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Case report

Unusual autopsy, unusual tissue(s) for DNA, but a useful genetic profile: A case of the DNA profiling from the human tissue of challenged provenance☆

Enrica Macorano [a,*], Bianca Beltrame [b], Nunzia Ilaria Vacca [c], Francesca Vacca [c,d], Giacoma Mongelli [c], Gerardo Cazzato [e], Aldo Di Fazio [f], Francesco Introna [a]

[a] Section of Legal Medicine, Department of Interdisciplinary Medicine (DIM), University of Bari "Aldo Moro", Piazza Giulio Cesare, 11, 70124, Bari, Italy
[b] Section of Legal Medicine, University of Brescia, Piazzale Ospedali Civili, 1, 25123 Brescia, Italy
[c] Biochemical Lab Service Srl, Via E. A. Mario, 3 - 73100, Lecce, Italy
[d] Center for Synaptic Neuroscience and Technology – NSYN@Unige Italian Institute of Technology (IIT), Largo Rosanna Benzi, 10, 16132, Genova, Italy
[e] Section of Molecular Pathology, Department of Precision and Regenerative Medicine and Ionian Area (DiMePRe-J), University of Bari "Aldo Moro", Bari, 70124, Italy
[f] Regional Complex Intercompany Institute of Legal Medicine, Via Potito Petrone, 85100, Potenza, Italy

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ABSTRACT

The autopsy of the non-fresh cadaver is characterized by inherent difficulties in that it requires the adoption of genetic and histological investigation techniques to the specific case. The case that the authors present in this paper concerns the corpse of a young woman who had already been autopsied, then treated with 20 % neutral buffered formaldehyde, a preserving agent, to enable its intercontinental transport, and then autopsied again. At the judge's request, a second judicial autopsy was performed in order to verify the cause of death and to carry out genetic investigations. As fresh tissue was not available to perform the genetic analysis, three different tissue matrices were taken: retina, liver, and iliopsoas muscle. The biological matrices taken were chosen as they were considered less likely to be in contact with formaldehyde and therefore probably less prone to artifacts caused by the action of formalin on the DNA structure. All three biological matrices were used to obtain a genetic profile. In particular, the genetic data obtained from the retina was found to be better than the genetic profile obtained from the iliopsoas muscle. In turn, the genetic profile obtained from the iliopsoas muscle was found to be better than the genetic data obtained from the liver sample.

1. Introduction

Forensic genetic determinations are used in forensic science for multiple purposes, in order to use DNA profiling to identify a subject accurately.[1] Also not to be underestimated is the ability of forensic genetics in reconstructing kinship lines.[2] In more complex cases, and in some special situations, mitochondrial DNA can be used.[3] Regarding the living people and recently deceased individuals, there are numerous operational guidelines for the collection of samples suitable for forensic genetics analysis, however, the situation becomes more complex in the case of highly deteriorated or severely decomposed corpses. In the main literature, extraction using ocular swabs has been described in highly deteriorated cadavers. This method has been considered quite valuable, both because it is simple to perform and inexpensive, but more importantly, it is useful in improving laboratory results by supplementing data provided by other genetic investigations.[4] Helm et al. performed a genetic investigation on corpses in an advanced stage of decomposition, by analysis tissue swabs of the aortic wall, urinary bladder wall, brain, liver, oral mucosa, and skeletal muscle, with good results.[5] There are cases in which extracting the genetic profile from the cadaver is difficult and matrices are not available for analysis.[6] In the case of small plane crashes, the bodies of victims may be dismembered into many parts, and it is essential to attribute as many remains as possible to each victim with absolute certainty. This is the reason for which in some cases it is essential to carry out genetic investigations on unusual matrices.[7] Sporadically, some even more special cases may occur, such as the case

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* Corresponding author.
E-mail addresses: enricamacorano@gmail.com (E. Macorano), bbeltrame@unibs.it (B. Beltrame), nunzia.vacca@geneticslab.it (N.I. Vacca), francescavacca2@biologo.onb.it (F. Vacca), giacoma.mongelli@geneticslab.it (G. Mongelli), gerardo.cazzato@uniba.it (G. Cazzato), aldodefaziomedicolegale@gmail.com (A. Di Fazio), francescointrona@uniba.it (F. Introna).

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of a cadaver that has already undergone autopsy, then treated with anti-putrefactive fluids, which ensure its preservation. This case may arise, for example, in the situation of international transportation of corpses, for which the regulations[8] require that the anti-putrefactive liquid (for example 20 % neutral buffered formaldehyde used in our presented case) must be injected into the corpse, and then the body will be closed in a zinc case. In cases such as these, DNA extraction for genetic profiling can be quite complex, as formaldehyde contributes to DNA degradation, leading to numerous artifacts in the genetic profile extraction, generation of data and sequential interpretation.[9] Indeed, it's well recognized that formaldehyde fixation usually makes a DNA degradation via a cross-linking mechanism, leading to fragmentation of DNA molecules.[10] More in details, formaldehyde can cause significant damage to DNA, such as crosslinks between DNA and proteins, and modifications like cytosine deamination, leading to sequence artifacts during subsequent analyses.[11] Studies have shown that formaldehyde-fixed, paraffin-embedded (FFPE) tissues are prone to higher mutation rates and sequencing errors compared to fresh frozen tissues.[12]

Various strategies have been developed to minimize sequence artifacts from FFPE simples such as pretreatment with uracil-DNA-glycosylase (UDG), which removes uracil residues resulting from cytosine deamination, that is one method shown to reduce errors.[13] Furthermore, advances in DNA extraction methods and protocols, including temperature control and optimized use of DNA polymerases, also contribute to better outcomes in molecular and genetic analysis,[14] although it was not possible to apply them in our case for logistic reasons. DNA extraction procedures must consider the tissues that are available, the different decompositional conditions, and need specific care and special analytical choices. For these reasons, we choose and sampled three different, "unusual" matrices, differentiated by anatomical site, in different contact with formaldehyde, to verify the quality of extracted DNA by correlating it with formaldehyde exposure.

2. Case presentation

A young Italian woman had been working as part of the staff on an overseas cruise ship for a few months. During this period, one morning the woman was found dead in her cabin; specifically, the woman was found suspended from a beam present in the cabin by the belt of her uniform. The local police officers were then notified, and they carried out the superficial inspection and investigative inquiries. A first complete autopsy was performed on the woman's body, and at the end, the organs were placed within a plastic bag, which was then placed within the body cavity. The autopsy concluded that the cause of death to be asphyxial death by hanging. The body was then transferred to Italy to be buried, but family members requested a second autopsy to clarify the cause of death.

At the preliminary cadaveric inspection, about 20 days after death, the corpse turned out to have already been autopsied and treated with 20 % neutral buffered formaldehyde, presented diffuse greyish-brown colour and exuded intense odour of formalin. The corpse also showed diffuse increased firmness, showing excellent preservation according to the time of death. Focal areas of fungal colonization were present on the face.

A second complete autopsy was then performed, including the complete section of the body and limbs, with macroscopic analysis and dissection of the organs placed within a plastic bag and a thorough dissection of the muscles and vascular-nervous bundle of the neck region in absence of larynx, trachea, thyroid and hyoid bone, removed during the first autopsy. The autopsy concluded the cause of death to be asphyxial death by hanging of a likely suicidal nature.

Fragments of the main organs examined and, in particular, of the muscles of the neck, were taken and set up for histological analysis, to assess the presence of haemorrhagic infiltrates, then to evaluate the viability of the lesions. At the opening of the carotid arteries, the presence of a tear in the intima, with a transverse course (Amussat sign), with hemorrhagic infiltration was revealed.[15–17]

In addition, selected tissue fragments were taken during autopsy operations for subsequent genetic investigations. In particular, given the widespread presence of formaldehyde in the tissues, the following were choosen.

- a fragment of liver parenchyma, taken from the deepest portion of the organ;
- a fragment of iliopsoas muscle, taken from the deepest portion of the muscle;
- the whole eyeball, apparently less in contact with formaldehyde.

The eyeball was dissected to obtain a fragment of its inner portion, the retina, which is more vascularised and therefore more useful for genetic investigations.

Genetic analyses were performed in the following days on the three different biological matrices (liver parenchyma, iliopsoas muscle and retina) taken during the autopsy.

3. Materials and methods

3.1. Histological analysis

During the autopsy, fragments of the main tissues and organs were taken for histological investigations. In particular, skin samples were taken from two dyschromic areas in the left and right laterocervical region of the neck, a fragment of the right sternocleidomastoid muscle at the clavicular insertion, a liver sample, a kidney sample, four heart samples, two lung samples (one from the right lung and one from the left lung). The aforementioned samples were fixed and dehydrated in the ascending alcohol series, diaphanized in xylol and embedded in paraffin. After obtaining 5 μn thick sections, the preparations were stained using the Hematoxylin-Eosin (H&E) method. The analysis of the histological preparations showed the presence of recent hemorrhagic infiltration at the bilateral laterocervical skin tissues, confirming the vitality of the lesions. In the lungs, oedema, diffuse vascular congestion and localized areas of hemorrhagic extravasation were detected (Fig. 1). Fig. 2 shows hemorrhagic extravasation in a fragment of the right sternocleidomastoid muscle. Fig. 3 shows the histological features of the liver.

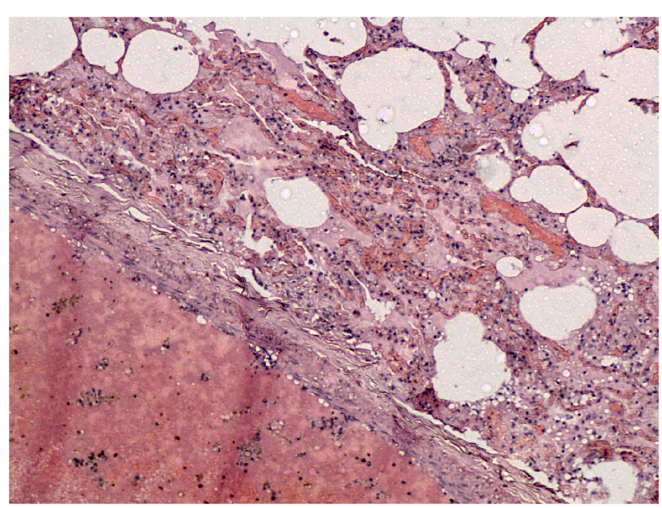

Fig. 1. Right lung with diffuse aspects of vascular congestion and localized areas of blood extravasation (Hematoxylin and Eosin, Original Magnification 10x).

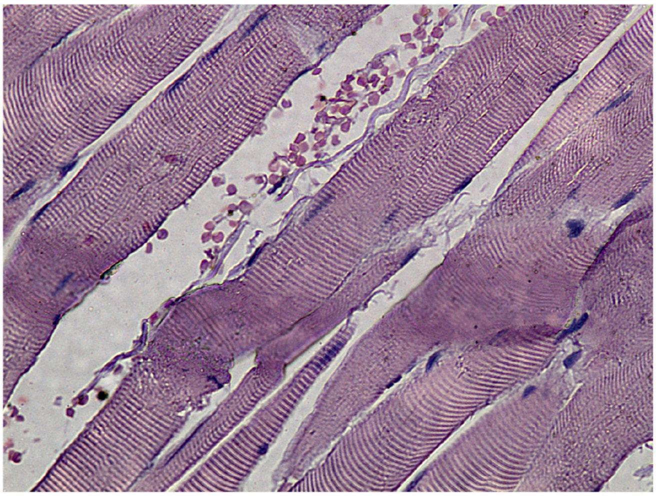

Fig. 2. Histological photomicrograph showing fragments of the clavicular insertion of the right sternocleidomastoid muscle: note the presence of areas of recent hemorrhagic infiltration between the striated muscle bundles, with laceration of the muscle fibrils (Hematoxylin and Eosin, Original Magnification 20x).

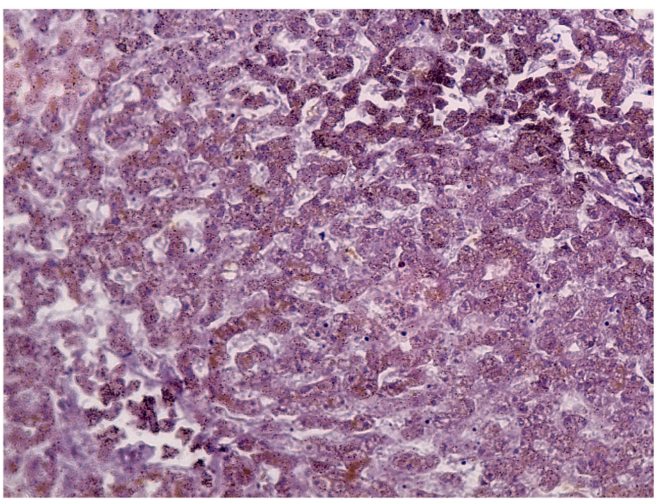

Fig. 3. Histological photomicrograph showing normal cytoarchitecture of the liver, with presence of hemosiderin (Hematoxylin and Eosin, Original Magnification 20x).

3.2. Sampling procedures and sample collection

3.2.1. Retina

For the eyeball, a swab (Copan Italia spa®, Brescia, Italy) was taken at the retina.

3.2.2. Liver

For the liver, a tissue sample was taken using a scalpel.

3.2.3. Iliopsoas muscle

For the iliopsoas muscle, a tissue sample was taken using a scalpel.

3.3. DNA extraction and quantification

DNA extraction was carried out using innuPREP Forensic DNA Kit-IPC16 (AnalytikJena). No modifications to the standard tissue sample protocol have been applied (protocol n. 7). DNA quantification was performed using QuantiFluor™-ST (Promega) and QuantiFluor™dsDNA System kit (Promega).

The results of the DNA quantification were 3254 ng/μl, 1511 ng/μl and 1237 ng/μl respectively from the retina, liver, and iliopsoas muscle.

3.4. DNA amplification, electrophoresis and data analysis software

PCR was performed using GlobalFiler™ IQC (Applied Biosystems) for autosomal markers, on "VeritiTM Dx Thermal Cycler" (Thermo Fisher Scientific). For each sample, two amplification replicates were performed using the same experimental conditions.

The amplification replicates are consolidation procedures to verify the repeatability of the data. The execution of typing replicates involves amplification with multiplex-PCR systems of the same DNA extract while keeping the amplification conditions (amount of template DNA and number of cycles) and the multiplex-PCR system used constant.

Electrophoresis was carried out on a SeqStudio Genetic Analyzer (Applied Biosystems), followed by GeneMapper ID v3.2 IDX (Applied Biosystems) software. For the interpretation of autosomal STRs, the analytic threshold (AT) was set at 50 RFU (Relative Fluorescence Unit) and the stochastic threshold (ST) at 150 RFU, as internal validation.

4. Results

The three samples taken from the retina, liver, and iliopsoas muscle were analyzed.

4.1. Retina

From the retina, both replicates (Fig. 4A and B) produced a complete single female profile. All obtained peaks are above the stochastic threshold, value below which alleles tend to disappear due to low amplification effects of the template.[18] The Stochastic Threshold (ST) represents a quality indicator of allelic signals to alert the analyst to the possibility that not all the genetic information of the biological sample/repertoire may have been detected during the analysis. The ST is essential especially when examining specimens characterized by a limited amount of DNA and/or significant degradation. Under such conditions, stochastic events may produce amplification artifacts.[19]

Since in both replicates high molecular weight markers showed lower RFU heights compared to low molecular weight markers (for example, in replicate number 1 locus D3S1358 allele 15 10404 RFU, allele 16 7859 RFU – locus TPOX allele 8489 RFU) (Fig. 4A), the DNA used showed effects of degradation. In particular, the TPOX polymorphism is widely used for paternity tests and personal identification.[20,21]

Despite the degraded DNA, both replicates yielded overlapping and consolidated results.

4.2. Liver

From the liver, the first replication showed an incomplete female profile as not all loci in the amplification kit were positive for typing (TPOX). Despite the fact that the starting DNA is degraded (high molecular weight markers showed lower RFU heights compared to low molecular weight markers), and despite stochastic effects in the purple (drop-out of allele 17 of marker D2S1338), the profile obtained from replicate I can be used for comparative purposes for loci whose alleles show above the stochastic threshold. The second replication failed, returning a profile that was not useful for comparative purposes (Fig. 5A and B).

4.3. Iliopsoas muscle

From the deep iliopsoas muscle, a single female profile was obtained in both replicates. For the first replicate (replicate I), a complete profile was obtained. For the second replicate (replicate II), an incomplete profile was obtained (for the TPOX and D2S1338 loci, a drop-out locus

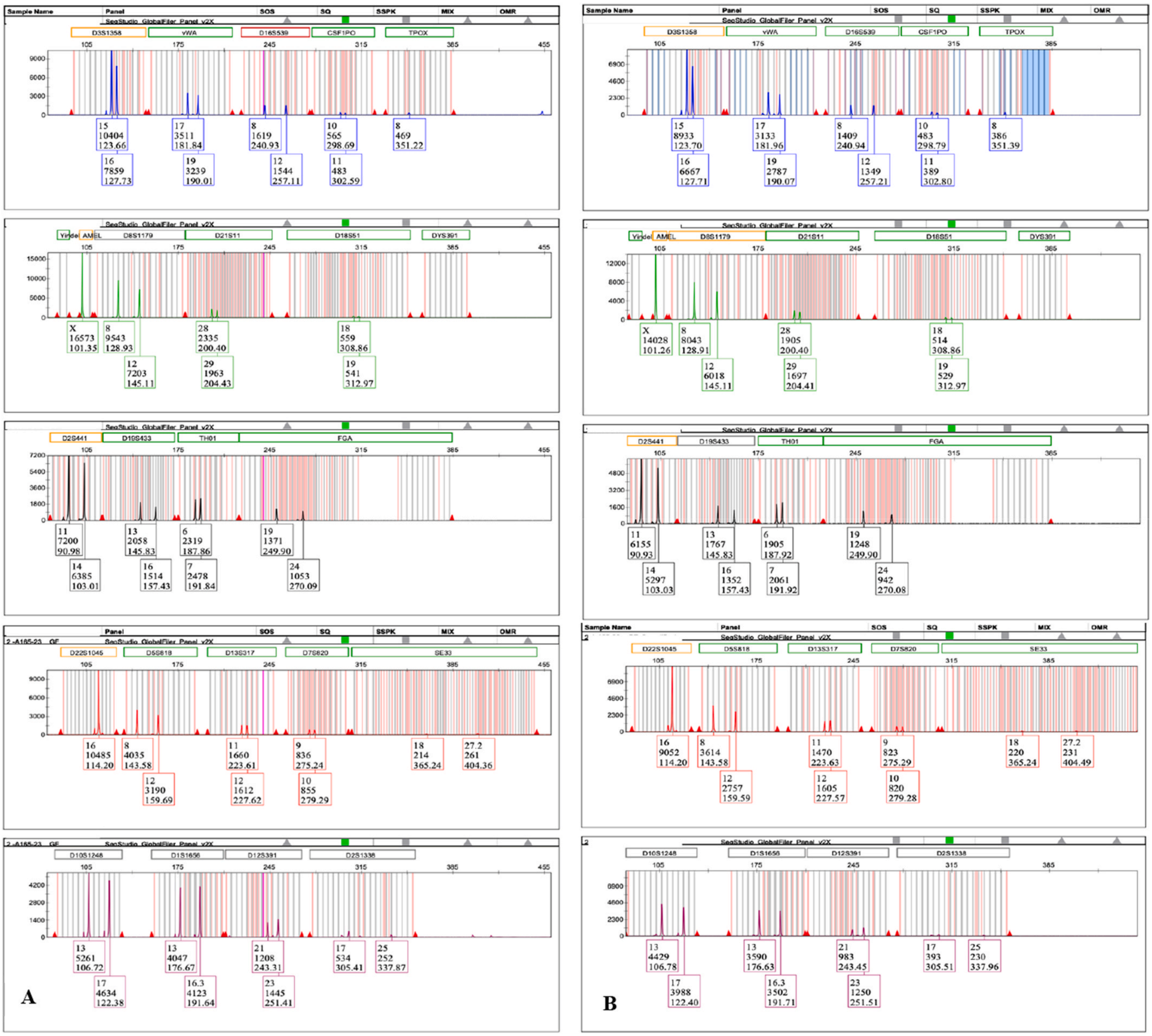

Fig. 4. A: Autosomal electropherogram from first replicate (retina); B: Autosomal electropherogram form second replicate (retina).

occurred, and also for the D2S1338 locus, drop-ins occurred). Although not all of the peaks obtained were above the stochastic threshold and the starting DNA was degraded, the replicates performed gave results that were superimposable on each other and therefore consolidated at most of the typed loci (for 19 out of 22 markers for autosomal DNA), resulting in a DNA profile useful for comparative purposes (Fig. 6A and B).

5. Discussion

Autosomal polymorphism (STR) analysis is used in forensic science for personal identification of human remains.[22] However, in some cases can be difficult to obtain the genetic profile..[23] Often only a few cadaveric tissues are available or in any case the material available for DNA extraction may be very compromised.[24] In our work we present the particular case of an individual found dead abroad and already subjected to autopsy and treatment with 20 % buffered neuter formaldehyde to ensure preservation, as required by the regulations for the international transport of corpses, as reported in the Italian mortuary police regulations.[25] Specifically, this regulation requires that anti-putrefactive liquid (formaldehyde) be injected into the corpse once it is closed inside a zinc case.[8] As is well known, formalin can be responsible for different problems during the genetic profiling with subsequent difficulty in the interpretation of the results.[26] Therefore, DNA extraction procedures must consider the tissues available and requires attention and special analytical choices. This case report wants to be defined as a pilot study in the decision process of the more suitable tissues to utilise in genetic enhancement for molecular investigations, in order to obtain autosomal profiles that are useful for comparative purposes. For these reasons, we choose and sampled three different, "unusual" matrices by anatomical site in different contact with formaldehyde to verify the quality of the extracted DNA by correlating it with exposure to that antiputrefactive liquid. According to the guidelines of Italian Forensic Genetics (Ge.F.I.)[27] it was necessary to obtain at least two replicates for each tissue in order to obtain a consensus genetic profile. For the liver, which is the tissue most in contact with formaldehyde, only one of the two replicates returned a genetic profile, while replicate II yielded a negative result. Therefore, it was not possible to consolidate the results of replicate I and build a consensus profile for

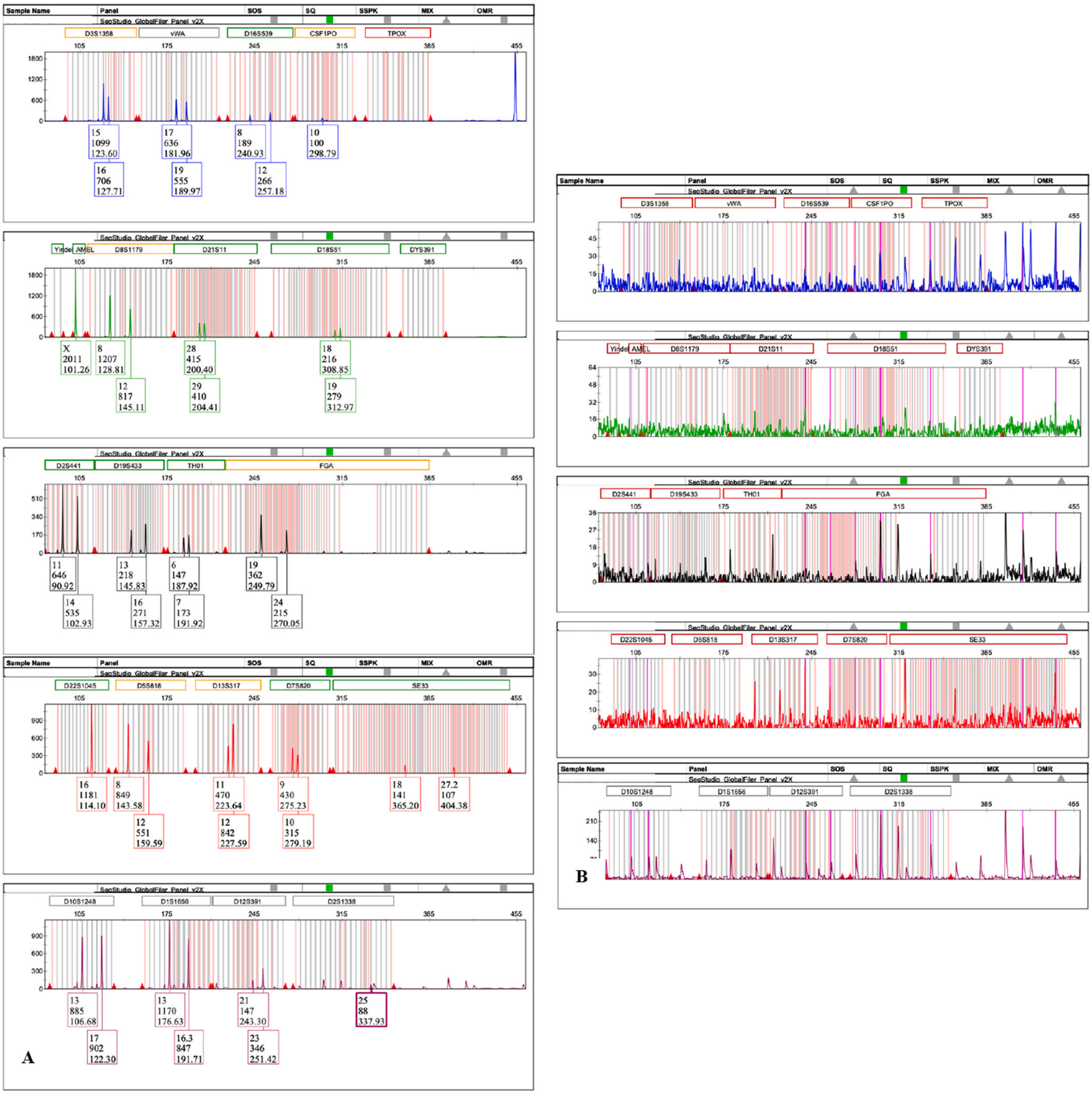

Fig. 5. A: Autosomal electropherogram from first replicate (liver); B: Autosomal electropherogram form second replicate (liver).

possible comparative investigations; indeed, genetic profile obtained from replicate I was a complex profile because it was not complete and subject to numerous stochastic effects, probably due to previous tissue manipulation and formaldehyde treatment. For the iliopsoas muscle, both replicates performed were successful. The genetic profile obtained from replicate II was complex and is not complete, because subject to numerous stochastic effects, probably due to previous tissue manipulation and formalin treatment. A single female sex profile was obtained for both. Overlapping results were obtained for 19 out of 22 markers analyzed for autosomal DNA, thus returning consolidated results used to construct a consensus profile. For the retina, which is the less modified tissue by formaldehyde, a single complete female profile was obtained in both replications performed. Both yielded superimposable results from each other, thus returning consolidated results, used to construct a consensus profile.

Given the exceptionality and different scenario that one can encounter while performing genetic investigations, each situation must be evaluated according to the "expert opinion", and to the guidelines of the Italian Forensic Geneticists (Ge.F.I.).[27]

Regarding the potential problems that formaldehyde may entail in carrying out the following genetic investigations, as previously mentioned, in optimal situations it would be advisable to carry out pre-treatments capable of decreasing the formation of deaminated cytosines responsible for variations in the DNA sequence analyzed by PCR and Next Generation Sequencing (NGS) techniques.[12–14] In particular, in our case, the exceptional logistical circumstances did not allow us to take advantage of techniques now incorporated in the flow-chart of genetic sequencing.[28,29]

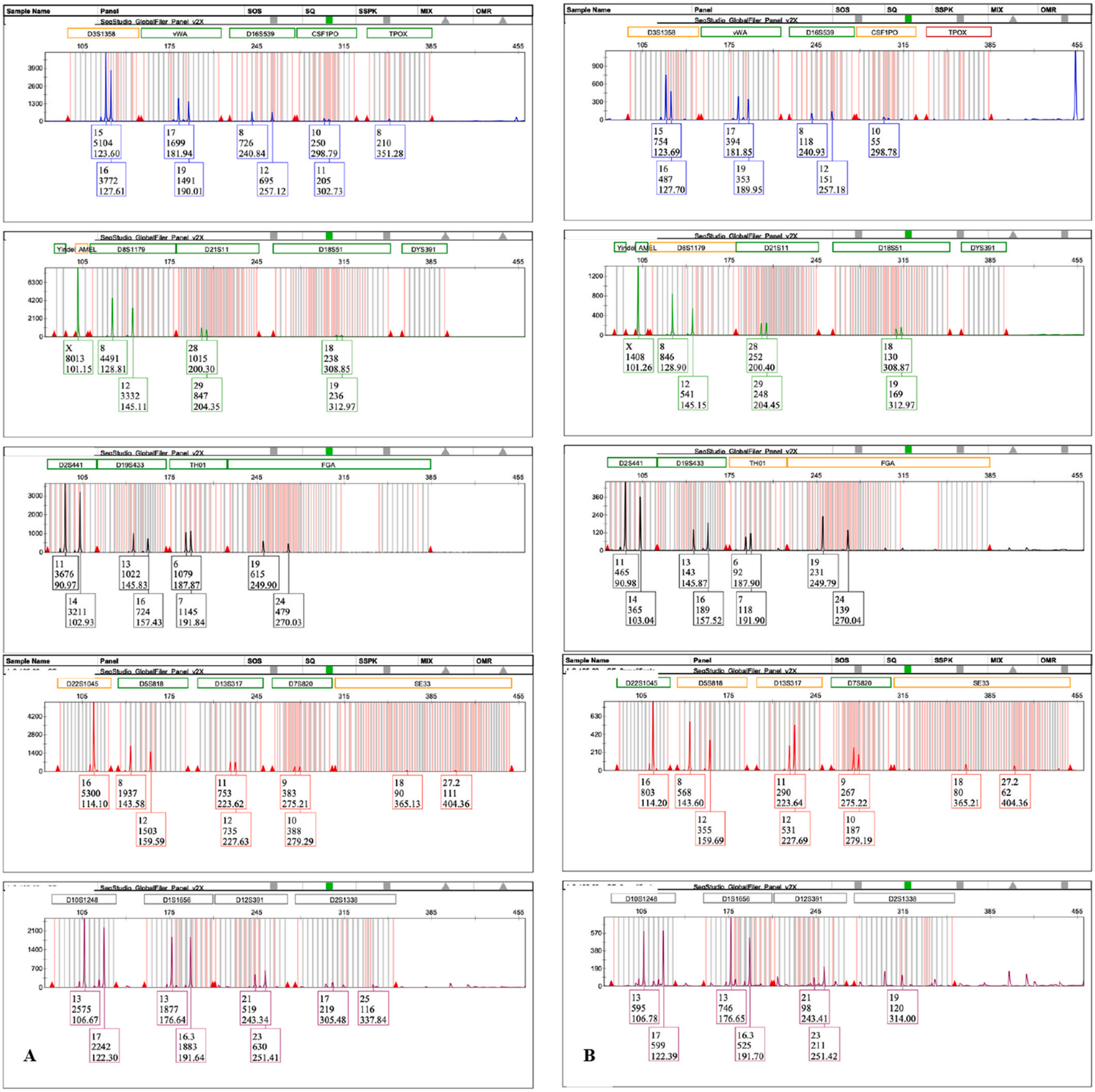

Fig. 6. A: Autosomal electropherogram from first replicate (iliopsoas muscle); B: Autosomal electropherogram form second replicate (iliopsoas muscle).

In this case report, statistical evaluations were not performed for identification purposes because reference profiles of family members were not available.

6. Conclusion

In conclusion, the case discussed by the authors is "unusual" as there was a need to perform the extraction of a genetic profile from a corpse already submitted to a first complete autopsy, then treated with formaldehyde and subsequently subjected to a second complete autopsy.

Among the matrices selected for extracting the genetic profile (retina, liver, and iliopsoas), the retina has proven particularly useful in obtaining a valid genetic profile.

Due to these results and biological reasoning, in the absence of further scientific work regarding the performing of genetic profiles from "unusual" cadaveric tissues, this work aims to encourage the forensic scientific community to choose, on a case-by-case basis, the best tissues from which to perform DNA extraction to obtain autosomal profiles that are useful for comparative purposes, with low rates of stochastic phenomena. In fact, their use could be decisive in difficult cases such as those of disaster victim identification (DVI), or when the cadaveric tissues or otherwise the material available for DNA extraction may be highly compromised.

Declaration of competing interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

References

1. Alvarez-Cubero MJ, Saiz M, Martinez-Gonzalez LJ, et al. Genetic identification of missing persons: DNA analysis of human remains and compromised samples. *Pathobiology*. 2012;79:228–238. https://doi.org/10.1159/000334982.
2. Franceschetti L, Mazzarelli D, Ragni C, et al. Why identification matters: an explorative study on six cases of family reunification. *Int J Legal Med*. 2024. https://doi.org/10.1007/s00414-024-03163-w. Epub ahead of print. PMID: 38228885.
3. Friedman M, DeSalle R. Mitochondrial DNA extraction and sequencing of formalin-fixed archival snake tissue. *Mitochondrial DNA*. 2008;19:433–437. https://doi.org/10.1080/19401730802449170. PMID: 19489136.
4. Agostini V, Bailo P, Chiti E, et al. Ocular swabs on exhumed bodies: an alternative to the collection of "classical" tissue samples in forensic genetics. *Forensic Sci Int: Genetics*. 2020;44, 102206. https://doi.org/10.1016/j.fsigen.2019.102206. ISSN 1872-4973.
5. Helm K, Matzenauer C, Neuhuber F, et al. Suitability of specific soft tissue swabs for the forensic identification of highly decomposed bodies. *Int J Legal Med*. 2021;135 (4):1319–1327. https://doi.org/10.1007/s00414-021-02601-3. Epub 2021 Apr 20. PMID: 33880634; PMCID:PMC8205910.
6. Rubio L, Santos I, Gaitan MJ, Martin de-las Heras S. Time-dependent changes in DNA stability in decomposing teeth over 18 months. *Acta Odontol Scand*. 2013;71: 638–643. https://doi.org/10.3109/00016357.2012.700068.
7. Vermeij E, Zoon P, Gerretsen R, Otieno-Alego V. The outcome of the forensic triage preceding disaster victim identification in the downing of Malaysia Airlines flight 17. *Forensic Sci Res*. 2022;7(3):566–575. https://doi.org/10.1080/20961790.2022.2043611. Published 2022 Nov 4.
8. D.P.R. 10 settembre. n. 285. Regolamento di polizia mortuaria. https://presidenza.governo.it/USRI/ufficio_studi/normativa/D.P.R.%2010%20settembre%201990,%20n.%20285.pdf; 1990.
9. Cazzato G, Caporusso C, Arezzo F, et al. Formalin-fixed and paraffin-embedded samples for Next generation sequencing: problems and Solutions. *Genes*. 2021 Sep 23;12(10):1472. https://doi.org/10.3390/genes12101472. PMID: 34680867; PMCID: PMC8535326.
10. Zsikla V, Baumann M, Cathomas G. Effect of buffered formalin on amplification of DNA from paraffin wax embedded small biopsies using real-time PCR. *J Clin Pathol*. 2004 Jun;57(6):654–656. https://doi.org/10.1136/jcp.2003.013961. PMID: 15166276; PMCID: PMC1770336.
11. Cazzato G, Caporusso C, Arezzo F, et al. Formalin-fixed and paraffin-embedded samples for Next generation sequencing: problems and solutions. *Genes*. 2021 Sep 23;12(10):1472. https://doi.org/10.3390/genes12101472. PMID: 34680867; PMCID: PMC8535326.
12. Do H, Dobrovic A. Sequence artifacts in DNA from formalin-fixed tissues: causes and strategies for minimization. *Clin Chem*. 2015;61:64–71. https://doi.org/10.1373/clinchem.2014.223040.
13. Feldman MY. Reactions of nucleic acids and nucleoproteins with formaldehyde. *Prog Nucleic Acid Res Mol Biol*. 1973;13:1–49.
14. Williams C, Pontén F, Moberg C, et al. A high frequency of sequence alterations is due to formalin fixation of archival specimens. *Am J Pathol*. 1999;155:1467–1471. https://doi.org/10.1016/S0002-9440(10)65461-2.
15. Hejna P. Amussat's sign in hanging–A prospective autopsy study. *J Forensic Sci*. 2011 Jan;56(1):132–135. https://doi.org/10.1111/j.1556-4029.2010.01548.x. Epub 2010 Sep 14. PMID: 20840289.
16. Asirdizer M, Kartal E. Neck vascular lesions in hanging cases: a literature review. *J Forensic Leg Med*. 2022 Jan;85, 102284. https://doi.org/10.1016/j.jflm.2021.102284. Epub 2021 Nov 18. PMID: 34801830.
17. Mileva B, Goshev M, Valcheva M, Alexandrov A, Braynova I. Forensic interpretation and importance of simon's bleeding, amussat's sign and other typical findings of hanging as diagnostic signs. *Cureus*. 2024 Apr 8;16(4), e57809. https://doi.org/10.7759/cureus.57809. PMID: 38721204; PMCID: PMC11077616.
18. Westen AA, Grol LJ, Harteveld J, Matai AS, de Knijff P, Sijen T. Assessment of the stochastic threshold, back- and forward stutter filters and low template techniques for NGM. *Forensic Sci Int Genet*. 2012 Dec;6(6):708–715. https://doi.org/10.1016/j.fsigen.2012.05.001. Epub 2012 May 26. PMID: 22633964.
19. Coble MD, Bright JA. Probabilistic genotyping software: an overview. *Forensic Sci Int Genet*. 2019 Jan;38:219–224. https://doi.org/10.1016/j.fsigen.2018.11.009. Epub 2018 Nov 11. PMID: 30458407.
20. Picanço JB, Raimann PE, Paskulin GA, et al. Tri-allelic pattern at the TPOX locus: a familial study. *Gene*. 2014 Feb 10;535(2):353–358. https://doi.org/10.1016/j.gene.2013.10.019. Epub 2013 Oct 18. PMID: 24144843.
21. Yang Q, Liu B, Shao C, et al. Characterization of the extra copy of TPOX locus with tri-allelic pattern. *BMC Genet*. 2019 Feb 14;20(1):18. https://doi.org/10.1186/s12863-019-0723-2. PMID: 30764755; PMCID: PMC6376737.
22. Dumache R, Ciocan V, Muresan C, Enache A. Molecular DNA analysis in forensic identification. *Clin Lab*. 2016;62(1-2):245–248. https://doi.org/10.7754/clin.lab.2015.150414. PMID: 27012057.
23. Prinz M, Carracedo A, Mayr WR, et al. DNA Commission of the International Society for Forensic Genetics (ISFG): recommendations regarding the role of forensic genetics for disaster victim identification (DVI). *Forensic Sci Int: Genetics*. 2007;1 (Issue 1):3–12.
24. Marrone M, Tarantino F, Stellacci A, et al. Forensic analysis and identification processes in mass disasters: explosion of gun powder in the fireworks factory. *Molecules*. 2021 Dec 31;27(1):244. https://doi.org/10.3390/molecules27010244. PMID: 35011477; PMCID: PMC8746669.
25. DPR285/90, Regolamento Polizia Mortuaria.
26. Bonin S, Petrera F, Niccolini B, Stanta G. PCR analysis in archival postmortem tissues. *Mol Pathol*. 2003 Jun;56(3):184–186. https://doi.org/10.1136/mp.56.3.184. PMID: 12782767; PMCID: PMC1187316.
27. Raccomandazioni GeFI. *nelle indagini di identificazione personale. Ge.F.I.* 2018.
28. Bieler J, Kubik S, Macheret M, Pozzorini C, Willig A, Xu Z. Benefits of applying molecular barcoding systems are not uniform across different genomic applications. *J Transl Med*. 2023 May 5;21(1):305. https://doi.org/10.1186/s12967-023-04160-0. PMID: 37147717; PMCID: PMC10163729.
29. Mathieson W, Thomas GA. Why formalin-fixed, paraffin-embedded biospecimens must Be used in genomic medicine: an evidence-based review and conclusion. *J Histochem Cytochem*. 2020 Aug;68(8):543–552. https://doi.org/10.1369/0022155420945050. Epub 2020 Jul 22. PMID: 32697619; PMCID: PMC7400666.