

# Croatian contributions to the first systematic DNA-based large-scale identification of mass graves war victims

Šimun Anđelinović<sup>1\*</sup> ,  
Dragan Primorac<sup>2,3,4,5,6,7\*</sup> ,  
Marija Definis<sup>1,4,8</sup>, Arijana Vuko<sup>1</sup>, Ivana Kružić<sup>8</sup> ,  
Željana Bašić<sup>8†</sup> ,  
Ivan Jerković<sup>8†</sup> 

<sup>1</sup>University Hospital of Split, Split, Croatia

<sup>2</sup>St. Catherine Specialty Hospital, Zabok/Zagreb, Croatia

<sup>3</sup>University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania, USA

<sup>4</sup>University of Split School of Medicine, Split, Croatia

<sup>5</sup>Medical School, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia

<sup>6</sup>Henry C. Lee College of Criminal Justice and Forensic Sciences, University of New Haven, New Haven, Connecticut, USA

<sup>7</sup>Eberly College of Science, The Pennsylvania State University, University Park, Pennsylvania, USA

<sup>8</sup>University of Split Faculty of Forensic Sciences, Split, Croatia

\*Joint first authorship.

†Joint senior authorship.

## Correspondence to:

Željana Bašić, Faculty of Forensic Sciences, University of Split, Split, Croatia;  
[zbasic@unist.hr](mailto:zbasic@unist.hr)

## Cite as:

Anđelinović Š, Primorac D, Definis M, Vuko A, Kružić I, Bašić Ž, Jerković I. Croatian contributions to the first systematic DNA-based large-scale identification of mass graves war victims.

ST-OPEN. 2026;7:e2026.2619.3

## DOI:

<https://doi.org/10.48188/so.7.6>

The large-scale DNA identification of war victims emerged in the early 1990s as a response to unprecedented forensic challenges posed by mass graves and highly degraded human remains during and after the wars in Croatia and Bosnia and Herzegovina. This historical perspective revisits the origins and long-term impact of the first systematic applications of DNA-based technology during the massive identification of mass grave victims during wartime, which started between 1993 and 1994 at the Clinical Department of Pathology, Forensic Medicine and Cytology, University Hospital of Split. Through the integration of classical forensic methods with early PCR-based DNA typing and the establishment of a kinship reference database, Croatian scientists, in collaboration with leading American experts, developed a methodological framework capable of resolving complex mass-fatality cases under wartime conditions. This work was formally recognized in 1995 before the United States Congress, providing rare institutional validation of a forensic program operating outside established Western infrastructures. Over the following three decades, the approaches developed in this context evolved into a standardized forensic practice that incorporates STR analysis, mitochondrial DNA, and forensic genomics. Their application has extended far beyond the regional context and has contributed to the global approach to disaster victim identification and post-conflict recovery. The Croatian experience thus represents an important moment in the transition of DNA analysis from isolated forensic use to a systematic, large-scale tool for human identification, with continuous scientific, institutional, and humanitarian implications.

**Keywords:** DNA identification; war victims; mass graves; forensic genetics; Croatia; international collaboration; disaster victim identification

## Introduction

The identification of missing persons is an essential step not only for achieving personal closure for families, but also for achieving post-conflict justice, where it often represents the only undisputed evidence (1). In the final decades of the 20<sup>th</sup> century, established forensic tools included dental records, fingerprint analysis, and ante- and post-mortem data comparison (2). DNA emerged as the most reliable method of identification only in the late 20<sup>th</sup> century (3, 4), and its early application remained sporadic, largely limited to individual forensic cases and closed mass disasters (5–8). In Croatia and Bosnia and Herzegovina, following the outbreak of the Homeland War in 1991 in the context of the aggression against Croatia and the subsequent conflict in Bosnia and Herzegovina (9), more than 150,000 individuals had died or gone missing by 1992 (10, 11). In this context, Croatian scientists, working under war conditions and without an established institutional framework, in close collaboration with leading American forensic experts, developed one of the earliest systematic, large-scale DNA-based identification programs for mass-casualty victims.

## DNA-based methods in forensics before the Croatian initiative

The forensic use of DNA for human identification traces to Jeffreys, Wilson and Thein's development of DNA fingerprinting at the University of Leicester in 1985 (3, 4). Its forensic potential was rapidly demonstrated in criminal investigations, most notably in the Colin Pitchfork case (12), where DNA evidence allowed both exclusion of a false confessor and identification of the true perpetrator through mass screening. Through the late 1980s and into the early 1990s, its forensic application remained essentially confined to criminal casework and isolated high-profile identity cases (8), such as the recovery of a murder victim from skeletal remains through mitochondrial sequencing (13). Early applications in mass-fatality contexts emerged in the early 1990s, including aircraft disasters and fire-related incidents, but these were limited in scale and methodological integration (5–8, 14–18). At the time, international disaster victim identification protocols relied primarily on fingerprints, dental records, and anthropological comparison (2), as DNA-based methods were not yet systematically incorporated. These were primarily singular achievements, many of them relying on non-degraded or minimally degraded samples (5–8, 14–16, 18–20). No institution had yet designed a framework capable of simultaneously recovering remains from multiple mass graves, constructing a kinship-based reference database at scale, and integrating DNA with the full framework of classical forensic disciplines within a unified identification protocol. This design challenge was systematically addressed at the University Hospital of Split, where the first systematic DNA-based identification of war mass-grave victims was carried out in 1993–1994, at a time when no comparable program had yet been implemented elsewhere (21). From a broader international perspective, the early 1990s represent a transitional phase in which forensic DNA analysis was beginning to move beyond criminal casework into mass-fatality identification. Initial applications were reported in incidents such as the Scandinavian Star ferry fire in 1990 (14, 15), the Airbus A320 crash at Mont Ste-Odile in 1992 (16), and the Waco disaster in 1993 (6), where DNA was used selectively alongside conventional identification methods. Subsequent

events, including the AMIA bombing in 1994 and the Spitsbergen aircraft disaster in 1996, demonstrated increasing methodological integration and the growing reliability of DNA-based approaches (5, 18). Within this the Croatian experience represents one of the earliest documented examples of systematic DNA-based identification of highly degraded skeletal remains from mass graves in a wartime context. This approach combined field recovery, kinship-based reference sampling, and laboratory analysis into a unified identification framework (21, 22).

## Sources and approach

This article is based on a narrative and historical reconstruction of the early development of DNA-based identification of war victims in Croatia. The analysis integrates multiple categories of sources, selected for their direct relevance, contemporaneity, and evidentiary value in documenting both scientific and operational aspects of the identification process. Key sources underpinning this reconstruction include the following representative materials, presented in approximate chronological and evidentiary order:

- Perkin-Elmer Corporation. *Early Development of DNA Identification in Croatia* (1993) – documentary laboratory record showing the establishment of forensic DNA capability in Split and the first systematic DNA-based identification of war mass-grave victims, under wartime conditions (23).
- Farn K. *Heroes of Hope* (WTNH News 8, 1995) – television documentary providing direct visual documentation of exhumations, field conditions, and interaction between forensic teams and victims' families (24).
- Gunby P. *Medical Team Seeks to Identify Human Remains From Mass Graves of War in Former Yugoslavia*. *JAMA* (1994) – early international medical report describing the introduction of DNA methods in Croatia and collaboration with US experts (25).
- Slocum B. *State team to identify war dead: AmeriCares leads in Bosnia aid effort*. *Connecticut Post* (1994) – contemporaneous newspaper report documenting the early international involvement in establishing DNA-based identification capacity in Croatia, including AmeriCares support, Perkin-Elmer technology transfer, and collaboration with US forensic experts (26).
- Browne MW. *DNA Experts Expect to Identify Massacre Victims*. *The New York Times* (1994) – contemporaneous international newspaper report describing early forensic DNA efforts in the identification of war victims in Bosnia and Croatia, including field operations, involvement of international experts, and the emerging use of PCR-based methods in mass-fatality contexts (27).
- Marshall E. *Tracing Croatia's "Disappeared"*. *Science* (1995) – report highlighting the scientific and humanitarian significance of DNA-based identification efforts in Croatia within a global context (28).
- Myers L. *DNA Test May Solve War Mysteries in Croatia*. *Chicago Tribune* (1994) – newspaper report describing the early application of DNA analysis in Croatia, including in-

- ternational collaboration, technology transfer, and the involvement of forensic experts and humanitarian organizations in the identification of war victims (29).
- Commission on Security and Cooperation in Europe. *Mass Graves and Other Atrocities in Bosnia* (US Congress, 6 December 1995) – official Congressional hearing transcript containing sworn expert testimony on the forensic work conducted in Split and its international evaluation (30).
  - Primorac D, Anđelinović Š, Definis-Gojanović M, et al. *Identification of War Victims from Mass Graves in Croatia, Bosnia and Herzegovina by the Use of Standard Forensic Methods and DNA Typing*. *Journal of Forensic Sciences* (1996) – first scientific publication presenting the methodology and results of DNA-based identification in the Croatian wartime context (22).
  - *Post Mortem*. *People Weekly* (1996) – contemporaneous media account reflecting public dissemination and broader awareness of forensic identification efforts (31).
  - Promega Corporation. *Profiles in DNA*, Vol. 4, No. 3 – technical report summarizing methodological developments in DNA typing from skeletal remains and their application in the Croatian context (32).
  - Primorac D, Anđelinović Š, Definis-Gojanović M, et al. *Identification of Skeletal Remains in Croatia and Bosnia and Herzegovina, Including the Homeland War – A 30-Year Review*. *Croatian Medical Journal* (2024) – comprehensive retrospective synthesis of the long-term scientific and operational impact of the Croatian program (21).

## Perspective and limitations

This article presents a historical reconstruction based in part on the experiences and contributions of individuals directly involved in the described events. As such, it reflects a perspective informed by first-hand participation, supported by contemporaneous documentation, scientific publications, and independent institutional records. While care has been taken to integrate multiple source types and include external validations (e.g., peer-reviewed literature, international reports, and Congressional testimony), the narrative may emphasize aspects that were more visible or better documented within this specific collaborative framework. Accordingly, the account should be interpreted as a documented perspective on early developments in forensic DNA identification, rather than an exhaustive global history of the field.

## The Kupres identifications and the emergence of a Croatian-American partnership

On 4 April 1992, Bosnian Serb forces attacked the Kupres region of Bosnia and Herzegovina, killing Croat civilians and soldiers and burying many of them in mass graves (24, 33). The graves were later found to contain highly decomposed remains, in some cases with ligatures on the wrists and/or ankles, and even commingled human and animal bones, which

further complicated identification (22, 24). Families were left for months and years without reliable information, while some were deliberately misled into believing that their relatives were still alive. As later described in the documentary material, they had lived on “false hope” (24).

Field recovery and exhumation, starting in 1993, were conducted under dangerous conditions. Graves in the Kupres area had to be excavated carefully, as explosive devices had been placed inside them by Serbian forces to harm the excavators and further fragment the remains. The remains themselves were very fragile, so recovery was performed manually. The forensic teams thus confronted immediate danger in conditions marked by direct evidence of execution and concealment (24) (Figure 1).



**Figure 1.** Mass grave exhumations in the Kupres region during the early phase of forensic investigation, showing recovery procedures and multidisciplinary team involvement.

During that period, it became evident that most human remains would not be identifiable using standard forensic methods. Recognizing the limitations of conventional pathology, Šimun Anđelinović, then Head of the Clinical Department of Pathology, Forensic Medicine and Cytology, reached out to Dragan Primorac, who at the time was a postdoctoral fellow at the University of Connecticut Health Center. Primorac was deeply engaged in molecular biology research, focusing on the molecular mechanisms underlying osteogenesis imperfecta and a form of osteochondrodystrophy called nanomelia. He was among a select group of exceptionally promising young physicians sent abroad by Matko Marušić of the Zagreb School of Medicine, with a clear mission: to acquire advanced knowledge and transfer cutting-edge scientific expertise back to Croatia (34).

Understanding the urgency and historical importance of the moment, Primorac immediately contacted Henry C. Lee from Connecticut State Police. What was initially intended to be a brief ten-minute meeting evolved into an intense and visionary discussion lasting more than two and a half hours, during which they explored the scientific, ethical, and logistical foundations of potential of using forensic genetics for human identification. That conversation laid the groundwork for Lee's first visit to Croatia and marked the beginning of a transformative collaboration that would profoundly shape the future of mass grave victim identification through forensic DNA analysis.

The recovery was conducted by Croatian forensic teams, joined by American experts, including Henry C. Lee, and by other forensic specialists such as Michael Baden and Barbara Wolf, within a broader Croatian-American collaboration that combined field investigation, laboratory development, and international documentation of the events (24, 28). As part of this effort, a US television crew (WTNH News 8, Channel 8) was brought to Croatia and Bosnia and Herzegovina, where, for the first time, the exhumations and their context were recorded and broadcast to the American public (24).

In one of these documentary records, "Heroes of Hope" from 1995 (24), the conditions of exhumation were captured directly, including the statement that "we have to do whatever we can do the best", reflecting the operational constraints under which the work was carried out (24). The same material documents the human dimension of fieldwork. Henry Lee noted that "as an individual, I wish I could do much more to help them", while Kendra Farn described the encounter with survivors as something that "went beyond words" (24) (Figure 2, Figure 3).



**Figure 2.** Henry C. Lee with journalist Kendra Farn during the investigation, with an improvised structure used as a temporary autopsy facility.



**Figure 3.** The forensic team meets community members at the local school in Kupres.

In March 1994, the first operational mission established a DNA-based identification capacity at the University Hospital of Split. At that point, there was no functioning forensic DNA laboratory, and the expectation was that building one would take months (23). Instead, the team set up the laboratory “from scratch in less than two days”; by the third day, bone samples were ready for extraction, and by the fifth day, the team had obtained DNA from a control case involving a child and confirmed the result with parental blood samples (23). This result showed that PCR-based DNA typing could be applied to degraded skeletal remains from the war context and to advance the identification of victims from Kupres (21–23). Following recovery, the remains were transported to the University Hospital of Split, where identification continued in direct contact with families of the missing (Figure 4).

In this phase, the scientific process acquired its full humanitarian dimension. As Anđelinović stated, “our whole hospital is some sort of their last hope” (24). The first victims from the Kupres area were identified using AmpliType PM + HLA DQA1 PCR Amplification and Typing Kits (22, 23). This development was critical because conventional methods alone were insufficient. This was further demonstrated in subsequent analyses of skeletal remains from mass graves, where multiplex short tandem repeat (STR) systems



Figure 4. Identification of missing persons through visual comparison of personal belongings and associated photographic documentation by family members (University Hospital of Split Archives).



Figure 5. Forensic identification in practice: joint Croatian-American autopsy work at the University Hospital of Split on victims recovered from Kupres mass graves.



**Figure 6.** Timeline of key events in the development of DNA-based identification of war victims (1985–present). Track badges indicate concurrent process domains: field = exhumation and biological sample collection; laboratory = analytical and methodological development; international = collaborative, media, and institutional recognition; context/legacy = armed conflict chronology and long-term institutional outcomes. Blue diamonds denote scientific milestones and orange diamonds denote international milestones. The Kupres mass graves (Bosnia and Herzegovina, 1992) are highlighted as the central case driving development of the systematic DNA-based identification program at Clinical Hospital Center Split. B&H – Bosnia and Herzegovina, ICMP – International Commission on Missing Persons, ICTY – International Criminal Tribunal for the former Yugoslavia, ISABS – International Society for Applied Biological Sciences, JAMA – Journal of the American Medical Association.

(AmpFISTR® Profiler®, Profiler Plus™, COfiler™ and PowerPlex® 16) enabled the recovery of multilocus DNA profiles even from highly degraded bone and tooth samples with minimal or undetectable quantities of human DNA (32).

In the Kupres case, thirty-five of sixty-one victims could be identified by standard forensic methods (Figure 5), but the remainder required DNA analysis, which then became integral to the entire identification framework rather than a marginal supplement (21, 22). At the same time, blood and hair samples from relatives of approximately 150 missing persons were collected, and one of the first kinship-based forensic DNA reference datasets in a mass-conflict setting was created (21, 22). To clarify the temporal sequence of events and the rapid development of DNA-based identification capacity in relation to the Kupres case, a timeline of key activities is presented in Figure 6.



**Figure 7.** Archival photograph taken prior to departure for a humanitarian mission to Croatia, organized by AmeriCares in the early 1990s. The image shows members of the American forensic delegation alongside Barbara Bush, whose support was instrumental in enabling the mission and facilitating the donation of Perkin-Elmer PCR technology. The photograph bears a handwritten dedication reading, “Dragan, Best wishes. Barbara Bush.” From left to right: Stephen Skakel, Henry C. Lee, Dragan Primorac, and Barbara Bush.

The involvement of American forensic experts, facilitated by AmeriCares and strongly supported through the advocacy of Barbara Bush (Figure 7), whose engagement was instrumental in enabling the humanitarian mission, including the donation of Perkin-Elmer PCR technology, brought together Henry C. Lee, Michael Baden, Barbara Wolf, Moses Schanfield, Dragan Primorac, Stephan Skakel, and others (23–25, 28). These scientists travelled to Croatia to work collaboratively with the Split team, which is consistent with the later characterization of the Split program as one of the earliest systematic DNA-based identification frameworks for war victims (21, 28). Their cooperation was not merely technical. As Anđelinović said of Lee, “we have very similar points of view on life”, and Primorac added, “if I obtain only 30% or 40% of what he obtained, I’ll be extremely successful” – a formulation that captures both the closeness of the collaboration and the asymmetry of experience that accelerated knowledge transfer (24).

Upon obtaining the DNA results, families were shown clothing, belongings, skeletal remains, and DNA-supported conclusions. Many initially reacted with mistrust because they had long been exposed to contradictory information, including extortion schemes based on claims that the missing were still alive (23, 24). Once the results were explained and accepted, however, identifications allowed funerals to take place and ended prolonged uncertainty for many families (22, 23).

The encounter with relatives also changed the forensic teams themselves. Henry Lee recalled that “meeting with the family changed my life perspective”, adding that life should be used “to do something meaningful, constructive” (24). These statements should not be read as embellishment; they mark the point at which scientific identification, psychological closure for families, and the evidentiary basis for later war-crimes proceedings converged into a single forensic mission (24, 30).

### Recognition at the United States Congress for scientific contributions (6 December 1995)

The most consequential external validation of the Croatian-American forensic collaboration was delivered not in a journal, but in a hearing of the United States Congress. On 6 December 1995, the Commission on Security and Cooperation in Europe, the Helsinki Commission, convened a hearing of the One Hundred Fourth Congress, First Session, entitled “Mass Graves and Other Atrocities in Bosnia,” chaired by Representative Christopher H. Smith and attended by Representatives Steny H. Hoyer, John Edward Porter, Bill Zeliff, Benjamin Gilman, James Moran, and Sheila Jackson-Lee. The hearing’s third witness was Barbara C. Wolf, a forensic pathologist from Albany, New York, whose testimony occupies an important place in the history of forensic science: a firsthand peer assessment of Split’s forensic infrastructure, entered into the permanent record of the United States Congress (30).

Dr Wolf had travelled to Croatia and Bosnia between 8 and 13 October, 1995, under the sponsorship of AmeriCares. The delegation she joined comprised some of the most distinguished forensic scientists in the USA: Michael Baden, co-director of the Forensic Sciences Unit of the New York State Police; Henry Lee, chief criminalist for the Connecticut State Police; Moses Schanfield, a DNA specialist from Denver; and David Rowe, Professor of Pediatrics at the University of Connecticut Health Center, and Dragan Primorac, a post-doctoral fellow at the University of Connecticut Health Center. Their purpose, as Wolf stated on the record, was unambiguous: “We went to Croatia and Bosnia to work with and lend our support to the forensic team from the Clinical Hospital in Split, Croatia” (30). That American experts travelled to Croatia, rather than the reverse, reflects the level of expertise already established by the Split team at that time (31). Joined by Henry C. Lee, Michael Baden, Moses Schanfield, and Mitchell Holland, the Croatian team undertook the unprecedented task of producing DNA evidence for the International Criminal Tribunal in The Hague as it confronted allegations of crimes against humanity. Primorac captured the ethos of the effort with a simple declaration: “All the data in our books will be available for prosecutors, no matter who committed the crimes” (28).

Dr Wolf's testimony described the work at Split with clinical precision. She reported visiting two mass graves near Kupres, one containing 34 bodies, one containing 3, and a third grave at Petrinja containing nearly 100 bodies. She testified that the American team worked directly alongside Anđelinović and his colleagues in the Split autopsy room, with five or six bodies on tables simultaneously and family members rotating through to attempt identification. By the end of a single working day, 27 of the 34 bodies from the first Kupres grave and all 3 soldiers from the second had been identified; "DNA testing", she told Congress, "is continuing on the remaining bodies yet unidentified". She also noted that the laboratory had been "set up a year ago with some guidance from Dr Lee" and was already expanding beyond standard DNA typing into mitochondrial DNA techniques (30).

The exchange that carries the greatest historical weight came during questioning by Representative Hoyer. Asked whether Croatian pathologists were competent to do good forensic work, Dr Wolf replied: "Very much so, and I think this was really an example of science crossing political lines. The techniques that we use in the United States were very much the same techniques that they were using there, including the DNA laboratory in Split". She further informed Congress that the exchange of expertise had been bidirectional: "Croatian scientists have come to this country and spent time working with the technologies. Our DNA experts, Dr Lee, Dr Schanfield, and others, have looked at their work and technology. The capabilities are certainly there. It is resources and people that are needed". When asked about the primary obstacles to identification, she was explicit: the challenge was not competence or methodology, but the volume of missing persons and the systematic destruction of antemortem records "because the entire towns are destroyed, there is very little to use", which made the kinship DNA database constructed at Split not merely useful but operationally indispensable (30).

This Congressional testimony is, to our knowledge, essentially unknown in Croatia. It deserves to be recognized. It constitutes a form of institutional recognition rarely accorded to science conducted outside the major Western powers: a formal assessment, on the record, under oath, before the United States Congress, that a Croatian hospital laboratory was operating at the frontier of its field, as a peer institution to leading forensic centers in the United States.

### Continuing scientific legacy

The true measure of the Croatian initiative is not only what it accomplished in 1993–1994 but what it set in motion. What began as PCR-based HLA typing on three Kupres bone samples evolved through the same Croatian-American network, into a systematic program of methodological evolution. The shift to multiplex STR analysis, combined with optimized extraction protocols that established the superiority of long-bone cortical samples over skull and rib elements, raised identification success rates from 20–25% to approximately 85% (21). Population allele frequency data required for statistically rigorous identification were generated in the first collaborative study between Croatian scientist Dragan Primorac and Bruce Budowle from FBI Laboratory. Where nuclear markers failed on maximally degraded material, the network developed mitochondrial approaches: immo-

bilized SSO probe analysis of hypervariable regions I and II, validated on bone samples in joint Croatian-American studies; the mt HV+ HaploArray for coding and non-coding polymorphic targets; and Y-STR and miniSTR analysis applied to World War II-era mass graves in Slovenia, Croatia, and Herzegovina that could not be resolved using standard methods (21). The logical extension to this path is forensic genomics: massively parallel next-generation sequencing of autosomal STR, identity SNP panels, and mitochondrial targets, deployed in the identification of Sister Marija Crucifiksa Kozulić, a case that directly reflected the methodological approach initiated at Kupres (35).

The practical reach of these methods has long transcended any single national context. The methodological framework applied in Croatia, simultaneous excavation, kinship-based reference database construction, multi-marker identification, shared key elements with a range of international contexts, including victims of the 11 September attacks in New York and Washington, D.C., to tsunami casualties, and to mass graves in Iraq, Syria, and Libya (21). The International Commission on Missing Persons, established in 1996 (36), eventually identified more than 27,000 individuals from the former Yugoslavia (37) based on methodological principles the Split team had pioneered. What was invented under crisis in a Croatian clinical hospital became, within a decade, part of international standard practice.

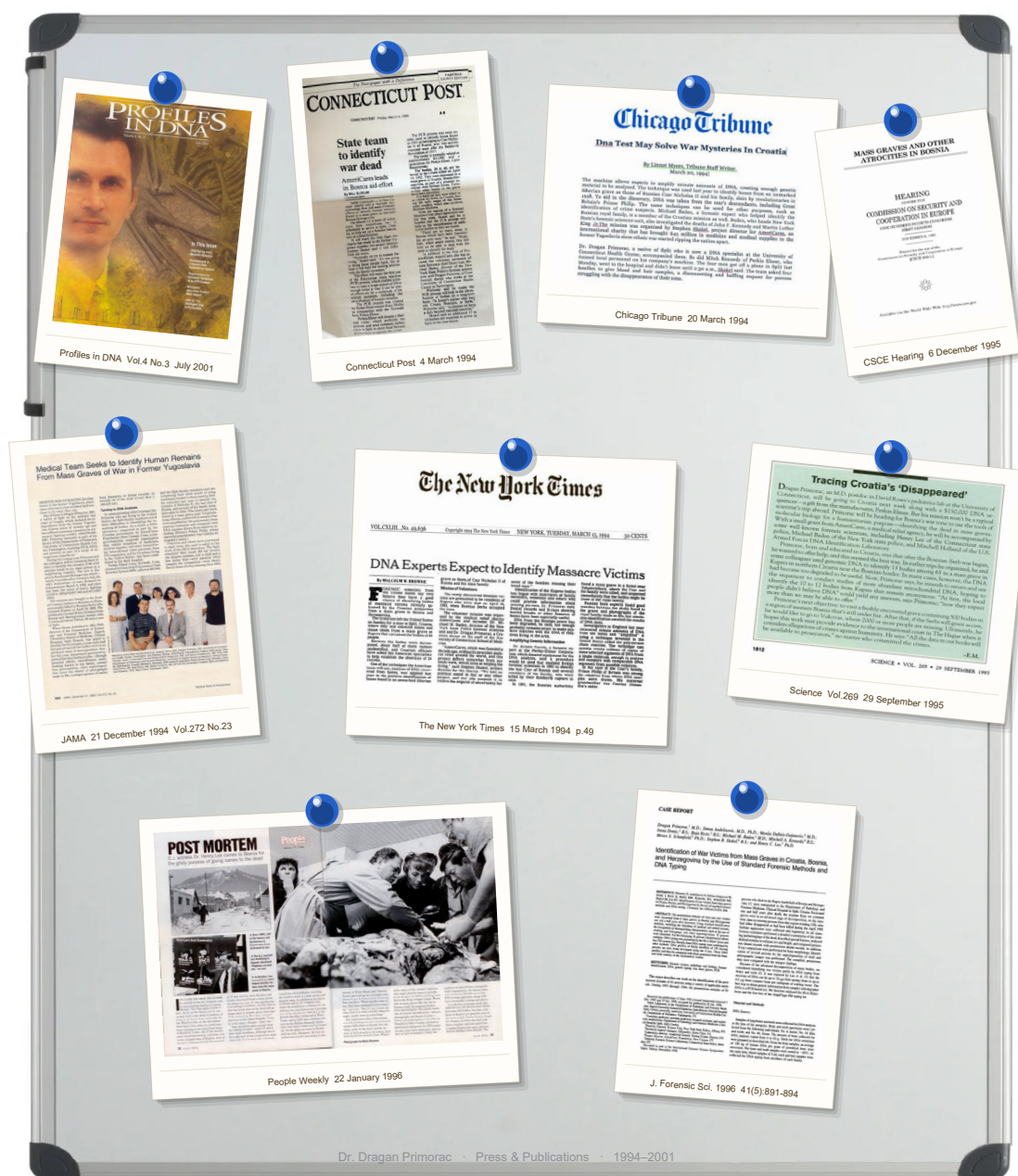
The collaboration that Dr Wolf described to Congress in 1995 as “science crossing political lines” has proven structurally durable. The same network, Primorac, Anđelinović, Lee, Baden, Holland, Budowle, Marjanović, and their scientific peers continue to publish, develop methods, and train scientists jointly. The 30-year review published in *Croatian Medical Journal* in 2024 (21) carries many of the same names as the 1996 paper in the *Journal of Forensic Sciences* (22). The International Society for Applied Biological Sciences (ISABS) has institutionalized the interdisciplinary ethos and united forensic genetics, anthropology, clinical medicine, and translational genomics, which was first employed in the identification rooms of University Hospital of Split (38). It was founded by Croatian (Dragan Primorac) and American (Moses Schanfield) scientists as an institutional framework for continuing interdisciplinary collaboration in forensic and applied genetics. Stanimir Vuk-Pavlović later joined ISABS, while Šimun Anđelinović served as the Chairman of the Organizing Committee in Croatia. The journey from HLA typing of three Kupres (22) victims to forensic genomic sequencing of ancient remains (39), coordinated by the same international scientific community, demonstrates that a Croatian-American partnership, born in wartime, has contributed to shaping the global practice of forensic identification for thirty years and counting.

## Conclusion

Thirty years after the excavations at Kupres, the record is clear and formally documented, including in the proceedings of the United States Congress. The team at University Hospital of Split did not work in the shadow of better-resourced institutions, nor did they await external guidance. They worked as peers and, in their specific domain, as early contributors in this domain, alongside American scientists who came to Croatia to collaborate on equal terms. Dr Wolf’s testimony before the Helsinki Commission on 6 December 1995, largely

unrecognized in Croatia until recently, captures that partnership at its moment of formal international recognition. This record should be acknowledged and integrated into the historical understanding of the development of forensic genetics in Croatia and its contribution to global forensic practice.

Beyond its scientific and methodological contributions, the Croatian experience attracted an unusual convergence of scientific, political, and media attention during the mid-1990s. The work conducted in Split was simultaneously documented in leading scientific journals (JAMA, Science), reported in major international media outlets (The New York Times, Chicago Tribune, People Weekly), and formally recognized in a hearing before the United States Congress (6 December 1995) (Figure 8). This parallel visibility across scientific, institutional, and public domains reflects not only the novelty of the methods employed,



**Figure 8.** Interactive overview of key scientific publications, media reports, and institutional milestones related to early DNA-based identification of war victims. Each item provides direct access to the original source (22, 25–32).

but also the broader significance of forensic identification as both a humanitarian and evidentiary practice. In this sense, the Croatian initiative did not evolve in isolation, but emerged at the intersection of science, international policy, and public awareness, further reinforcing its role in shaping the global framework of mass-fatality identification.

**Provenance:** Submitted.

**Received:** 31 March 2026 / **Accepted:** 17 April 2026 / **Published online:** 22 April 2026.

**Peer review:** Externally reviewed.

**Acknowledgements:** This work is dedicated to the memory of Dr Henry C. Lee, an extraordinary man, often regarded as the Sherlock Holmes of our time, one of the pioneers of modern forensic science, and, to us, a dear friend. At a time when forensic DNA analysis was only beginning to emerge, Dr Lee approached science with ingenuity and determination, developing and applying methods under conditions that today would seem modest, yet were foundational for the field. His work was not confined to established laboratories; it was driven by curiosity, persistence, and a deep belief that science must serve truth and humanity. Dr Dragan Primorac and Dr Šimun Anđelinović shared a profound friendship with Dr Lee, having the rare privilege of working alongside him during the historic introduction of forensic genetics into the identification of war victims from mass graves. Through this pioneering collaboration, they shared interdisciplinary knowledge and advanced technical expertise but also a deep understanding of the values that defined Dr Lee's life and work – scientific rigor, intellectual openness, humility, and an unwavering commitment to justice. His presence in Croatia during the early efforts to identify the victims of the 1991–1995 Homeland War reflected more than scientific collaboration. It was an act of solidarity, at a moment when science crossed borders to respond to human suffering. To those who knew Dr Henry C. Lee, he was not only one of the most influential figures in the development of modern forensic science, but also a generous colleague and a true friend.

**Funding:** No funding was received for this study.

**Authorship declaration:** ŠA, DP, MD, AV, IK, ŽB, and IJ conceived and designed the study. ŠA, DP, and MD acquired the data. DP, IJ, and ŽB analyzed and interpreted the data. ŽB and IJ drafted the manuscript. ŠA, DP, MD, AV, IK, ŽB, and IJ critically reviewed the manuscript for important intellectual content. ŠA, DP, MD, AV, IK, ŽB, and IJ gave approval of the version to be submitted. ŠA, DP, MD, AV, IK, ŽB, and IJ agree to be accountable for all aspects of the work.

**Disclosure of interest:** The authors completed the ICMJE Disclosure of Interest Form (available upon request from the corresponding author) and disclose the following activities and/or relationships: ŽB is the co-editor-in-chief of the ST-OPEN. She did not have an editorial decision-making role and had no access to the manuscript submission system. To ensure the integrity of the review process, the article has been reviewed in accordance with the guidelines and processes suggested by the Committee on Publication Ethics.

**Declaration of AI and AI-assisted technologies in the writing process:** During the preparation of this work, the authors used GPT-5.3 (OpenAI) to assist with language editing and proofreading, and Claude Sonnet 4.6 (the extended model) for generating Figures 6 and 7. After using this tool, they carefully reviewed and edited the content as needed and take full responsibility for the final content of the publication.

**Data sharing statement:** The data supporting the findings of this study are derived from previously published sources and publicly available materials, including scientific articles, historical records, and contemporaneous documentary transcripts. No new primary datasets were generated or analyzed during the current study. All relevant information is included within the article and its referenced sources.

## ORCID

Šimun Anđelinović  <https://orcid.org/0000-0002-9017-5634>

Dragan Primorac  (<https://orcid.org/0000-0001-5565-080x>)

Ivana Kružić  (<https://orcid.org/0000-0002-2285-2189>)

Željana Bašić  (<https://orcid.org/0000-0002-8327-1978>)

Ivan Jerković  (<https://orcid.org/0000-0003-4716-9375>)

## References

1. International Criminal Police Organization. Disaster victim identification guide. Lyon (FR): INTERPOL; 2023.
2. International Criminal Police Organization. Disaster victim identification guide. Lyon (FR): INTERPOL; 1997.
3. Jeffreys AJ, Wilson V, Thein SL. Hypervariable ‘minisatellite’ regions in human DNA. *Nature*. 1985;314(6006):67–73. <https://doi.org/10.1038/314067a0>
4. Jeffreys AJ, Wilson V, Thein SL. Individual-specific ‘fingerprints’ of human DNA. *Nature*. 1985;316(6023):76–9. <https://doi.org/10.1038/316076a0>
5. Corach D, Sala A, Penacino G, Sotelo A. Mass disasters: rapid molecular screening of human remains by means of short tandem repeats typing. *Electrophoresis*. 1995;16(9):1617–23. <https://doi.org/10.1002/elps.11501601267>
6. Clayton TM, Whitaker JP, Maguire CN. Identification of bodies from the scene of a mass disaster using DNA amplification of short tandem repeat loci. *Forensic Sci Int*. 1995;76:7–15. [https://doi.org/10.1016/0379-0738\(95\)01787-9](https://doi.org/10.1016/0379-0738(95)01787-9)
7. Clayton TM, Whitaker JP, Fisher DL, Lee DA, Holland MM, Weedn VW, et al. Further validation of a quadruplex STR DNA typing system: a collaborative effort to identify victims of a mass disaster. *Forensic Sci Int*. 1995;76(1):17–25. [https://doi.org/10.1016/0379-0738\(95\)01788-7](https://doi.org/10.1016/0379-0738(95)01788-7)
8. Holland MM, Fisher DL, Mitchell LG, Rodriguez WC, Canik JJ, Merrill CR, et al. Mitochondrial DNA sequence analysis of human skeletal remains: identification of remains from the Vietnam War. *J Forensic Sci*. 1993;38(3):542–53. <https://doi.org/10.1520/JFS13439J>
9. Marušić M. Croatia: past, present and future perspectives. New York (NY): Nova Science Publishers; 2020.
10. Mann J, Drucker E, Tarantola D, McCabe MP. Bosnia: the war against public health. *Med Glob Surviv*. 1994;1(3):130–46.
11. Judaš M, Radoš M, Lončar M, Kostović I. Medical center for human rights: war crimes and grave breaches of the Geneva convention. *Croat Med J*. 1993;34(3):334–41.
12. Roewer L. DNA fingerprinting in forensics: past, present, future. *Investig Genet*. 2013;4(1):22. <https://doi.org/10.1186/2041-2223-4-22>
13. Hagelberg E, Gray IC, Jeffreys AJ. Identification of the skeletal remains of a murder victim by DNA analysis. *Nature*. 1991;352(6334):427–9. <https://doi.org/10.1038/352427a0>
14. Jakobsen J, Remvig P. Identification of victims after a fire on the ferry “Scandinavian Star.”. *Tandlaegebladet*. 1991;95(8):325–30.
15. Solheim T, Lorentsen M, Sundnes PK, Bang G, Bremnes L. The Scandinavian Star ferry disaster 1990 – a challenge to forensic odontology. *Int J Legal Med*. 1992;104(6):339–45. <https://doi.org/10.1007/BF01369554>
16. Ludes B, Tracqui A, Pfitzinger H, Kintz P, Levy F, Disteldorf M, et al. Medico-legal investigations of the Airbus A320 crash upon Mount Ste-Odile, France. *J Forensic Sci*. 1994;39(5):1147–52. <https://doi.org/10.1520/JFS13698J>
17. Connor M. The archaeology of contemporary mass graves. *SAA Bull*. 1996;14(4):1–3.
18. Olaisen B, Stenersen M, Mevåg B. Identification by DNA analysis of the victims of the August 1996 Spitsbergen civil aircraft disaster. *Nat Genet*. 1997;15(4):402–5. <https://doi.org/10.1038/ng0497-402>

19. Hsu CM, Huang NE, Tsai LC, Kao LG, Chao CH, Linacre A, et al. Identification of victims of the 1998 Taoyuan Airbus crash accident using DNA analysis. *Int J Legal Med.* 1999;113(1):43–6. <https://doi.org/10.1007/s004140050277>
20. Robb N. 229 people, 15,000 body parts: pathologists help solve Swissair 111's grisly puzzles. *CMAJ.* 1999;160(2):241–3.
21. Primorac D, Andelinović Š, Definis-Gojanović M, Škaro V, Projić P, Čoklo M, et al. Identification of skeletal remains in Croatia and Bosnia and Herzegovina, including the homeland war – a 30-year review. *Croat Med J.* 2024;65(3):239–48. <https://doi.org/10.3325/cmj.2024.65.239>
22. Primorac D, Andelinović Š, Definis-Gojanović M, Drmić I, Rezić B, Baden MM, et al. Identification of war victims from mass graves in Croatia, Bosnia, and Herzegovina by the use of standard forensic methods and DNA typing. *J Forensic Sci.* 1996;41(5):891–4. <https://doi.org/10.1520/JFS14019J>
23. Perkin-Elmer Corporation. Early development of DNA identification in Croatia (Perkin-Elmer Documentation). 1993 [cited 2026 Apr 17]. Available from: <https://repositorij.forenzika.unist.hr/object/forenzikast:679>
24. Farn K. Heroes of Hope [Internet]. WTNH News 8 (Channel 8); 1995 [cited 2026 Apr 17]. Available from: <https://www.youtube.com/watch?v=E-pBnXWcV7A>
25. Gunby P. Medical team seeks to identify human remains from mass graves of war in former Yugoslavia. *JAMA.* 1994;272(23):1804. <https://doi.org/10.1001/jama.1994.03520230016007>
26. Slocum B. State team to identify war dead: AmeriCares leads in Bosnia aid effort. *Connecticut Post.* 1994 Mar 4.
27. Browne MW. DNA experts expect to identify massacre victims. *New York Times.* 1994 Mar 15.
28. Marshall E. Tracing Croatia's "disappeared.". *Science.* 1995;269(5232):1812.
29. Myers L. DNA test may solve war mysteries in Croatia. *Chicago Tribune.* 1994 Mar 20.
30. United States. Congress. House. Committee on International Relations. Mass graves and other atrocities in Bosnia. Washington (DC): US Government Printing Office; 1996.
31. Post mortem. *People (Chicago).* 1996 Jan 22.
32. Alonso A, Andelinovic S, Martin P, Sutlovic D, Erceg I, Huffine E, et al. DNA Typing from skeletal remains: evaluation of multiplex and megaplex str systems on dna isolated from bone and teeth samples. *Profiles in DNA* [cited 2026 Apr 17]. 2001. Available from: <https://www.draganprimorac.com/wp-content/uploads/2010/05/Profiles-in-DNA-Vol4-No3-web.pdf>
33. Marijan D. Expert opinion: on the war connections of Croatia and Bosnia and Herzegovina (1991–1995). *Čas za suvremenu povij.* 2004;36(1):249–89.
34. Sambunjak D, Marušić M. Between forwarding and mentoring: a qualitative study of recommending medical doctors for international postdoctoral research positions. *BMC Med Educ.* 2011;11:31. <https://doi.org/10.1186/1472-6920-11-31>
35. Marshall C, Sturk-Andreaggi K, Gorden EM, Daniels-Higginbotham J, Sanchez SG, Bašić Ž, et al. A forensic genomics approach for the identification of Sister Marija Crucifiksa Kozulić. *Genes (Basel).* 2020;11(8):938. <https://doi.org/10.3390/genes11080938>
36. Huffine E, Crews J, Kennedy B, Bomberger K, Zinbo A. Mass identification of persons missing from the break-up of the former Yugoslavia: structure, function, and role of the International Commission on Missing Persons. *Croat Med J.* 2001;42(3):271–5.
37. Rizvić A, Krstičić A, Mandžuka A, Pučić M, Jašaragić E, Blau S. Managing large volume data sets in the process of identifying missing persons: Contributions from the International Commission on Missing Persons. *J Forensic Sci.* 2024;69(5):1690–8. <https://doi.org/10.1111/1556-4029.15474>
38. International Society for Applied Biological Sciences (ISABS) [Internet]. 2026 [cited 2026 Apr 17]. Available from: <https://www.isabs.hr>
39. Bašić Ž, Fox AR, Anterić I, Jerković I, Polašek O, Andelinović Š, et al. Cultural inter-population differences do not reflect biological distances: an example of interdisciplinary analysis of populations from Eastern Adriatic coast. *Croat Med J.* 2015;56(3):230–8. <https://doi.org/10.3325/cmj.2015.56.230>