2	I	Adult	19–40	Yes	1172.00	/	/

*Data from Sabaux et al. (2021); M = male, NA = not applicable, I = indeterminate.

Temmerman (2007). If the weights per deposit of each grave are compared, the highest weight is in 67% of the cases (4 out of 6) associated with deposit related to the principal container.

The calibrated radiocarbon dates (Table 3, Figure 2) from the cremation deposits range from LBA to EIA, from the 12th to the 6th century BC. Large calibrated confidence intervals have been obtained for the dates falling on the Hallstatt plateau, between 800 and 400 BC in the IntCal20 calibration curve which was caused by variation in solar activity (Pearson et al. 1983; Stuiver and Becker 1986; Wijma et al. 1996; van der Plicht 2004). Performing a χ^2-test permits to obtain more precise and accurate radiocarbon dates with narrower confidence intervals and to detect if two samples from the same grave belong to the same chronological event or not (Ward and Wilson 1978). It is important, however, to keep in mind that because of a potential old-wood effect two bone fragments that do not belong to the same chronological event, based on the radiocarbon dates, could still belong to the same individual (see discussion).

For grave 4 of Herstal, the χ^2-test of the dates with ID 08055 and 08066 in deposit A were too far apart to belong to the same chronological event (T = 7.5; 5% = 3.8; df = 1), with 08055 being between 64 and 185 years older than 08066 for 1σ probability, calculated using the tool Difference in OxCal 4.4. The same phenomenon was observed in grave 6 (T = 20.3; 5% = 9.5; df = 4), permitting to identify the radiocarbon dates belonging to at least two distinct chronological events. Three new dates were performed on samples from grave 4 and confirmed the presence of radiocarbon dates belonging to distinct chronological events (Table S1), samples 08458 and 08100 returning dates close to sample 08066 (T = 0.2; 5% = 6.0; df = 2) while 08108 returning dates closer to 08055 (T = 0.7; 5% = 3.8, df = 1). Those new samples are indeed too far apart to belong to the same event (08458, 08100, 08108 – T = 21.891; 5% = 6.0; df = 2).

Radiocarbon dates from grave 9 from Achelse Dijk cover a large time span between 257 and 671 years for the 1σ probability, calculated using the tool Difference in OxCal 4.4. (179–1201 years for the 2σ probability). The χ^2-test shows that the dates (08460, 01329, 08461, 01328, 08462) do not correspond to the same chronological event (T = 185.995; 5% = 9.5; df = 4). The tests further revealed that at least three distinct chronological events are represented. 08460 and 01329 returning similar ^{14}C dates (T = 1.8; 5% = 3.8; df = 1), 08461 being different to all other dates (see table 3), and 01328 and 08462 returning similar dates as well (T = 1.0; 5% = 3.8; df = 1). The grave was a pack of bones split in two deposit (A and B—Table 1) and the three bones with the oldest radiocarbon dates came from deposit A, while the fragments with the most recent dates came from deposit B (see Figure 2).

Graves 23 and 41 from Grand Bois present in both case one sample in deposit A that is older than the other ones. Indeed sample 04226 (T = 23.634; 5% = 9.5; df = 4) in grave 23 stands alone while samples 08464, 08463, 04227, 05097 seem to belong to the same time event (T = 3.5; 5% = 7.8; df = 3). The same pattern is identified in grave 41, 04224 is isolated (T = 52.044; 5% = 7.8; df = 3) while 08192, 08191, 04225 return similar dates (T = 0.8; 5% = 6; df = 2). Eventually, for grave 85-143 from Rekem, the χ^2-test indicated that the dates with ID 08381 (deposit A) and 08382 (deposit B) are too far apart and do not belong to the same chronological event (T = 7.978; 5% = 3.8; df = 1).

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Table 3. Radiocarbon dates and $^{87}Sr/^{86}Sr$ of the calcined human bones

CRUMBEL ID	Graves	Deposit	Bone type	Lab number	^{14}C years BP	Cal BCE (95.4%)	$^{87}Sr/^{86}Sr$	2SE
01329	Achelse Dijk 9	A	Diaphysis	RICH-29640	2772 ± 24	994–834	0.714580	0.000011
08150	Achelse Dijk 9	A	Diaphysis	/	/	/	0.714670	0.000014
08460	Achelse Dijk 9	A	Diaphysis	RICH-30829	2819 ± 26	1047–905	0.714679	0.000008
08461	Achelse Dijk 9	A	Diaphysis	RICH-30830	2583 ± 26	810–596	0.708793	0.000010
01328	Achelse Dijk 9	B	Diaphysis	RICH-29634	2466 ± 28	760–420	0.712869	0.000011
08146	Achelse Dijk 9	B	Diaphysis	/	/	/	0.714125	0.000014
08149	Achelse Dijk 9	B	Cranial	/	/	/	0.713642	0.000013
08152	Achelse Dijk 9	B	Rib	/	/	/	0.713818	0.000013
08462	Achelse Dijk 9	B	Diaphysis	RICH-30831	2427 ± 26	746–405	0.713890	0.000010
04226	Grand Bois 23	A	Diaphysis	RICH-28731	2655 ± 30	899–787	0.711456	0.000015
05096	Grand Bois 23	A	Cranial	/	/	/	0.712268	0.000020
08032	Grand Bois 23	A	Diaphysis	/	/	/	0.711943	0.000012
08117	Grand Bois 23	A	Rib	/	/	/	0.711120	0.000061
08121	Grand Bois 23	A	Cranial	/	/	/	0.712244	0.000018
08257	Grand Bois 23	A	Diaphysis	/	/	/	0.712237	0.000014
08463	Grand Bois 23	A	Diaphysis	RICH-30832	2522 ± 25	787–546	0.712272	0.000011
08464	Grand Bois 23	A	Diaphysis	RICH-30834	2539 ± 27	795–549	0.712741	0.000010
04227	Grand Bois 23	B	Diaphysis	RICH-28733	2505 ± 27	778–542	0.711074	0.000015
05097	Grand Bois 23	B	Diaphysis	RICH-30841	2474 ± 25	768–478	0.712014	0.000017
05098	Grand Bois 23	B	Cranial	/	/	/	0.710766	0.000013
08113	Grand Bois 23	B	Cranial	/	/	/	0.711608	0.000019
08256	Grand Bois 23	B	Diaphysis	/	/	/	0.711636	0.000011
08465	Grand Bois 23	B	Diaphysis	/	/	/	0.711396	0.000014
04224	Grand Bois 41	A	Diaphysis	RICH-28706	2743 ± 28	971–816	0.713096	0.000021
05111	Grand Bois 41	A	Cranial	/	/	/	0.711036	0.000013
08028	Grand Bois 41	A	Rib	/	/	/	0.711031	0.000011
08035	Grand Bois 41	A	Diaphysis	/	/	/	0.711147	0.000013
08120	Grand Bois 41	A	Rib	/	/	/	0.711281	0.000024
08191	Grand Bois 41	A	Diaphysis	RICH-29632	2497 ± 29	777–518	0.711011	0.000015
08192	Grand Bois 41	A	Diaphysis	RICH-29635	2531 ± 24	791–549	0.710942	0.000014

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04225	Grand Bois 41	B	Diaphysis	RICH-28707	2519 ± 25	786–545	0.711068	0.000037
05112	Grand Bois 41	B	Cranial	/	/	/	0.711122	0.000022
08029	Grand Bois 41	B	Rib	/	/	/	0.711855	0.000010
08031	Grand Bois 41	B	Diaphysis	/	/	/	0.710904	0.000012
08114	Grand Bois 41	B	Rib	/	/	/	0.711211	0.000020
08012*	Herstal 4	A	Rib	/	/	/	0.712491	0.000012
08055*	Herstal 4	A	Diaphysis	RICH-28092	2901 ± 25	1201–1008	0.712142	0.000016
08066*	Herstal 4	A	Diaphysis	RICH-29015	2806 ± 24	1043–899	0.713393	0.000015
08067*	Herstal 4	A	Cranial	/	/	/	0.712886	0.000013
08108[T]	Herstal 4	A	Cranial	RICH-30784	2957 ± 28	1262–1055	0.712412	0.000016
08458	Herstal 4	A	Diaphysis	RICH-30785	2795 ± 25	1013–846	0.712466	0.000010
08068*	Herstal 4	B	Cranial	/	/	/	0.712447	0.000011
08069*	Herstal 4	B	Rib	/	/	/	0.712610	0.000015
08100[T]	Herstal 4	B	Cranial	RICH-30783	2812 ± 25	1046–901	0.712669	0.000020
04236*	Herstal 6	A	Diaphysis	RICH-28697	2730 ± 26	921–816	0.711697	0.000015
06088*	Herstal 6	A	Diaphysis	/	/	/	0.711545	0.000011
06089*	Herstal 6	A	Rib	/	/	/	0.711735	0.000010
08049*	Herstal 6	A	Diaphysis	RICH-29024	2718 ± 26	911–811	0.712897	0.000016
08071*	Herstal 6	A	Cranial	/	/	/	0.711740	0.000015
09120	Herstal 6	A	Diaphysis	/	/	/	0.711732	0.000015
09121	Herstal 6	A	Diaphysis	/	/	/	0.711693	0.000013
09122	Herstal 6	A	Humerus distal	/	/	/	0.711710	0.000014
09123	Herstal 6	A	Humerus distal	/	/	/	0.711525	0.000013
01035*	Herstal 6	B	Diaphysis	RICH-27245	2799 ± 28	1043–842	0.711693	0.000013
04231*	Herstal 6	B	Diaphysis	RICH-28686	2808 ± 24	1043–901	0.711722	0.000016
08015*	Herstal 6	B	Rib	/	/	/	0.711678	0.000010
08016*	Herstal 6	B	Diaphysis	RICH-29025	2673 ± 25	900–797	0.713057	0.000010
08053*	Herstal 6	B	Diaphysis	/	/	/	0.711685	0.000020
08072*	Herstal 6	B	Cranial	/	/	/	0.711704	0.000014
08096*	Herstal 6	B	Cranial	/	/	/	0.711880	0.000021
08381	Rekem 85-143	A	Diaphysis	RICH-30457.1.2	2964 ± 23	1265–1058	0.712512	0.000009
08382	Rekem 85-143	B	Diaphysis	RICH-30472	2868 ± 25	1124–931	0.712314	0.000007

*Data from Sabaux et al. (2021);
[T]New radiocarbon date but Sr data from Sabaux et al. (2021).

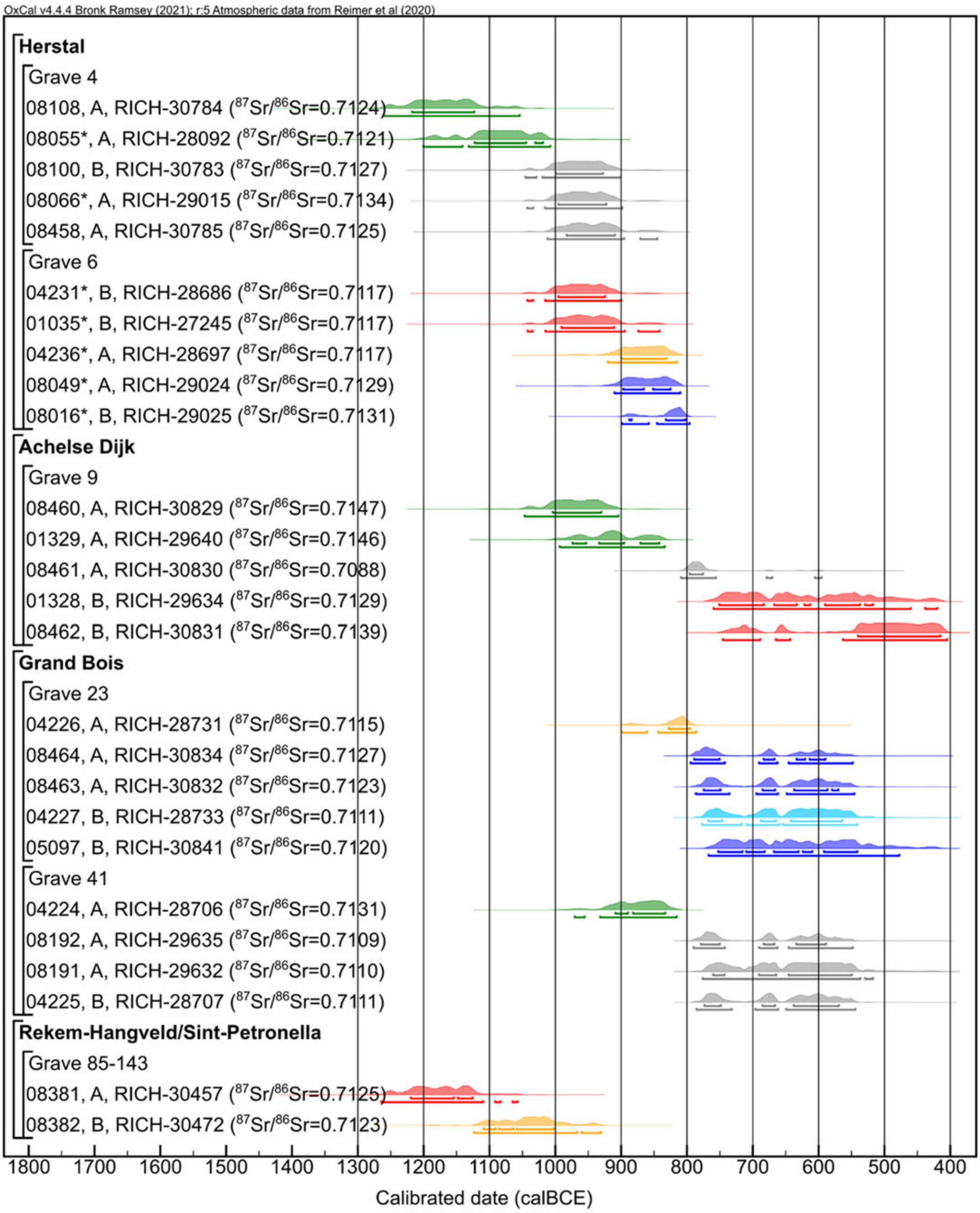

Figure 2. *Calibrated radiocarbon dates with $^{87}Sr/^{86}Sr$ isotope ratios from Herstal, Achelse Dijk, Grand Bois and Rekem. Each colour in each grave corresponds to a different individual based on the combination of osteology, radiocarbon dating and strontium (MNI = 14 or 15) (*data from Sabaux et al. 2021).*

The $^{87}Sr/^{86}Sr$ from the different bone fragments of the six graves range from 0.7088 to 0.7147 (Table 3, Figure 3). The $^{87}Sr/^{86}Sr$ differences between diaphysis of the same graves are quite large and range from 0.0003 up to 0.0013 for Herstal Grave 4, equals 0.0014 in Herstal grave 6, range from 0.0009 to 0.0012 for Grand Bois grave 23, from 0.0010 to 0.0021 for Grand Bois grave 41 and from 0.0012 to 0.0059 for Achelse Dijk. In Rekem grave 85-143, however, the results are very similar (0.7123 and 0.7125).

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Table 4. *MNI evaluated based on individual and combined methodologies*

Graves	MNI (osteology)	MNI (^{14}C)	MNI ($^{87}Sr/^{86}Sr$)	Final MNI
Herstal 4	1	2	2	2
Herstal 6	2	2	2	3
Achelse Dijk 9	1	1 or 3	2 or 3	3
Grand Bois 23	1	2	2	2 or 3
Grand Bois 41	1	2	2	2
Rekem 85-143	1 or 2	1 or 2	1	1 or 2

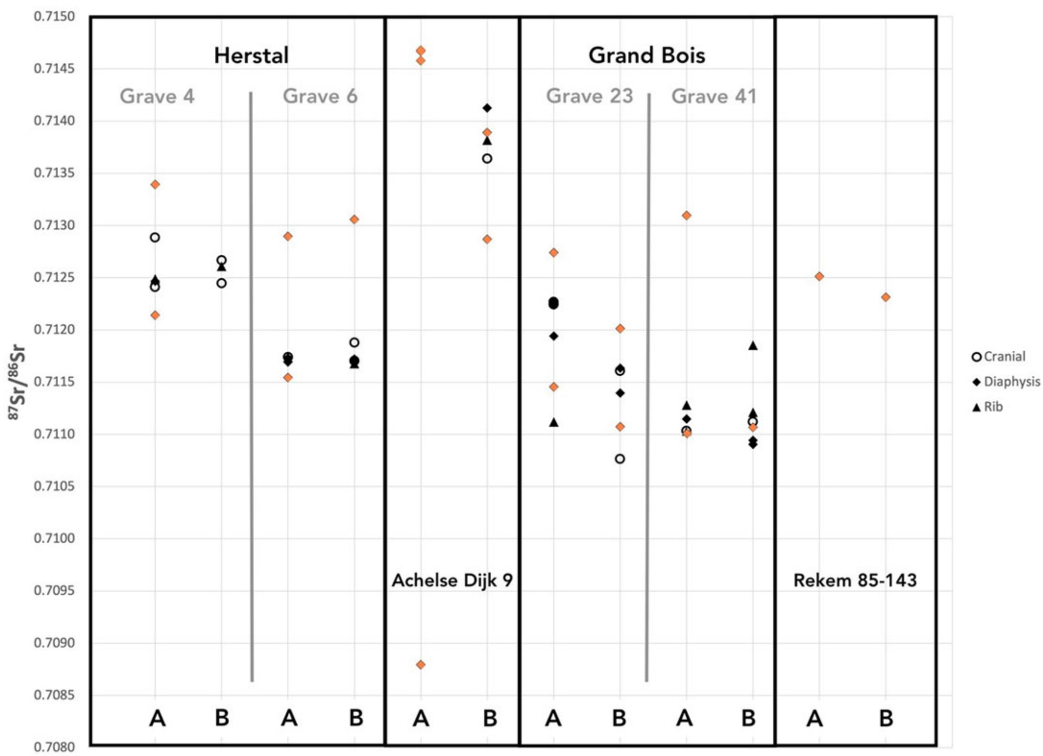

Figure 3. *$^{87}Sr/^{86}Sr$ from the graves with deposits A and B that showed large $^{87}Sr/^{86}Sr$ differences between the various skeletal elements from Herstal, Achelse Dijk, Grand Bois and Rekem individuals. Orange colour in each grave corresponds to the dated samples.*

Discussion

Based on the different analyses carried out on the six cremation deposits different MNI can be calculated (Table 4). The osteological evaluation allowed to identify up to two individuals in Herstal 6 and Rekem 85-143 but could not detect the presence of additional individuals in the other graves. This is not altogether surprising seeing the extreme complexity of working with highly fragmented cremated bones. The strontium data, on the other hand, highlights differences between different bone fragments as high as 0.0059. Those differences could be the results of mobility between two regions with very different biologically available strontium. Indeed, the difference in $^{87}Sr/^{86}Sr$ might be explained by bone turnover as different bones represent different stages of life. However, the analysis of different bone fragments from the same skeletal category (i.e. with comparable turnover rates), still shows a large difference. An alternative explanation would then be, when two rib or two diaphysis fragments present large

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differences ($\Delta^{87}Sr/^{86}Sr > 0.0010$), that these bone fragments belong to distinct individuals who consumed foods from different geological areas. The threshold of > 0.0010 is rather arbitrary and should be considered with caution and in relation with the biologically available strontium variability around the site under investigation. Still, in the case of Achelse Dijk 9, where a difference of 0.0059 is observed between two fragments of diaphysis, one can be quite confident that these bone fragments do not belong to the same individual.

While $^{87}Sr/^{86}Sr$ provide additional data to detect distinct individuals within a cremation deposit, radiocarbon dates are a powerful tool to further investigate such graves. Two main possibilities can explain large differences in radiocarbon dates of burned bones: (1) the bones belong to different individuals or (2) the bones were affected by the old-wood effect. The measurements of multiple bones per graves enable, in most cases, to differentiate between these two options. Indeed, old-wood effect is not expected to be homogenous as experimental studies have shown that cremated bone can incorporate between 36 and 95% of carbon from the fuel (Hüls et al. 2010; Rose et al. 2020; Snoeck et al. 2014; Zazzo et al. 2012). As such, if there is a large variability between the dates, old-wood effect is a possibility. This is observed in the five dates of Achelse Dijk 9. In Rekem 85-143, as only two bone fragments were radiocarbon dated, it is also difficult to exclude the old-wood effect. In all other cases, however, two groups of dates are observed, suggesting two different cremation events, and thus two different individuals.

It is when combining all three methodologies (i.e. osteology, radiocarbon dating and strontium isotope analyses) that this method becomes really powerful in identifying the MNI of a cremation grave (Table 4). In the case of Achelse Dijk 9, the radiocarbon dates suggest a potential old-wood effect as an explanation for the large spread in the dates. However, the strontium isotope data clearly shows that the intermediate date (grey in Figure 2) must belong to another individual seeing the very large difference in $^{87}Sr/^{86}Sr$ between the five diaphysis fragments (0.0059). As such, there is not one but three individuals in that grave. In Rekem 85-143, the two bone fragments have very similar $^{87}Sr/^{86}Sr$ (0.7123 and 0.7125) and are not different enough to confirm the presence of two individuals.

In Grand Bois 23, 14 bones were analyzed for $^{87}Sr/^{86}Sr$ of which 5 were radiocarbon dated. The 14 bones show a large spread in strontium isotope ratios suggesting changes in landscape use or mobility over the lifetime of the individuals present in that grave. One bone fragment is particularly complex to interpret: bone 04227 (light blue in Figure 2). It is radiocarbon date matches with the more recent group of dates but its $^{87}Sr/^{86}Sr$ is lower (0.7111 compared to 0.7120, 0.7123 and 0.7127). It is, however, close to that of the bone fragment with the oldest date (0.7115—Figure 2). It could belong to that older individual but was impacted by an old-wood effect. Alternatively, it could belong to a third individual or diaphyseal turnover rates may be much more variable than initially thought. In any case, two distinct individuals could clearly be identified.

The case of Herstal 6 also shows that the combination of radiocarbon dates and $^{87}Sr/^{86}Sr$ enables to increase the MNI from two to three while, individually, each methodology only identified two (Figure 2). In Herstal 6, all 16 bone fragments but two have a very narrow range of $^{87}Sr/^{86}Sr$ (0.7115 to 0.7119—Figure 3). The two fragments with higher values (0.7129 and 0.7131) also have the more recent dates (Figure 2) and are present in different deposits (A and B). A similar case is seen in Grand Bois 41, where 11 out of 12 bone fragments have $^{87}Sr/^{86}Sr$ between 0.7109 and 0.7119 (Figure 3). The last bone fragment has a value of 0.7131 and is the bone fragment returning the oldest radiocarbon date.

The inclusion of the remains of multiple individuals in the same cremation might have different explanations; behavioural choices, simultaneous cremation events and/or using the same pyre site multiple times, whereby cremated remains from several ceremonies accumulated (un)intentionally (Booth and Brück 2020). The presence of multiple individuals in one grave could result from people dying around the same time, cremated and interred together (Louwen 2021). However, the difference in radiocarbon dates suggest that the individuals were not burned at the same time. The large differences in $^{87}Sr/^{86}Sr$ further suggest in several of these cases that the individuals whose bones were found together consumed food from different areas and might actually have come from elsewhere. Seeing the large difference in calibrated radiocarbon dates (up to several centuries), one may wonder if any of this was intentional. The deceased could belong to socially related groups, emphasising certain social relations in death such as familial significance (Booth and Brück 2020; Brück and Booth 2022; Louwen 2021; Oestigaard and Goldhahn 2006; Rebay-Salisbury 2018). Indeed, as family graves are found in modern cemeteries, they could have existed during the BA–IA to emphasise certain relations in death (Louwen 2021). Such multiple graves with possible family meaning were already observed in few Middle Bronze Age sites in Britain (Caswell and Roberts 2018), in LBA-EAI urnfield cemeteries in southern Germany and Austria (Sørensen and Rebay-Salisbury 2023), in the IA in northern Europe (Ettel 2014) and were detected recently in some LBA–EIA sites in The Netherlands (Louwen 2021). Moreover, cremation enables the burying individuals from different generations together as the process transforms the corpse to small fragments of bones that can be kept for a certain amount of time (Louwen 2021). Nevertheless, whether the presence of several individuals within a cremation grave is intentional or not is not possible to assess with the current dataset and requires further investigation.

Conclusion

This study has clearly demonstrated that from a methodological point of view, though expensive, multi-sampling and combining osteological analyses with radiocarbon dates and $^{87}Sr/^{86}Sr$ on the same fragments of calcined bone can be used to better infer the MNI in cremation deposits, detecting multiple individuals in the same grave which is not possible to do using conventional osteological methods alone. It also shows that taking only one sample per grave might miss the complexity of the grave dynamics. It also highlights the crucial importance to carry out all analytical measurements on the same bone fragment to ensure that the results can be securely linked to the same individual. Further research is also needed to better understand how bone turnover might affect $^{87}Sr/^{86}Sr$.

From an archaeological point of view, this research shows that the divergence of Herstal with the presence of double or even triple cremation burials is clearly not an isolated case but a more common phenomenon, during LBA–EIA in Belgium and probably other regions. Furthermore, it raises the question of intentionality linked to the presence of several individuals within a single cremation grave.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2024.82

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