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Objectives and Scope

The discipline of forensic science has nurtured many publications oriented toward research and case reports, as well as broad-based formal treatises. Rapid advances in forensic science have created a need for a review journal to bridge the gap between research-oriented journals and reference volumes.

The goal of *Forensic Science Review* is to fill this void and provide a base for authors to extrapolate state-of-the-art information and to synthesize and translate it into readable review articles. The addition of this journal extends the spectrum of forensic science publications.

Articles bring into focus various narrowly defined topics whose literature has been widely scattered. Articles are presented to stimulate further research on one hand and worthwhile technological applications on the other. The publisher's aim is to provide forensic scientists with a forum enabling them to accomplish this goal.

Technological applications based on basic research are emphasized. Articles address techniques now widely used in forensic science as well as innovations holding promise for the future.

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The journal, original founded by President Shih-Si Yen, President of the Central Police University (Taoyuan, Taiwan), is currently published by Forensic Science Review with executive editorial offices located in Arlington (Texas, US) and the Department of Criminal Justice, University of Alabama at Birmingham (Alabama, US).

Both professional review/commentary and review articles published in **Forensic Science Review** are mostly invited contributions. Review articles are peer-reviewed. The invitation process normally originates from the recommendations of the Editorial Board. Unsolicited articles from the general readership are also welcomed but should be preceded by a query letter to the Editor-in-Chief for presentation to the Editorial Board. Query letters and editorial correspondence should be addressed to: Editor-in-Chief, **Forensic Science Review**, Department of Criminal Justice, University of Alabama at Birmingham, Birmingham, AL 35294, US or preferably through E-mail to rayliu@uab.edu. Honoraria are presented to authors and reviewers upon distribution of the issue in which the article appears. All published articles represent the opinions of the authors and do not represent the official policy of the publisher or the institution with which the author is affiliated, unless clearly specified.

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Forensic Science Review's Professional Review and Commentary (R&C) section highlights contemporary issues and events in the profession of forensic science. To contribute updates or commentary or to recommend books for review, please contact Ray Liu (rayliu@uab.edu).

[a]The views expressed are those of the authors and do not necessarily reflect the view, the position, or the policy of *Forensic Science Review* or members of its editorial board.

Forensic Odontology in Latin America

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According to the US National Academy of Sciences (NAS), forensic odontology (FO) is "the application of the science of dentistry to the field of law", and "includes several distinct areas of focus: the identification of unknown remains, bite mark comparison, the interpretation of oral injury, and dental malpractice" [1]. However, many authors prefer to distinguish this definition according to a Latin American perspective, either because of the expert's "field of action" [2], or simply because the Latin American forensic odontologist has a different training and degree than his/her Anglo-Saxon counterpart [3]. Undoubtedly, FO will always depend on the legal system of the country that claims it; we will seek in this report to focus on a reality that is not exactly "generic", but rather imprinted on the "identity" culturally associated with *latinoamericanidad* (Latin Americanness), for some radically different from the West or from modernity, for others self-proclaimed as a guarantee of epistemic or political authenticity [4]. Latin American FO has its own characteristics that can be explained from its birth, history, and current challenges as it seeks to insert itself globally.

The term "historicity", beyond its scarce use in academia, has been mentioned as having different interpretations and meanings in the social sciences. In this review, following Hirsch and Stewart's proposal, I will seek to "[r]econfigur[e] 'historicity' to index the fuller qualities of this social and personal relationship to the past and future mak[ing] it a complex social and performative condition, rather than an objectively determinable aspect of historical description" [5]. According to these authors, to understand historicity in a particular ethnographic context such as Latin America, I will not only associate historical facts or events but also the perception that Latin American peoples have made of them, leading to the current situation of FO on this side of the world. Latin America is not a continent, but a region that gathers about 20 countries in which a language derived from Latin is mostly spoken: Spanish, Portuguese, or French. These countries were colonized by Spain, Portugal, and France, becoming independent from them in the first part of the 19th century [6]. These assertions have not been without hot discussion; while Latin America also includes people who do not speak languages derived from Latin (the so-called "original peoples" with languages such as Quechua, Aymara, Guarani, Mayan, Mapuche, etc.), at the same time it excludes territories such as Puerto Rico (with a majority Spanish language), the French-speaking province of Quebec in Canada, and some Caribbean islands where French is spoken [6]. Contrary to some minimalist denominations, there is no "Latin American race" but an enormous ethnic complexity in which ancestry, miscegenation, birthplace, genetics, and even self-perception are all variables of ethnographic evaluation [7]. However, even though Latin America is seen as a region of contradictions, its countries share many similarities: as we have already seen, they have a common history of colonialism and independence, similar macroeconomic characteristics, and a deep-rooted heritage of armed conflicts with great social impact [6]. Ramos gives a very good reflection on "Latin American identity" when he states that in order to make sense of that identity, a broad, holistic perspective is required, one that includes diverse and contradictory dynamics and elements, and at the same time a view that appropriately relates the past with the future [8].

European Beginnings of Latin American Forensic Odontology Identity

To situate FO historically in Latin America is, inescapably, to take note of the Cuban Dr. Oscar Amoëdo Valdés (1863–1945), for many the "father of forensic dentistry worldwide" [9,10]. Coming from a modest family, young Amoëdo learned about the dental profession in the office of a renowned dental surgeon in the city. His tutor recommended the enthusiastic young man to continue his studies at the Central Academy of Dentists in Havana, from which he graduated with honors in 1884, at the age of 21. Eager to improve his skills, he entered New York Dental College, from which he graduated in 1888 [11]. In those years, dental practice in Latin America was basically "colonial", difficult to regulate, and exercised by individuals with no medical or scientific education [12,13]. Once he graduated, Amoëdo returned to Havana, where he performed several highly complex procedures, initiating his scientific research tasks with articles published periodically in the *Chronique Médico Chirurgicale* [11]. In 1889, he was sent as a delegate

to the International Dental Congress in Paris, where he decided to settle and study medicine [11]. In those years, the colonial model of university education was replaced by a Napoleonic model of university, an influence resulting from the French Revolution, which was assumed by the leaders of Latin America who sought to implement an enlightened and positivist ideology to support different professionals essential to ensuring national edification [14]. In Paris, Amoëdo became a clinical instructor, assistant professor, and professor at the École Odontotechnique de Paris, where he practiced for more than 15 years [11]. At the end of the 19th century, and with the penetration of positivism in Latin America, Europe represented the panacea of the scientific discourse "with encyclopedic and universalist pretensions", and Latin America as the new world, the "naïve and in need of an imposed savior" [15]. In the field of dentistry, France enjoyed a central prestige in those years; the French Revolution had also transformed the view of public health, hospital practice, and specialization, making Paris the center of European medicine, and where surgery was one of the many fields in which French superiority was reflected [12]. Dentistry, already enhanced by the scientific approach of the pioneering physician Pierre Fauchard (1678–1761), was strengthened by certified practice and the free market of practice and teaching, leading French dental surgeons to be recognized as "the most sought-after of the time" [12]. In 1892, the French state regulated the dental profession by recognizing the École Odontotechnique de Paris (founded in 1884) as a public utility and authorizing it to train its students to obtain the title of dental surgeon [16]. In Paris, Amoëdo's name appeared in those years among the great professors of dental surgery for his professional, technical, and pedagogical competence and dental knowledge, even as a foreigner (not being French meant an important gap in his academic development) [11].

The year 1897 would be profoundly significant not only for Amoëdo's work but also for FO. On May 4, Paris would be the scene of a terrible catastrophe that left 126 people dead and more than 200 seriously injured. The *Bazar de la Charité*, a charity event organized by the French Catholic aristocracy in Paris, was reduced to ashes in less than 10 minutes after a fire broke out in a prototype cinematograph that used an ether and oxygen system for its operation. The flammable nature of the installations and decorations favored the rapid spread of the flames; the women in attendance were unable to escape through the exits, which were few and narrow [17]. At the request of the Paraguayan Consul, Albert Haus, and following a standard already established in the literature of those years [18], it was proposed to examine the victims by taking into account their dental records, particularly those of the Parisian upper classes [2, 17]. Although Amoëdo did not participate directly in the identification of the victims, he recounts: "[t]he numerous and important services rendered by our colleagues to identify the unfortunate victims of that terrible day only increased our desire to continue this study" [17]. A detailed chronicle of the forensic work was presented by Amoëdo at the 12th International Congress in Moscow, then published in The Dental Cosmos that same year [19], giving rise to his doctoral thesis work in medicine and future seminal work *L'Art Dentaire en Médecine Légale* [17], a book that introduced the value of the FO in medicolegal identification tasks. The eminent pathologist Prof. Paul Brouardel said about this work: "This is not a thesis but a treaty of odontology. He filled in all the great gaps which remained in the field of forensic identification" [10]. This work gathers more than 600 pages of not only anatomical, pathological, and radiological evaluations, but also specific technical proposals in all branches of FO, and also supervises dental jurisprudence, concluding with 52 observations and personal experiences in forensic identification (including his expert advice in the evaluation of the supposed remains of Louis XVII). In 1899, Amoëdo also presented to the American Dental Society of Europe his essential communication entitled "The identification of corpses by a dental expert", in which he underlines not only the importance of having a dental expert, but also the risk of neglecting his possible observations [10], a statement curiously still valid today. Amoëdo died in Toulouse, France in 1945. For many, this modest Cuban dental surgeon with an elegant and distinguished appearance represents the foundational and formal character of FO [10,11], a unique motivation for future specialists, as will be seen below.

Back in Paris in 1897, a young Chilean doctor was specializing as a dental surgeon at the prestigious École Odontotechnique, with a scholarship from the Chilean government. This young man, also a teacher at the Faculty of Medicine and Pharmacy of the University of Chile, was looking for support in the very prestigious France for the creation of a specialty in diseases of the mouth, and thus create in Chile a new model of modern teaching of what was then called *Dentística* [20]. In those years, Europe and Latin America had important exchanges between their academic and scientific communities with the migration of professors and scientists and intellectual contributions of extraordinary quality [14]. Even though there are no documents that certify it, it is logical to think that this young man, named German Valenzuela Basterrica, met Prof. Amoëdo and perhaps was even a privileged witness to the events at the Bazar de la Charité. The year *L'Art Dentaire en Médecine Légale* was published, Valenzuela Basterrica returned to Chile with new knowledge and ideas,

including the creation of a Dental School that was similar to the French model. The difficult local circumstances forced him to start this project in an almost shameful way and to continue in this way for some years, until another event would be decisive not only for Chilean dentistry but also for Latin American FO [20]. On February 5, 1909, the building of the German Legation in Santiago (the capital of Chile) burned to the ground, leaving the charred remains of, presumably, the German citizen Wilhelm Beckert, secretary of the Legation. The presumptions were based on the wedding ring and other clothes and personal objects found next to those remains, in addition to the suspicious disappearance of both the Legation's doorman and the enormous sum of money from the safe. This evidence led to the thinking that Ezequiel Tapia, the doorman, upon being surprised by Beckert, murdered him and then started the fire in the building to hide the crime and flee with the money. However, some rumors and doubts in the autopsy of those remains led the judge in charge of the case to ask Germán Valenzuela Basterrica (at that time, director of the very humble Dental School) to examine the teeth of the corpse to confirm the presumptions about its identity. Valenzuela Basterrica's report was conclusive: the corpse did not belong to Beckert but to Tapia. Once the crime was discovered, Beckert was captured a few days later, tried, and finally executed in 1910, definitively resolving a conflict that had taken on serious international political connotations. For his service, Valenzuela Basterrica only asked for the construction of a suitable building for his Dental School (today, the Faculty of Dentistry of the University of Chile), a request that the government gladly accepted and fulfilled, inaugurating it in 1911 [2].

Forensic Odontology and Latin American Criminal Anthropology

Since the end of the 19th century, coinciding with European positivism, there has been a need throughout Latin America to promote the creation of identification and anthropometry services, inserted in police stations, or even in prisons (in Argentina, this service would be directed by the renowned Juan Vucetich, creator of the, at that time, new identification system: dactyloscopy). This need, according to del Olmo (1999), derived mainly from the concern for the control of immigrants, the possible increase in delinquency, and the implementation of a "criminal anthropology" (basically positivist ideology with strong Italian and French influence) that studies and anticipates the delinquent individual (even with possible eugenic traits). This led to the institutionalization of international organizations that fought for social control of the criminal problem, the unification of anthropometric procedures, and the elaboration of common prison regimes [21]. To this end, these organizations convened congresses that allowed the exchange of ideas and intellectual development between countries with progressive changes in the way of dealing with crime from "scientific principles". The impact of criminological positivism was undeniable in Latin American criminal anthropology, with Brazil and Argentina leading this trend and radiating immediately to other countries in the region [22]. Latin America sought to send its delegations to European events timidly at the beginning (with a brief interruption due to the First World War), and much more representative and growing in later years [21].

The case of the German Legation, beyond its transcendental significance for Chilean dentistry, represented an inescapable milestone in the development and consolidation of Latin American FO [2,23]. The first decades of the 20th century saw the creation of chairs and departments of FO at the university level (and with it the beginnings of formal undergraduate and postgraduate training), the publication of books, and the inclusion of specialized services in police agencies, aligning themselves with the profile of criminal anthropological identification so much in vogue in those years. The works of Joaquín Gnecco, Juan Ubaldo Carrea and Juan Ramón Beltrán in Argentina, Guillermo Aspúrua in Venezuela, Henrique Tanner de Abreu and Luis Lustosa da Silva in Brazil, and Armando López de León in Guatemala, among others, stand out [24–26]. For example, it is worth mentioning the work of López de León in 1924, "Criminal Odontology", in which he proposes classifying the palatal rugae according to groups of temperaments as indicators of the character of an individual, offering a service "that the Science of Dental Surgery can provide to the police, in the identification of certain criminals, or perhaps all of them, as well as their victims" [27].

In 1942, Lustosa da Silva explained psychotic pictures and criminal tendencies from oral diseases, such as impacted third molars, dental caries, simple anomalies, and defective treatments [28]. As a consequence of the strong initiative of Cuban odontologists started two years before [28], in 1946, Havana hosted the "First Pan-American Congress of Legal Medicine, Legal Odontology and Criminology" (the quality of "Pan-American" would be given by the presence of North American delegates and the strong policy of continental coordination, according to del Olmo [21], evident in the agreements, resolutions, and recommendations of the congress). This event officially recognized the autonomous character of Latin American FO. The Legal Odontology section gave rise to 15 lectures by speakers from Argentina, Brazil, Costa Rica, Cuba, Chile, Guatemala, Peru, and Venezuela, demonstrating

the important future projections of the discipline in the field of criminal identification [21]. In the same line, World War II would offer an even greater opportunity for FO: the US and Europe were suffering from "the most gigantic problem of identification" they have ever faced [29], and the role of Scandinavian forensic odontologists in identifying casualties was quite remarkable [30]. The dental records of young men, which are necessary to assess their health status upon enlistment for military service [31], were challenged for post-war identification. In 1947, the American Dental Association included "the several military dental corps" and "the Veterans Administration" among the institutions offering dental care that needed a standard method for the symbolic designation of teeth, so they proposed adopting the Zsigmondy-Palmer dental notation [32], also known as the "Military system" [33]. In line with this renewed enthusiasm for post-war FO (consolidating in the following years the European protagonism led by the Swede Gösta Gustafson in 1966 [34] and his founding presidency of the International Organization for Forensic Odontostomatology, or IOFOS, in 1973 [2]), the following decades would see in Latin America the projection of academics and scientists with transcendental contributions in identification: Vicente Bertini in Argentina, Julio Peñalver in Venezuela, Jorge Castroverde in Cuba, Aquiles Echeverri in Colombia, Carlos Basauri in Peru, and Eduardo Daruge in Brazil [2,24]. However, dental identification was perceived as a mixture of FO content with anthropology, orthodontics, economics, dental hygiene, and history, which indicated that FO was (and perhaps still is) searching for its Latin American identity [35].

Ideology, Politics, and Latin Americanism

As mentioned above, Latin America sought, from the beginning of the 20th century, to insert itself internationally into the search for solutions to crime but without escaping the ideological and political guidelines of the time. Although since 1909 the invitation to the US to participate in scientific congresses would be encouraged in line with the recent policies of Pan-Americanism, the scene would change radically in the years following World War II. The threat of the installation of communist or overly reformist regimes in Latin America (crystallizing the bipolarity of the Cold War and marking American political and economic hegemony) would provoke a series of interventions based on American interests in the region. This would lead to a manifest reactivity in a latinoamericanismo (Latin Americanism) that, for some authors, still refuses to disappear [36]. The beginning of the 20th century brought to Latin America conceptions that would deny the supposed mechanisms of control and alignment of the bourgeois sectors [15]. The emancipatory projects, their economic and legal models, and language barriers were all reasons for trying to project a united America, a new Latin American identity that, despite the failure of many of these initiatives, shaped a historical and cultural personality that has managed to survive to the present day and which still underlies many current integration schemes and projects [21,36]. As will be seen below, according to this author, this could explain many of the behaviors and current state of Latin American FO.

In Cuba, the triumph of the Cuban revolutionary movement in 1958 had strong national and international repercussions, transforming not only political and economic relations with the US but also affecting the fragile Latin American social balance. The Cuban government participated hand in hand with most Latin American nations taking sides in the Cold War, leading to military responses that sought to restructure the state and reorder society as a whole. During the 1960s and 1970s, most Latin American countries transformed into dictatorial regimes, managing to consolidate themselves as stable forms of government for long periods. It is not the intention of this report to unravel the delicate fabric that Latin Americanism had built in opposition to US intervention. However, it is worth noting what is mentioned by Naranjo Navas et al.: "the Latin American revolutionary views foreign cultural traditions with suspicion, because the foreign is a source of evil, and the divine is everything considered native, indigenous, millenary, in itself, everything conceived as ancestral wisdom" [37]. On the other hand, military dictatorships severely repressed the university community with a complete emptying of socially and politically significant educational content, the expulsion of academics, and censorship [38]. A critical examination of Latin America throughout the 20th century shows a long history of massacres and bloodsheds, with episodes of revolutionary uprisings and subsequent efforts to crush them [39]. For Ruiz, political and social tensions created a highly difficult situation for Latin American universities that still explains many of their problems today: the high politicization of state universities permeated university life for decades, conspiring against a constructive sense of purpose in these Latin American institutions and accelerating their academic decline. The violence between groups on both sides created chaos that in several places led to forced or voluntary emigration to other latitudes of excellent academics and a considerable weakening of academic quality in most of them [14]. This phenomenon profoundly affected Latin American FO. The revolutionary movements disrupted any scientific initiative perceived as pro-American [40]: in Cuba, the Society of Legal Odontology and Criminological

Studies, founded in 1944 and with an important leading role in the aforementioned First Pan-American Congress of Legal Medicine, Legal Odontology and Criminology, was dismantled in 1958 due to the forced emigration of its board of directors [41]. However, the situation was not very different in the antipodes of regional politics: dictatorships had a profound effect on the control, censorship, and even expulsion of scientists [42]. The Peruvian Society of Forensic Odontology (founded in 1975 by Basauri) and the Argentine Society of Legal Odontology (SADOL, founded in 1977) both suffered circumstances derived from their respective military juntas, with only the latter surviving, revived almost three decades later [35,43]. The ideological and political manipulation of leftist groups on the one hand, and the hardening and repressive criminal action of the dictatorships on the other, led to stagnation, regression, and international disinsertion of the academy during those 20 or 25 years, even well into the eighties [14], with consequences (for this author) still visible in the behavior of Latin American FO, as will be seen below.

The 1980s brought new nuances to the Latin American reality. The reinstallation of democracies (after the dictatorships were defeated in the streets or at the ballot box), and with it, the visibility of the mechanisms of torture, forced disappearances, and deaths of people who opposed the dictatorial regimes, exposed staggering numbers of people murdered and abandoned in mass and clandestine graves [44]. Human rights violations and, fundamentally, the need to identify these victims, were sufficient impetus for Latin America to bring in forensic specialists to investigate these crimes. The arrival of the North American expert Clyde Snow in 1985 by summoning archaeologists, anthropologists, and physicians to begin exhumation and analysis of skeletonized remains initiated a stage of training and subsequent creation of the Equipo Argentino de Antropología Forense (Argentine Forensic Anthropology Team) (EAAF), which had important interventions not only throughout Latin America, but also in Africa, Europe, and Asia, thus promoting the creation of similar teams in Guatemala and Peru [45]. Curiously, although these forensic anthropology teams claim to have worked with odontologists, they are not part of their permanent staff and the reports only refer to specific works.

Latin American Forensic Odontology and the Gartner's Hype Cycle Model

As mentioned, the historicity of Latin American FO associates historical facts with insights and opportunities with growth. Far from being seen as an upward continuum in its development, Latin American FO shows more similarities with Gartner's hype cycle model (at least in its theoretical appearance) [46], in which specific events act as triggers of both growth expectations and disillusionment, and where slopes of enlightenment and plateaus of productivity are absolutely heterogeneous and dependent on their regional contexts. Although more than 25 years of political and social "obscurantism" in Latin American FO up to the mid-1980s show very few reports available, it is also true that these same reports expose trigger events that are very attractive to explore. In 1976, Chilean odontologist Luis Ciocca (at the time, an orthodontist) was contacted to identify the remains of a woman who had been found on the beach with signs of torture on her body. The positive identification of the victim was the first proof of the practices carried out by the military dictatorship in Chile, which led Ciocca not only to change forever his professional orientation, but also to the publication in 1980 of his book *Elementos de Odontología Legal* (*Elements of Legal Odontology*). A few years later, the first FO course was dictated in Chile and the Chilean Society of Legal Odontology (SOLCH) was founded [2].

The 1980s brought (along with the democratizing processes in several countries in the region) a resurgence of leadership and initiatives in Latin American FO. To the precursor works of the aforementioned Luis Ciocca in Chile [2] and the Colombian Aquiles Echeverri [47], both published in 1980, we can add other essential works such as those of Elida Briñón in Argentina in 1983 [48] and Alberto Correa Ramírez in Mexico in 1990 [49]. The participation of forensic odontologists in recognized catastrophic events in those decades would lead not only to a revitalization of their roles in identification procedures, but also to an increase in the number of forensic odontologists in the services, and a consolidation of the different scientific societies that brought together these specialists [50–53]. However, democratic transition and consolidation would not come without insufficiencies and weaknesses [54], many of which would also be reflected in the performance of Latin American FO. It is the opinion of this author that reports of errors or insufficiencies in dental procedures and identifications in Chile [55], Argentina [51], or Peru [53] are nothing more than the consequence of the lack of standards and protocols, functioning "as islands of individuals practicing in isolation, oblivious to the global strides made in every facet of science" [56].

At a global level, FO was enhanced in 1968 with the recommendation of the Fédération Dentaire International (FDI) to include FO content in the curricula of dental schools, in 1973 with the founding of the International Organization for Forensic Odonto-stomatology (IOFOS) as the only global association setting standards in FO (*https://iofos.eu*), and in 1984 with the presentation of the first Interpol Disaster Victim Identification (DVI) Guide

(reinforcing the strong role of FO in identification) [57]. Despite this, Latin America remained alien to all these processes and standards, either due to lack of resources, institutional support, the advent of genetics as a new standard, or simply due to political ideology [22] (some authors even use the word "chauvinism" [58]). At least until the end of the first decade of the 21st century, Latin American participation on the global stage has barely been more than timid. Only in 2012 would Latin America be represented in IOFOS with the entry of the Associação Brasileira de Ética e Odontologia Legal (ABOL, from Brazil), and in 2019 with the entry of the Sociedad de Odontoestomatólogos Forenses Iberoamericanos (SOFIA) [59], the latter bringing together more than 160 members from almost all of Latin America.

Current Situation and Challenges

In August 2004, the Area on Emergency Preparedness and Disaster Relief of the Pan American Health Organization (PAHO), in collaboration with the Department Health Action in Crises of the World Health Organization (WHO), published *Management of Dead Bodies in Disaster Situations* [53]. The document, available in English and Spanish, collaborated with professionals from several Latin American and Caribbean countries and was presented as a manual providing "the technical information that will support the correct approach to handling dead bodies", including among its principles making every effort to identify the bodies [53]. Although the document cites different major disasters in this region and dedicates a special chapter to the Mesa Redonda fire in Lima, Peru, which highlights the problems caused by a lack of protocols and coordination (including dental identification tasks) [53], the manual has a strong inclination to weigh anthropology over odontology as a counterpoint to the Interpol DVI recommendations [60]. In this author's experience, the incidence of Interpol recommendations is minimal in Latin America [61], with a strong assimilation of the PAHO manual, which, in addition to the aforementioned advent of anthropology and genetics, has collaterally and significantly decreased the presence of odontologists in DVI tasks. The invisibilization of this role is evident in the reports of DVI procedures in the Ycuá Bolaños supermarket fire in Paraguay (2004, 327 dead [62]), the earthquake in Haiti (2010, at least 150,000 dead [63]), or the earthquake and tsunami in Chile (2010, 525 dead [64]). In the experience of this author, who was delegated by the Argentine Government to help in the identification of victims of the Aero Caribbean Flight 883 crash in Cuba (2010, 68 dead) [65], although Cuba's Institute of Legal Medicine impeccably carried out identification tasks based on the PAHO manual (in fact, its highest authorities are the main authors of the chapter, Medicolegal Work in Major Disasters, in that manual) [53], the participation of dentists had not been considered in their initial protocols, and they did not have local dentists trained for these tasks.

Only a few Latin American countries have managed to stand out in the area of FO in the last 15 years, either due to institutional policies or at least due to individual efforts. In Venezuela, the response to some catastrophic events and the installation of formal training allowed the creation of new FO positions throughout the country, going from less than twenty positions at the beginning of the year 2000 to more than double in just 10 years [52]. In Peru, the problems reported in the Mesa Redonda fire led to a greater supply of forensic professionals — among them dentists — for the Institute of Legal Medicine [53] (currently Peru has a large offer of specialization in FO, in addition to at least three scientific associations other than FO). In Colombia, the history of internal conflict between its inhabitants, guerrillas, drug trafficking, and the extraordinary number of victims of homicide and forced disappearance led to the installation of the Attorney General's Office of Investigation, the Technical Investigative Corps (CTI), and the National Institute of Legal Medicine and Forensic Sciences, providing protection to specialized dental identification laboratories throughout the country, and the implementation of dental identification guides and protocols [66,67], which have been recognized as being of high quality and up to date [58]. Also in Colombia, the renowned FO specialization program at the Pontificia Universidad Javeriana of Bogotá has trained specialists who have settled in different Latin American countries. Between them, Panama and Costa Rica have managed to crystallize years of good intentions, with support from the US in some cases, the foundation of scientific associations, and the implementation of high-quality expert services [68,69]. The Dominican Republic, El Salvador, Guatemala, Honduras, and Nicaragua have also managed to have FO services institutionally, with greater or lesser development, but in response to the growing demand for expert services due to high levels of violence, armed conflicts, and frequent natural disasters [70]. Curious are the cases of FO in Argentina and Chile, countries with an undeniable historical background and academic presence in both the training of specialists and scientific productivity, but they suffer from currently having insufficient state support for the generation of positions or recognition in their judicial courts, considering the history of natural or anthropic disasters already mentioned in both countries [3,71,72]. Again, in this author's experience, Argentina and Chile have a preponderance of anthropology (in many cases with marked political overtones) or genetics in

identification tasks and a focus of practice on addressing dental malpractice (only one of the four areas declared by the NAS [1]), which, according to this author, are all probable consequences of the respective negative experiences of FO mentioned above.

Brazil deserves a separate chapter in this segment. This country represents the best administration of opportunities that Latin America could have provided in FO. The solid historical background of the Brazilian FO has already been mentioned, resulting in the consolidation of master's, doctoral, and specialization programs since the beginning of 1990 [25], including a growing and positive labor insertion of its graduates [73]. ABOL, its scientific FO association, has grown systematically since 1996, peaking in 2022 at its 15th Brazilian Meeting of Forensic Dentistry in the city of Ribeirao Preto. The congress had almost 500 attendees, more than 100 speakers from Belgium, Chile, Croatia, Italy, Norway, Peru, Portugal, the Dominican Republic, and all over Brazil (*https://www.cbol-online.com.br*), in addition to the special participation of the IOFOS board. As mentioned previously, Brazil was the first Latin American country to join IOFOS, with Prof. Ricardo Henrique Alves da Silva currently holding the vice presidency of the prestigious global association (https://iofos.eu) [59]. In terms of scientific productivity, Brazil currently represents 73% of what has been published in Latin American FO, and the two researchers with the highest productivity and international ties also belong to that country [59].

Perhaps one of the most important challenges for Latin American FO is to understand its own identity in light of recognizing its own problems and the need to standardize its solutions. It has already been mentioned that there is a significant focus on forensic odontological research on dental age estimation, a topic that Latin America has followed with a clear influence of European problems [74]. However, Latin America has its own characteristics that challenge these standards [75], in addition to problems linked not only to natural disasters but also to indicators of violence with atypical and absolutely wasted case studies [76]. Although Latin America mostly shares a language, the great heterogeneity of its countries and realities has made it significantly difficult to establish common objectives and solutions to their problems. With countries that are unable to resolve their own internal conflicts (some countries in the region have up to three scientific associations devoted to FO, with serious communication problems between them), achieving standardization of protocols is a very difficult challenge (quality assurance in FO is still a review and update material for IOFOS at a global level [77]). On November 7, 2009, the Sociedad de Odontoestomatólogos Forenses Iberoamericanos (SOFIA) was founded (*https://www.sofia.lat*), seeking to resolve these controversies and unite people in search of a common good. Currently, SOFIA has more than 160 members from 21 different countries and has been a member of IOFOS since 2019. SOFIA has sought at its 14 annual assemblies (only interrupted in 2020 by the COVID-19 pandemic) to align its precepts and respond to scientific, academic, legal, and social demands with Latin American identity, but also with representativeness in the global discussion of the search for standardization. Latin America has an FO not only with an important background, but also with a very promising future on the world stage.

Devés Valdés states that "Latin American thought since the beginning of the 19th century has oscillated between the search for modernization and the reinforcement of identity. The attempt to balance both dimensions has been equally permanent", with an alternation in which modernization has been shaped according to issues coming from countries at the forefront of progress and technology, while identity brings rejection of the same influence and demand of the indigenous, artistic, social, and humanistic at the expense of technology [78]. We agree that these tensions, beyond marking an obvious complexity, affirm an intellectual, institutional, and epistemological space of enormous vitality. Latin American FO is at the end of an adolescence of self-discovery — vigorous and at the same time contradictory — moving towards a reflective, executive, and conciliatory adulthood that seeks to integrate into the global community.

Concluding Remarks

Latin American FO is a faithful reflection of the history, contradictions, and attitudes of Latin America in all its dimensions. With a permanent tension between its need to modernize (adhering to the avant-garde, standardization, and technologization under European or North American influence) and its commitment to reaffirming its native identity (claiming its independent, idiomatic, and introspective culture), Latin American FO has traveled lights and shadows, transcendental brightness, and anodyne darkness, which is extremely dependent on the moment and historical context. Currently, Latin American FO is experiencing an evident rise and global presence but still faces the challenge of recognizing its identity, its own problems, and its necessary solutions. Today is an excellent opportunity to contribute to the international scene with its particular approaches, efforts, and proposals, and thereby provide, from its uniqueness, the measures and limits that would allow standards to be defined.

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Upcoming Events

ADLM (Association for Diagnostics & Laboratory Medicine) 2024
(*https://meeting.myadlm.org/*)

July 28–Aug. 1, 2024; McCormick Place Convention Center
Chicago, IL, US

APA Annual Convention 2024 — American Psychological Association
(*https://convention.apa.org/*)

Aug. 8–1o, 2024; Seattle Convention Center
Seattle, WA, US

International Association for Identification — 108th Educational Conference
(*https://theiai.org/conference.php*)

Aug. 11–17, 2024; Peppermill Resort
Reno, NV, US

IACP Impaired Driving amd Traffic Safety Conference
(*https://www.theiacp.org/IDTSconference*)

Aug. 16–18, 2024; Marriott Marquis
Washington, DC, US

ACS Fall National Meeting & Exposition 2024
(*https://www.acs.org/meeting/acs-meetings/fall.html*)

Aug. 18–22, 2024; Colorado Convention Center
Denver, CO, US

American Society of Questioned Document Examiners 82nd Annual Conference
(*https://asqde.org*)

Aug. 26–28, 2024; Grand Hyatt Atlanta
Atlanta, GA, US

International Conference on Forensic Nursing Science & Practice
(*https://www.forensicnurses.org/page/IAFN/*)

Aug. 27–29, 2024; Sheraton Denver Downtown
Denver, CO, US

TIAFT 61st Annual Meeting of the International Association of Forensic Toxicologists
(*https://www.tiaft.org/tiaft-annual-meeting.html*)

Sept. 2–6, 2024; Congress Centre
St. Gallen, Switzerland

58th Congress of the European Societies of Toxicology
(*https://www.eurotox2024.com/*)

Sept. 8–11, 2024; The Tivoli Congress Center
Copenhagen, Denmark

Midwestern Association of Forensic Scientists — 2024 Annual Meeting
(*https://mafs.net/page-18404*)

Sept. 8–13, 2024; InterContinental Kansas City at the Plaza
Kansas City, MO, US

International Congress of Therapeutical Drug Monitoring and Clinical Toxicology 2024 Congress
(*https://www.iatdmct.org/events/22nd-annual-congress-of-the-iatdmct/*)

Sept. 15–18, 2024; Centre for Arts and Creativity
Banff, Alberta, Canada

Northwest Association of Forensic Scientists — 2024 Annual Conference
(*http://nwafs.org/wordpress/fall-meeting/*)

Sept. 16–19, 2024; Virtual only
Spokane, WA, US

National Association of Medical Examiners
(*https://name.memberclicks.net/annual-meetings*)

Sept. 19–23, 2024; Hyatt Regency Denver at Colorado Convention Center
Denver, CO, US

Toxi2024 — 2nd Global Summit on Toxicology and Applied Pharmacology
(*https://www.thescientistt.com/2024/toxicology*)

Sept. 23–25, 2024; Crowne Plaza Dubai Deira
Dubai, UAE

ISHI 35: International Symposium on Human Identification
(*https://www.ishinews.com/attend/*)

Sept. 23–26, 2024; JW Marriott Hill County
San Antonio, TX, US

20th Meeting of the International Association of Craniofacial Identification — Articial Intelligence Meets Craniofacial Identification
(*https://iaci2024.com*)

Oct. 2–6, 2024; University of Granada (and online)
Granada, Spain

2024 International Association of Bloodstain Pattern Analysts
(*https://www.iabpa.org/conferences.php*)

Oct. 7–11, 2024; Crowne Plaza Hotel
Kansas City, MO, US

5th Regional TIAFT Meeting in Türkiye
(*https://regionaltiaftturkiye2024.com*)

Oct. 9–11, 2024; Dicle University Congress & Culture Center
Diyarbakir, Türkiye

2024 Postmortem Toxicology for Forensic Pathology Fellows and Toxicologists Course
(*https://www.cfsre.org/education/continuing-professional-education/postmortem-toxicology*)

Oct. 7–10, 2024; Mutter Museum; Virtual
Philadelphia, PA, US

The 13th World Gene Convention in Europe
(*https://www.bitcongress.com/wgc2024europe/Welcome.asp*)

Oct. 16–18, 2024; Crowne Plaza Dublin Blanchardstown
Dublin, Ireland

International Association of Chiefs of Police 2024
(*https://www.theiacpconference.org/*)

Oct. 19–22, 2024; Boston Convention & Exhibition Center
Boston, MA, US

SCIX 2024 — Annual Meeting of the Federation of Analytical Chemistry and Spectroscopy Societies
(*https://scixconference.org*)

Oct. 20–25, 2024; Raleigh Conference Center
Raleigh, NC, US

GAB 2024 (5th Edition of Global Conference on Addiction Medicine. Behavioral Health and Psychiatry)
(*https://addiction-behavioral-conferences.magnusgroup.org*)

Oct. 21–23, 2024; Best Western Plus Hotel &
Conference Center; Virtual
Baltimore, MD, US

Northeastern Association of Forensic Scientists — Annual Conference
(*https://www.neafs.org/neafs-annual-meeting*)

Oct. 21–25, 2024; Harrah's Resort
Atlantic City, NJ, US

Society of Forensic Toxicologists — Annual Meeting
(*https://soft-tox.org/agenda*)

Oct. 27–Nov. 2, 2024; Union Station Hotel
St. Louis, MO, US

Southwestern Association of Forensic Scientists — 45th Annual Conference (*http://swafs.us/*)

Oct. 6–10, 2024; Double Tree by Hilton
Little Rock, AR, US

NPS Discovery:
2024 Novel Synthetic Drugs Threat Symposium
(*https://www.cfsre.org/education/continuing-professional-education/online-live-education/nps-discovery-2024-novel-synthetic-drugs-threat-symposium*)

Nov. 11–13, 2024; Science History Institute; Virtual
Philadelphia, PA, US

American Academy of Forensic Sciences — 77th Annual Meeting (*https://www.aafs.org/*)

Feb. 17–22, 2025; Baltimore Convention Center
Baltimore, MD, US

PITTCON Conference and Expo
(*https://pittcon.org*)

March 1–5, 2025; Boston Convention and Exhibition Center
Boston, MA, US

ACS Spring National Meeting & Exposition 2025
(*https://www.showsbee.com/fairs/14149-ACS-National-Meeting-Exposition-2004.html*)

Mar. 23–25, 2025; San Diego Convention Center
San Diego, CA, US

2025 ACMT Annual Scientific Meeting
(*https://www.acmt.net/annualmeeting-rfp/*)

April 4–6, 2025; Fairmount Hotel
Vancouver, BC, Canada

14th World Gene Convention (WGC 2025)
(*https://www.clocate.com/world-gene-convention-wgc/43385/*)

April 23–25, 2025; Nara Royal Hotel
Nara, Japan

California Association of Criminalists Seminar
(*https://www.cacnews.org/events/seminar/seminars.shtml*)

April 27–May 2, 2025; Sacramento County District
Attorney's Office
Folsom, CA, US

American Society of Forensic Laboratory Directors — 52nd Annual Symposium
(*https://www.ascld.org/ascld-annual-symposium/*)

April 4–8, 2025; Hyatt Regency Denver
Denver, CO, US

Southern Association of Forensic Scientists — 2025 Annual Meeting
(*https://safs1966.org/annual-meeting/*)

May 5–9, 2025; Hyatt Regency Jacksonville
Riverfront Jacksonville, FL, US

Mid-Atlantic Association of Forensic Scientists — 2025 Annual Meeting
(*https://www.maafs.org/annual-meeting*)

May TBA[a], 2025; TBA[a]
Richmond, VA, US

73rd ASMS Conference on Mass Spectrometry and Allied Topics
(*https://asms.org/conferences/annual-conference*)

June 1–5, 2025; Baltimore Convention Center
Baltimore, MD, US

Forensic Analysis of Human DNA — Gordon Research Conference
(*https://www.grc.org/forensic-analysis-of-human-dna-conference/2025/#*)

June 22–27, 2025; Jordan Hotel at Sunday River
Newry, ME, US

[a]TBA: To be announced.

Oral Fluid — A New Matrix for US Federal Workplace Drug Testing Programs

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The US Department of Health and Human Services (HHS) published the first Mandatory Guidelines for Federal Workplace Drug Testing Programs using Oral Fluid (OFMG) on October 25, 2019, and published the revised OFMG with an effective date of October 10, 2023 [1,2]. This article summarizes the use of oral fluid as a test specimen in US federal workplace drug testing programs.

Background

The US Government prohibits illicit drug use by federal employees, whether on- or off-duty. Under federal law, federal agencies must implement a comprehensive program to ensure a drug-free federal workplace, including drug testing. The US Department of Health and Human Services (HHS) establishes the scientific and technical guidelines for federal workplace drug testing programs and for the National Laboratory Certification Program (NLCP), the accreditation program for forensic toxicology laboratories to become certified to test federally regulated specimens. Within HHS, these responsibilities are assigned to the Substance Abuse and Mental Health Services Administration (SAMHSA). All federal agencies and their service providers must follow the Mandatory Guidelines for Federal Workplace Drug Testing Programs (hereafter referred to as the "HHS Guidelines" or "Guidelines").

The HHS Guidelines address all areas of a drug testing program, from specimen collection through laboratory testing and reporting of the results to the Medical Review Officer (MRO), as well as the MRO's review, verification, and reporting of the drug test results to the federal agency. First published in 1988, the Guidelines have become the gold standard for workplace drug testing programs in the United States. Over the years, SAMHSA has continued to revise the Guidelines and the NLCP based on new federal policies, testing technologies, and scientific information.

Urine was the only specimen type allowed under the HHS Guidelines until the effective date of the first Mandatory Guidelines for Federal Workplace Drug Testing Programs using Oral Fluid (OFMG) on January 1, 2020 [1]. The current OFMG were effective October 10, 2023, and the current Mandatory Guidelines for Federal Workplace Drug Testing Programs using Urine (UrMG) were effective February 1, 2024 [2,3]. A federal agency may choose to use urine, oral fluid, or both specimen types in their workplace drug testing programs.

SAMHSA certifies urine laboratories and oral fluid laboratories that perform all testing (initial and confirmatory) for federal agency specimens. In addition, SAMHSA certifies instrumented initial test facilities (IITFs) to perform initial drug and specimen validity tests for urine specimens, report negative and negative-dilute specimen results, and forward specimens with other results to an HHS-certified urine laboratory. The receiving laboratory tests specimens from an IITF using the same procedures as specimens received from a collection site. IITFs are not allowed for oral fluid testing.

HHS Guidelines: General Requirements

The Guidelines specify the drugs that a federal agency may test routinely (i.e., in all specimens). An agency is also authorized to test post-accident and reasonable suspicion specimens for any drug classified by the US Drug Enforcement Administration (DEA) as Schedule I or II under the Controlled Substances Act [4]. Further, an agency may request a waiver from HHS to test all specimens for any Schedule I or II drug.

The authorized drug testing panels (i.e., specifying initial and confirmatory test analytes and cutoffs for each drug) are presently included in Section 3.4 of the current UrMG and OFMG. As described in that section, these panels will remain in effect until SAMHSA publishes a Federal Register Notification (FRN) with the authorized drug testing panels, biomarker testing panels, and required nomenclature for laboratory reports. SAMHSA will publish testing panels each year to enable timely changes (e.g., adding or removing analytes, changing cutoffs) in response to drug use trends and new scientific information.

Specimens submitted for testing under the HHS Guidelines must undergo initial drug testing, and those specimens with positive initial test results must undergo a confirmatory test to identify and quantify the specific drug

analyte(s). The UrMG and OFMG allow the use of immunoassay or an alternate technology for the initial drug tests and require a more specific confirmatory test using mass spectrometric identification, e.g., gas chromatography-mass spectrometry (GC-MS), liquid chromatography-MS (LC-MS), GC-MS/MS, LC-MS/MS, or equivalent.

In addition to testing for drugs, HHS-certified laboratories may conduct specimen validity tests to identify specimens that are not valid for testing and those that may have been adulterated or substituted by the donor. The UrMG specify required specimen validity measurands (i.e., creatinine, pH, one or more oxidants, specific gravity); test methods and cutoffs for screening, initial, and confirmatory tests; and reporting criteria. Both the UrMG and OFMG include general specimen validity test requirements to allow laboratories to implement additional specimen validity tests (e.g., for specific adulterants, for biomarkers). A laboratory must obtain SAMHSA approval before implementing a specimen validity test for oral fluid and before implementing a biomarker test for either urine or oral fluid specimens.

OFMG: Specific Requirements

While urine collections are routinely unobserved, the oral fluid collection process requires that all oral fluid collections be observed by the collector, who remains with the donor throughout the collection. Thus, oral fluid collections are less susceptible to donor attempts to alter their drug test through substitution, dilution, or adulteration of their specimen. The 2019 OFMG did not include criteria for identifying and reporting oral fluid specimens as substituted; however, SAMHSA revised the 2023 OFMG to define a substituted oral fluid specimen and require reporting oral fluid specimens as substituted based on biomarker testing. SAMHSA also revised the OFMG wording to specify requirements for OF performance test (PT) samples to assess laboratory specimen validity tests.

The OFMG allow collection of neat (undiluted) oral fluid; however, at this time, specimens are usually collected using a device with an absorbent pad that is inserted in the oral cavity to collect the oral fluid, then placed into a tube containing a buffer. These buffer solutions, which are created specifically for each device, are designed to prevent bacterial growth, stabilize drug analytes, and dilute the neat oral fluid to facilitate aliquoting and testing. Each device is designed to be utilized with the manufacturer's immunoassay calibrators and reagents.

The HHS initial and confirmatory test cutoffs are for neat (undiluted) oral fluid. For confirmatory testing, the laboratory must apply the appropriate dilution factor to results of specimens diluted with a buffer. An oral fluid immunoassay linked to a specific collection device will include pre-diluted calibrators, so a dilution factor is not needed for initial test results.

Both the UrMG and OFMG require split specimen collections, i.e., primary (A) specimen and split (B) specimen. For oral fluid, this can be accomplished by using two separate collection devices placed in the oral cavity for simultaneous A and B specimen collection; using one collection device with two pads that may be separated post-collection into A and B specimens; using two separate collection devices serially (i.e., with no more than 2 minutes between removal of the A device and placement of the B device in the oral cavity); using a device that directs the oral fluid into A and B tubes containing buffer; or collecting neat oral fluid and subdividing the collected specimen into A and B specimens. The OFMG require collection of at least 1 mL of neat oral fluid each for the A specimen and the B specimen.

Oral fluid collection devices must provide an indicator that demonstrates the device has collected a sufficient amount of oral fluid; a sealable, non-leaking container that maintains specimen integrity during storage and transport to the laboratory; components that ensure pre-analytical drug stability; and components that do not substantially affect the composition of the drugs/metabolites in the specimen.

The OFMG include minimum performance requirements for a collection device. The device must collect at least 1 mL of neat (undiluted) oral fluid. A device with a diluent or other component, process, or method that modifies the volume of the testable specimen must collect at least 1.0 mL (±10 percent) oral fluid, and the diluent volume must be within ±2.5 percent of the diluent target volume. All devices must maintain analyte stability for five days at room temperature (64–77 °F/18–25 °C) under the manufacturer's intended shipping and storage conditions, as documented by concentrations for the required drugs and/or metabolites that are at least 80% of the concentration at the time of collection. A device must recover at least 80 percent but no more than 120 percent of drug and/or drug metabolite in undiluted (neat) oral fluid at (or near) the initial test cutoff listed in the authorized drug testing panel.

In the 2023 OFMG, SAMHSA revised device requirements to clarify that a device may have one or two collection tubes, to require the collection tubes to be sufficiently transparent to enable visual inspection of the contents before opening, and to specify that the device lot expiration date on each specimen tube must reflect the expiration date of the buffer/diluent or (when no buffer/

diluent is used) the earliest expiration date of any device component. The 2023 OFMG also require laboratories to reject a specimen that was collected after the expiration date on the device (unless the B specimen meets criteria to be redesignated as the A specimen).

As noted earlier, both the UrMG and OFMG allow the use of immunoassay or an alternate technology (e.g., mass spectrometry) for the initial drug tests. At this time, all HHS-certified urine laboratories use immunoassay for initial drug testing. Immunoassay serves as an efficient, high-throughput initial test for drugs and for the specimen test validity measurands required by the UrMG.

Currently in the US, the Food and Drug Administration (FDA) classifies oral fluid collection devices used for federally regulated workplace drug testing as medical devices [5]. As described earlier, most devices include specimen tubes with a buffer which dilutes the collected oral fluid. Such devices were developed with specific immunoassay calibrators and reagents to be used for initial testing. Therefore, the collection devices and the associated immunoassay must be reviewed and cleared together by the FDA in accordance with its 510(K) program prior to use by US laboratories for drug testing of federally regulated specimens [6].

At the time of this writing, the majority of HHS-certified urine laboratories use GC-MS for confirmatory testing. One laboratory uses GC-MS/MS for all confirmatory drug tests, and several laboratories have implemented LC-MS/MS for one or more confirmatory drug tests. In contrast, most oral fluid laboratories use LC-MS/MS for confirmatory testing. This technology is sufficiently sensitive and precise for oral fluid drug testing to meet OFMG requirements (i.e., cutoffs, controls at 40% of cutoff).

The OFMG include requirements for validating oral fluid collection devices and assays prior to use with regulated specimens. The NLCP Manual for Oral Fluid Laboratories provides additional detail on study requirements (i.e., number of study samples, sample concentrations, acceptance criteria) for laboratory assay validation studies, periodic assay re-verification studies, and validation of oral fluid collection devices. Laboratories must verify that device manufacturer-stated specifications for oral fluid volume, analyte recovery, and analyte stability meet or exceed those required by the OFMG.

Applications and Certification Processes

The OFMG describe the application process and requirements to maintain certification for oral fluid laboratories, while the UrMG describe the application process and certification maintenance requirements for urine laboratories and IITFs. Applicants must satisfy specified testing and reporting criteria for NLCP PT samples (i.e., three sets for applicant IITFs and laboratories, and quarterly sets after certification) and demonstrate compliance with program requirements during NLCP inspections (i.e., an initial on-site inspection, on-site inspection three months after certification, on-site certification maintenance inspections and records audits two times a year, and additional records audits between certification maintenance inspections for large laboratories).

SAMHSA Support for New Laboratories

At the time of this writing, no oral fluid laboratories have applied for HHS certification. SAMHSA is currently offering support through the NLCP to new laboratories interested in HHS certification for a limited time, as described below.

SAMHSA has instituted a consultancy program for new laboratories interested in HHS certification as an oral fluid laboratory, urine laboratory, or urine IITF. The NLCP will arrange for a short-term consultant to work with the laboratory to perform a gap analysis before the laboratory completes their NLCP application. The consultancy is designed to assist new laboratories in understanding basic program requirements and to identify gaps that exist between their laboratory operations (e.g., facility, staffing, processes) and HHS/NLCP accreditation requirements. Gap analysis consultants are current NLCP inspectors selected for the program based on their extensive work with the NLCP and their in-depth program knowledge.

To assist new laboratories and current HHS-certified urine laboratories and IITFs seeking accreditation as an HHS-certified oral fluid laboratory, SAMHSA is waiving the oral fluid laboratory application fee, the fees for the three initial sets of oral fluid PT samples, the initial inspection fee, and the three-month follow-up inspection fee.

In addition, SAMHSA is offering free oral fluid reference samples that can be used to verify new or existing methods. These reference samples have been formulated to assess current OFMG requirements.

Additional Information

SAMHSA provides information on the Drug-Free Workplace Program on its website, *https://www.samhsa.gov/workplace*. In addition to the HHS Guidelines, resources include HHS Specimen Collection Handbooks for Federal Agency Workplace Drug Testing Programs (one for urine specimens and one for oral fluid specimens),

the HHS Medical Review Officer Guidance Manual for Federal Workplace Drug Testing Programs, and MRO Case Studies (separate documents for urine and oral fluid). The SAMHSA website also includes a link to a proof of the current Federal Custody and Control Form (CCF), guidance for using the form, and a list of HHS-certified laboratories approved to use an electronic Federal Custody and Control Form (ECCF). SAMHSA also includes links to the list of HHS-certified laboratories and IITFs published in the Federal Register each month.

Information is also available from the NLCP contractor, RTI International. A presentation, "*Introduction to the National Laboratory Certification Program*", is accessible to the public at *https://forensicrti.org/nlcp/*. The site includes access and subscription information for the NLCP's free electronic newsletter, *Drug Testing Matters*, which addresses topics of interest to laboratories, laboratory staff, and NLCP inspectors. NLCP staff are available to answer questions by email *nlcp@rti.org* or phone (919) 541-7242.

References

1. [US] Department of Health and Human Services: Mandatory Guidelines for Federal Workplace Drug Testing Programs Using Oral Fluid; *Federal Register* 84:57554; 2019.
2. [US] Department of Health and Human Services: Mandatory Guidelines for Federal Workplace Drug Testing Programs Using Oral Fluid; *Federal Register* 88:70814; 2023.
3. [US] Department of Health and Human Services: Mandatory Guidelines for Federal Workplace Drug Testing Programs Using Urine; *Federal Register* 88:70768; 2023.
4. [US] Drug Enforcement Administration: Schedules of Controlled Substances, 21 CFR §1308; *https://www.ecfr.gov/current/title-21/chapter-II/part-1308?toc=1* (Accessed May 19, 2024).
5. [US] Food and Drug Administration: Medical Devices; Exemptions from Premarket Notifications: Class II Devices; *Federal Register* 82:31976; 2017.
6. Kotarek J: *FDA Review of Drugs of Abuse (DOA) Assays*; *Drug Testing Advisory Board Meeting* (2023, December 5). *https://www.samhsa.gov/sites/default/files/meeting/documents/dtab-fda-review-doa-assays-12052023.pdf* (Accessed May 19, 2024).

NEW BOOKS AND BOOK REVIEW

New Forensic Science Books

Artificial Intelligence in Forensic Science — An Emerging Technology in Criminal Investigation Systems
K. Saini, S. S. Sonone, M. S. Sankhia, N. Kumar, Eds
CRC Press: Boca Raton, FL, US; Forthcoming

Bone Histology — A Biological Anthropological Perspective
C. Crowder, S. D. Stout, Eds
CRC Press: Boca Raton, FL, US; Forthcoming

Environmental Warfare in Gaza: Colonial Violence and New Landscapes of Resistance
S. C. Molavi, E. Weizman
Pluto Press: London, UK; Feb. 2024

Ethics and the Practice of Forensic Science
R. T. Bowen
CRC Press: Boca Raton, FL, US; Mar. 2024

Forensic Botany — Principles and Applications to Criminal Casework, 2nd ed
H. M. Coyle, Ed
CRC Press: Boca Raton, FL, US; Forthcoming

Forensic DNA Transfer
J. M. Taupin
CRC Press: Boca Raton, FL, US; Oct. 2023

Forensic Firearms in Criminal Trials — Legal, Investigative, and Scientific Aspects
J. K. Sinha
CRC Press: Boca Raton, FL, US; June 2024

Forensic Perspectives on Cybercrime (New Frontiers in Forensic Psychology)
J. McAlaney, P. J. Hills, T. Cole
Routledge Taylor & Francis: New York, NY, US; Mar. 2024

Forensic Science: An Illustrated Dictionary
J. C. Brenner
CRC Press: Boca Raton, FL, US; Dec. 2023

Forensic Science and Fingerprints: Lifting the Lid on the Science (Ebook)
The Open University, Ed
The Open University: Milton Keynes, UK; 2023

Forensic Science Laboratory Benchmarking — The FORESIGHT Manual
M. M. Houck, P. J. Speaker
CRC Press: Boca Raton, FL, US; Mar. 2024

Forensic Serology
S. S. Tobe
Academic Press: San Diego, CA, US; Forthcoming

Handbook of Bloodstain Pattern Analysis
T. L. Wolson, Ed
CRC Press: Boca Raton, FL, US; Forthcoming

Haschek and Rousseaux's Handbook of Toxicologic Pathology, Vol. 2: Safety Assessment and Toxicologic Pathology, 4th ed
W. M. Haschek, C. G. Rousseaux, M. A. Wallig, B. Bolon, Eds.
Academic Press: London, UK; 2023

Human Trafficking Investigation
K. L. Melton
CRC Press: Boca Raton, FL, US; Forthcoming

In the Belly of the Bear: An FBI Journey Behind the New Iron Curtain
J. Iverson
Rowman & Littlefield: Lanham, MD, US; April 2024

Introduction to Forensic Science — The Science of Criminalistics
J. T. Spencer
CRC Press: Boca Raton, FL, US; Forthcoming

Medical Illustration in the Courtroom — Proving Injury, Causation, and Damages
L. E. Coulter
CRC Press: Boca Raton, FL, US; Mar. 2024

Practical Forensic Pathology and Toxicology
P. E. Dean, R. H. Powers
CRC Press: Boca Raton, FL, US; Forthcoming

Ritual Human Sacrifice in Mesoamerica: Recent Findings and New Perspectives
R. G. Mandoza, L. Hansen, Eds
Springer: Cham, Switzerland; Mar. 2024

Scenario Based Multiple Choice Questions in Forensic Medicine
S. Bedi
MEU India: Amritsar, India; May 2024

Solving Problems with Microscopy: Real-life Examples in Forensic, Life and Chemical Sciences
J. A. Reffner, K. W. Kammrath, Eds
Wiley: Hoboken, NJ, US; Nov. 2023

Written in Bone: Hidden Stories in What We Leave Behind (Audiobook)
S. Black
Dreamscape Media: Holland, OH, US; 2021

Book Review

The Path of Flames: Understanding and Responding to Fatal Wildfires

Ashley Kendell, Alison Galloway, and Colleen Milligan, Eds
CRC Press: Boca Raton, FL, US; 2024

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The Path of Flames: Understanding and Responding to Fatal Wildfires is a comprehensive anthology that explores various facets of large-scale wildfires. This edited volume is structured into five sections, encompassing twenty-three chapters that delve into the complexities of response, recovery, and investigative issues related to fatal wildfires. Each chapter offers in-depth analysis and insights into different aspects of wildfire management, prevention, and aftermath.

This structure allows for an in-depth look at some of the challenges associated with catastrophic events like the November 2018 Camp Fire in the Sierra Nevada foothills. The chapters cover a wide range of topics, providing readers with an initial view into the multifaceted world of wildfire management and response:

- Historical context and theoretical foundations of large wildfires, examining their impacts both domestically and internationally;
- Analysis of wildfires that have caused significant resource and property damage, as well as multiple fatalities;
- Incident command practices and resource allocation strategies for coordinating public response;
- Approaches to managing mass fatality events in wildfire scenarios;
- Forensic aspects of recovery, handling, and identification of human remains, including perspectives from anthropologists, odontologists, and DNA specialists;
- Wildfire investigation techniques;
- Law enforcement organizations' responses and recommended practices; and
- Additional relevant topics in wildfire management and response.

This sweeping approach offers readers, particularly those new to the field such as college students or public officials, a valuable overview of the challenges and complexities involved in understanding and responding to fatal wildfires. While not exhaustively covering each subject, the book serves as a useful introduction for those seeking to grasp the breadth of knowledge required in wildfire operations and post-incident management.

The book's first section, "Overview of Wildfires and Wildfire Fatalities", introduces the subject of large-scale fire. It offers a broad perspective on wildfires, familiarizing readers new to the field with essential terminology and foundational concepts. This introductory material serves as an accessible entry point for those seeking to understand the complexities of wildfire management and response.

Section II, "Wildfire Management Response", addresses some of the challenges faced by public responders during large-scale wildfire incidents. The chapters in this section outline the multifaceted approach required in the initial stages of a wildfire emergency, including:

- Executing rescue operations for affected and potentially trapped individuals;
- Implementing fire suppression strategies;
- Establishing order within often chaotic environments; and
- Conducting preliminary investigations to determine the fire's origin and cause.

This section provides an overview of the critical decision-making processes and actions undertaken by first responders in the early stages of a wildfire event. The exploration of the Incident Command System illuminates how diverse groups of responders, often hailing from multiple agencies, efficiently organize into a unified and organized force during large-scale wildfire emergencies.

The third section of the book, "Mass Fatality Response", delves into the challenges of navigating the aftermath of a devastating wildfire to locate, recover, and identify victims' remains. The chapter authors draw on extensive experience to discuss:

- Patterns of victim behavior in the moments preceding death;
- The physiological effects of fire on the human body; and
- Effective strategies for organizing and conducting search and recovery operations.

This section provides readers with an overview of the complex and sensitive process of managing mass fatalities in wildfire scenarios, blending scientific knowledge with practical field experience.

Section IV, "Post Recovery Processes Following a Mass Fatality", offers the book's most in-depth exploration of forensic science practices. This comprehensive section covers:

- Establishing and managing an effective morgue operation; and
- Specific contributions of forensic specialists, including:
    - Pathologists;
    - Odontologists;
    - Anthropologists; and
    - The role of cutting-edge rapid DNA techniques in victim identification.

The section concludes with a detailed case study of the Grenfell Tower disaster — a devastating structure fire in a 23-story public housing building in London in June 2017. Although not a wildland fire, this analysis demonstrates how victim identification techniques employed in urban disasters can be effectively adapted to mass casualty wildfire scenarios. The examination bridges the gap between urban and wildland fire response, offering valuable insights for forensic professionals and emergency managers across various disaster contexts.

The book culminates with Section V, "The Impact of Wildfires", which broadens the perspective beyond the more typical forensic aspects to examine the wider societal implications of these disasters. This final section explores:

- Demographic factors associated with wildland fire victims;
- Psychological effects of mass disasters on first responders; and
- Broader social impacts and effects of wildfires.

The Path of Flames serves as a useful resource for readers seeking to understand the multifaceted challenges of wildfire response, particularly in cases involving fatalities. While primarily targeted at those new to the field, the book offers insights that can benefit a range of professionals, including:

- Emergency management personnel;
- Public officials and policymakers;
- Students in fire science, emergency management, or related fields;
- Journalists covering wildfire events; and
- Community leaders in fire-prone areas.

By presenting an overview of the complex efforts involved in wildfire response, from initial management to forensic investigation and long-term impact assessment, this book provides a solid foundation for anyone looking to familiarize themselves with the many aspects of large-scale wildfire incidents. Its approach to technical subjects makes it a useful introduction for those entering the field, while also offering valuable perspectives for more experienced professionals seeking to broaden their understanding of interdisciplinary approaches to wildfire management. In conclusion, *The Path of Flames* stands as a useful educational resource, illuminating the diverse facets of response to what have become increasingly frequent catastrophic wildfires worldwide.

TEITELBAUM'S COLUMN ON FORENSIC SCIENCE: HISTORICAL PERSPECTIVES

A History of Carbon Monoxide

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In recognition of Jeff Teitelbaum's extensive work in promoting forensic science knowledge and history, this article will present a brief history of carbon monoxide (CO). It accompanies my commentary in this issue, which describes the medicolegal aspects of CO in more detail [*Forensic Sci Rev* 36:92; 2024].

Cosmic and Planetary CO

"*CO is a funny little molecule. The triple bond that ties its carbon to its oxygen is the strongest covalent bond known on Earth*." [1]

Carbon monoxide is the second most abundant molecule in the gas phase of interstellar space. Only the molecule H_2 is more abundant [2]. Cold CO gas emits a clear and distinct radio signal and so can be used by astronomers to measure the motion of interstellar clouds and the formation of stars and exoplanets.

Several billion years ago, the Earth's atmosphere contained little oxygen but could have contained CO up to 100 parts per million concentration or 1,000 times higher than current levels. The detection of CO in an exoplanet's atmosphere may be a biosignature (**Figure 1**) of an early Earth-type evolution of life [4].

Thus, the highly toxic CO is of interest not only to forensic toxicologists, but to astronomers as well, and may be a sign of life as well as death.

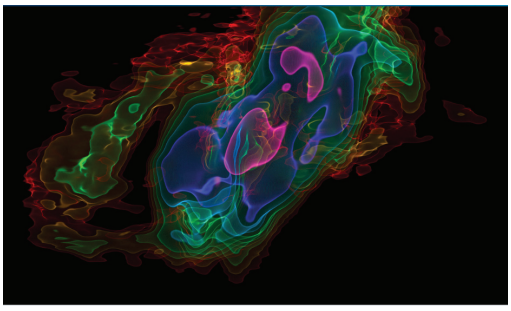

Figure 1. A visualization of cold carbon monoxide in the Sculptor Galaxy [3].

Pre- and Ancient History

"*Coal fumes lead to heavy head and death*." Aristotle (c 350 BCE) [5]

The effect of CO on human history has been underrated. Since humans first learned to control fire for warmth, cooking, and light, they have been plagued by a mysterious "demon" that comes quietly at night and takes the lives of the young and elderly and causes long-term suffering and disease. We now know this is due to CO produced by poorly ventilated fires.

CO may have influenced human art, as cave paintings in dark, isolated caves (**Figure 2**) require light to paint, and the only source of light at the time was provided by fire, which also produced CO. Low levels of CO have been found to produce visions and hallucinations, which may have inspired (and eventually killed) the painters. Archeologists seldom consider that CO poisoning may be behind the discovery of bones of ancient humans in caves [6].

Figure 2. The making of prehistoric art in a cave using CO-producing torches [*https://leseyziesdetayac.info/yheory-and-history-of-prehistoric-cave-art/*] (Accessed May 25, 2024).

In the 3rd century BC, it is thought that Hannibal used CO to kill prisoners. In the 4th century AD, two Byzantine emperors were likely to have died from CO emitted by charcoal braziers, which were commonly used in the Roman Empire at that time [7].

18th Century to Present

"*Carbon monoxide is the most widespread and important toxic agent of modern civilization, preeminently greater than classic plumbism, on account of its multitude of applications in industry*." *Legge, 1928*

The proper scientific and forensic toxicological study of CO poisoning did not really begin until the 18th century, when coal and the Industrial Revolution exposed humans to new sources of CO [8]. Shown in **Table 1** is a list of years when a few milestone studies were conducted [8].

Table 1. Historical highlights of CO since the 18th century (adopted, with additions, from Hopper et al. [8]).

Year	Study/Finding
1772	Joseph Priestly synthesized CO via CO_2 reduction
1778[a]	Troja coined the phrase "cherry-red" to describe the color COHb gives the blood [9]
1793	James Watt (inventor of the steam engine) suggested that coal fumes may displace oxygen from the blood
1815[a]	Coal (and water) gas lighting containing high CO concentrations was first used at the Chestnut Street Theatre in Philadelphia (**Figure 3**). Its use quickly spread and for the next 150 years caused untold thousands of deaths and long-term illnesses until it was replaced by electricity and natural gas [10]
1842	LeBlanc confirmed the presence of CO in coal fumes
1857	Claude Bernard, a French physiologist, described how CO displaces O_2 from the blood
1910[a]	Respiratory physiologist J. B. S. Haldane recommended miners use canaries or mice to detect CO gas in mines [11]
1913	The worst mining disaster in Britain occurred at the Senghenydd mine which killed 440 men, mainly due to CO poisoning [12]
1914[a]	World War I produced many new methods of CO poisoning due to explosions, dud shells, machine guns in poorly ventilated pillboxes or dugouts, tanks, airplanes, and other motorized vehicles, including ambulances [13]
1949[a]	Torgny Sjöstrand demonstrated endogenous CO from hemoglobin catabolism [14]
1970[a]	CO first detected in interstellar clouds [15]
1975[a]	Catalytic converters in passenger motor vehicles decreased the CO in exhaust from 7 to 12% to as low as 0.1%. The number of non-fatal CO poisonings decreased by 63% over 33 years [16]
1993[a]	First battery-powered home CO detectors became commercially available [17]
1993	CO is characterized as a neurotransmitter (gasotransmitter)
2005	First clinical trial that evaluated CO for the treatment of inflammation

[a] Entries added by this author.

Concluding Remarks

CO is widespread throughout the universe and has bedeviled humanity since fire was first invented. Its impact on human history has been underrated, which this short review shows. CO has been tamed somewhat and now therapeutic uses of low CO concentrations are being explored.

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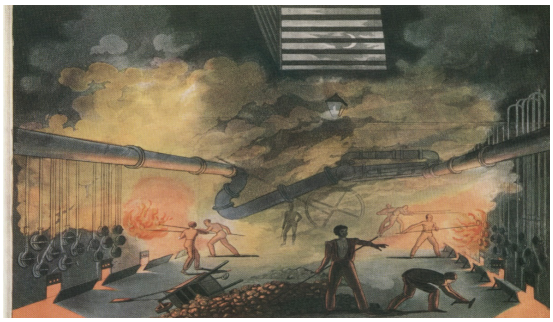

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COMMENTARY

Carbon Monoxide: An Ancient Silent Enemy*

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"Carbon monoxide poisoning has been a problem for humans ever since our ancestors learned to build fires in unventilated shelters." [1]

On a bright day on May 10, 1553, three newly built ships commanded by Sir Hugh Willoughby sailed down the Thames from Radcliffe, saluting King Edward VI with gun and cannon shots as they were towed past Greenwich. This was the first English Arctic expedition (**Figure 1**) and great hopes were raised regarding all the trading riches of the Orient, which they thought they could reach using the "northeast passage" around Russia.

The ships became separated in violent storms around the northwest coast of Norway. One ship continued and eventually reached the Bay of St. Nicholas, where they were escorted overland to Moscow.

It was decided on the other two ships to overwinter in a protected, good harbor, which was isolated, and uninhabited, at the mouth of a river. On a particularly cold day in the winter of 1554, the two ships' entire companies were assembled together below decks in one ship to conserve fuel. All the openings and gunports were sealed as well as the hatches, so that heat (as well as the smoke and gas) from the cooking fires could not escape. For the first time the cook and his mate were using "sea coal", rather than wood, which produces large amounts of carbon monoxide (CO).

In the summer of 1554, Russian fishermen discovered the two ships. The bodies of the crew were in the position in which they died, seated at tables, writing, platters in hand and spoons in their mouths. There were no survivors. Initially it was thought that the men died of exposure, starvation, or scurvy, but there was still fuel and lots of food on board, and these conditions do not cause death all at once. It wasn't until the historian Eleanora C. Gordon examined this unusual case that the true cause of death was determined: CO poisoning [2].

It is ironic that the second English Arctic expedition also almost succumbed to CO poisoning in a hut where they were overwintering, except that one man ran to the

James Wigmore has been a practicing forensic toxicologist for over 35 years and has testified in over 700 criminal cases across Canada and in personal injury, wrongful death, and coroner cases. He continues his Commentary series, this time on carbon monoxide. His newest book on carbon monoxide should be published next year (2025) by Irwin Law, which continues his internationally renowned "Wigmore on" series in forensic toxicology.

A more detailed biographical overview can be found in his previous Commentary on Cannabis [*Forensic Sci Rev* 35:74; 2023].

Figure 1. A historic tablet in London dedicated to Arctic explorers [*https://exploring-london.com/tag/ratcliff-stairs/*] (Accessed May 23, 2024).

*A short, extensive history of CO can be found in this issue [*Forensic Sci Rev* 36:90; 2024].

door and fell unconscious against it, opening the hut to fresh air which soon revived and saved everyone. CO exposure and poisoning has been a major problem in Arctic exploration ever since [3].

Shown in **Table 1** is a list of famous persons who might have died from CO poisoning [4].

Table 1. Some famous people who are alleged to have died from CO poisoning [4]

Name	Profession
Cleopatra	Ruler of Egypt
Seneca	Roman scholar
Jovian	Roman emperor
Edgar Allan Poe	Author
Emile Zola	Author
Sylvia Plath	Writer
Anne Sexton	Poet
Sir Bernard Spilsbury	Forensic pathologist
Vitas Gerulaitis	Tennis star
Benny Frey	MLB pitcher
Thelma Todd	Actress

CO Toxicity

> *"But of all signs and tests, the typical carbon monoxide or oxygen deficiency headache proved to be the most definite and reliable. It is a distinctly localized pain, usually frontal, throbbing intensified by laying down or exertion. It is sometimes accompanied by more or less nausea, readily increased to vomiting. The mind is not clear, except by an effort and one's surroundings seem a little strange. The temper is easily upset, very much as in alcohol intoxication and the judgement is likely to be bad.*" [5]

Carbon monoxide is an unusual poison. It is known as the silent killer as it is an invisible, non-irritating, and odorless gas and enters the body by inhalation. Once in the body, CO causes numerous indirect toxic effects:

- CO has a more than 200 times greater binding to hemoglobin than oxygen and forms carboxyhemoglobin (COHb).
- CO also impairs the dissociation of the remaining oxygen from Hb, further causing hypoxia to all the tissues of the body but especially the brain and heart.
- CO binds to myoglobin with an affinity 60 times greater than that of oxygen, which causes cardiac dysfunction and arrhythmias.
- CO also binds to other hemeproteins such as cytochrome a3, which results in cellular respiratory dysfunction.
- CO promotes the formation of free radicals and lipid peroxidation, especially in the brain [6].

But CO gas in our body is basically inert; less than 1% is converted by the liver into CO_2. CO seems to act like high intensity X-rays. It passes throughout the body unseen, causes the tissue damage, and then leaves.

The typical therapy is to promote CO to leave the body as quickly as possible to minimize its toxic, hypoxic effects. The half-life of CO in the body is approximately 4 to 6 hours in the normal ambient air; this can be reduced to about 1 hour by breathing 100% oxygen and about 20 minutes using hyperbaric oxygen therapy (HBOT) [7].

The adverse effects of CO increase with increasing carboxyhemoglobin concentration in the blood, as shown in **Table 2** [8].

Table 2: The effects of CO poisoning with increasing blood COHb concentration [8]

Conc. (%)	Effects
0.5–1.5	Typical levels in nonsmokers
4–9	Typical levels in smokers
10–20	Nausea, fatigue, rapid breathing, emotional, confusion, clumsiness
21–30	Headache, angina, visual impairment, decreased sensory perception
31–50	Dizziness, fainting, confusion, nausea, vomiting, problematic decision making
>50	Seizures, coma, severe acidosis, death

Chronic CO Poisoning: The Great Imitator

> "*You can't get a vaccination against this winter flu.*" [J. Wigmore; *https://www.linkedin.com/pulse/you-cant-get-vaccination-against-winter-flu-james-wigmore/* (Accessed May 23, 2024)]

> "*This is why I hate Google. You come across one site, match one symptom, and all of a sudden you're dying of carbon monoxide poisoning or cancer of the big toe.*" [K. J. McPike; *https://www.goodreads.com/author/quotes/14108115.K_J_McPike* (Accessed May 23, 2024)]

Chronic or occult CO poisoning is also referred to as the "winter flu" as its symptoms are very similar to the flu, and it tends to occur in winter, when the doors and windows are closed and the potential sources of CO such as furnaces, fireplaces, and water heaters are on. It is difficult to diagnose CO poisoning from the physical symptoms alone, as shown in **Table 3** [9].

Table 3: Chief complaint, discharge diagnosis, and COHb concentration in patients examined at hospitals due to flu-like symptoms [9]

Chief complaint	Discharge diagnosis	COHb conc. (%)
Nausea, cough	Urinary tract infection	17
General malaise	Viral syndrome	21
Headache	Tension headache	14
Weak, tired	Orthostatic hypotension secondary to diuretic use	18
Shortness of breath, cough	Bronchitis	15
Weak, dizzy, cough	Viral syndrome	14
Weak, dizzy cough	Urinary tract infection	11

An aide-memoire "COMA" is suggested to assist in determining possible CO poisoning in the ER [10]:

- **C:** Cohabitees; is anyone else affected, including pets?
- **O:** Outdoors; do your symptoms improve outdoors?
- **M:** Maintenance; are your fuel-burning appliances/vents properly maintained?
- **A:** Alarm; do you have a CO alarm?

It is important to detect CO poisoning at the ER and notify the fire department or gas company to test for a CO source, which if left undiagnosed could also put at risk the other persons living in the building.

Gothic Horror

> *"...all of us would have been dead in a few minutes by carbonic oxide [CO] gas poisoning generated by the presence of burning coal in a closed room and the laymen would have ascribed our deaths to ghosts and legends of haunted houses.*" [11]

> *"Every society has ancient myths of demons who come on cold nights to take the lives of the young and elderly. Poorly ventilated charcoal fires lead to heart disease, mental health problems and death.*" [12]

Humans have been exposed to the effects of CO for thousands of years. Once humans started using fire in closed environments such as caves or huts, they were exposed to the effects of CO. Fire torches were required for illumination in order to make the magnificent prehistoric cave art. But the torches would have produced CO, which could have caused visions and hallucinations in the artists and those who visited the caves. In a high enough concentration, CO could have killed entire families and tribes in these places in their sleep. And so, the finding of a large group of human bones does not necessarily mean violence or disease, but their deaths could be poisoning by the CO produced by their fires [12].

CO poisoning continued to plague humanity until proper ventilation of fires was devised, such as chimneys and the Franklin stove. But no sooner was this ancient enemy being controlled than it was introduced back into homes as an illuminating (coal) gas, which can contain up to 30% CO [2]! At this concentration CO could result in death in minutes.

Coal gas (produced by the heating of coal in the absence of air) was a revolution in illumination in the 19th century, as it was one-quarter the cost of candles and oil lamps, cleaner, and could be controlled more easily. Gas lighting was first used in theaters in the US in 1815 and spread rapidly to many other theaters. A major problem with coal gas was the amount of CO that accumulated in these theaters during a performance, which exposed the audience and performers to chronic CO poisoning. It is said that Charles Dickens suffered symptoms of CO poisoning during his performance tour of US theaters [14].

Any leak in the pipes or valves carrying the coal gas or the flame going out would have caused CO to enter homes, causing either chronic or fatal CO poisoning. Some of the chronic effects of CO poisoning include hallucinations, paranoia, and a feeling of dread, which could have contributed to superstitions and Gothic horror novels, which were popular during this time. There are several reports of haunted houses due to CO leaks [15]. Edgar Allan Poe (**Figure 2**) would have been exposed to low levels of CO, which may have inspired his horror stories and eventually caused his death [16].

Turning on the gas was a common, easy method of suicide until it was replaced by natural gas, which contains no CO [17]. A similar decrease in the suicide rate occurred when catalytic converters were required in automobiles, which substantially reduced their CO emissions [18].

Figure 2. Illustration of Edgar Allan Poe's "A Midnight Dreary" by Gustav Dore, showing several sources of CO [*https://art-passions.net/dore/the_raven.html*] (Accessed May 23, 2024).

War and Explosions

> *"I remember that after one of our successful offensives on the Western Front, pillboxes were found full of dead Germans untouched by shell fire. It is likely that these were cases of carbonic oxide [CO] poisoning and were not due to shell concussion as was said at the time.*" [19]

Virtually all explosions, gunfire, rockets, bombs, tank engines, etc. used in war produce carbon monoxide. In the open CO generally does not produce any toxicity, but when, for example, machine guns are fired in an enclosed concrete pillbox, leaving numerous smoldering, empty, cartridges inside, high CO levels can be produced there, causing death. Especially during World War I, CO poisoning was a common occurrence that was overlooked, and its effects were thought to be due to shell shock or lack of courage [20].

In World War II, gunners in the confined gun cockpits at the rear of the Whitney bomber developed symptoms that were initially thought to be due to "weakness of moral fiber", but instead were due to chronic CO poisoning during the flight [21]. In the Gulf War in Iraq, the massive burning of oil wells, which caused elevated environmental CO concentrations, is thought to have contributed to the Gulf War syndrome experienced by American troops [22].

Away from the battlefield, CO is also produced in mines, especially coal mines, and was so dangerous that canaries were often brought into the mines in cages to detect this gas. Canaries, with their high metabolism and small size, would be affected by CO and fall off their perches, allowing time for the miners to escape [23].

Explosions near houses to make highways or trenches for sewers can also produce CO, which can travel through the soil and spread throughout the nearby houses, causing substantial risks to the inhabitants [24].

Gasotransmitter

> *"All things are poison and nothing is without poison; only the dose makes that a thing is no poison."* [Paracelsus; *https://www.asmalldoseoftoxicology.org/paracelsus*] (Accessed May 23, 2024)

Carbon monoxide is produced endogenously in the body by the enzymatic catabolism of heme by the enzyme heme oxygenase during red blood cell turnover. This results in COHb concentrations in healthy individuals of less than 1%. Although CO is a toxic gas, it is also known as a gasotransmitter (gas neurotransmitter) and has been studied as a therapeutic drug for its anti-inflammatory, antimalarial, and antimicrobial effects [25]. Other important gasotransmitters include nitric oxide and hydrogen sulfide, and in its cell signaling role CO is considered essential for life [26].

The multiple effects of CO show why oxygen therapy to treat poisoning sometimes fails to prevent irreparable damage and results in delayed neurological sequelae. Other treatment options should include NO binding agents, ion channel therapy, and antioxidants [27].

Conclusion

Carbon monoxide has been an ancient enemy of humans for thousands of years, causing undetected deaths and chronic illnesses. Its role in our history and development of superstition and persecution of witchcraft has been underrated. CO has affected the outcome of numerous battles, undetected. Although the threat of CO poisoning has diminished in modern times due to lower exposure rates resulting from *inter alia* catalytic converters in cars and the replacement of coal gas with natural gas, it still returns in many other different ways like a will-o'-the-wisp.

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