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The foot in forensic human identification – A review

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ABSTRACT

The identification of human remains is a process which can be attempted irrespective of the stage of decomposition in which the remains are found or the anatomical regions recovered. In recent years, the discovery of fragmented human remains has garnered significant attention from the national and international media, particularly the recovery of multiple lower limbs and feet from coastlines in North America. While cases such as these stimulate public curiosity, they present unique challenges to forensic practitioners in relation to the identification of the individual from whom the body part originated. There is a paucity of literature pertaining to the foot in forensic human identification and in particular, in relation to the assessment of the parameters represented by the biological profile. This article presents a review of the literature relating to the role of the foot in forensic human identification and highlights the areas in which greater research is required.

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1. Introduction

It is incumbent upon forensic practitioners to attempt the identification of any recovered human remains, irrespective of the quantity or the stage of decomposition in which they are found. The process of human identification requires the completion of multiple stages of investigation and the combination of various evidentiary threads which may lead to a putative identity of the deceased. Only once a presumptive identification has been made, can confirmation of identity be sought through the use of DNA or any other primary source of identity. The methods and approaches utilised in this process are, however, dependent on numerous factors including the context in which the remains are found, the anatomical regions recovered and the degree of decomposition or fragmentation of the remains.

In the early stages of the identification process, it is necessary to establish data relating to the four parameters of biological identity, ancestral origin, biological sex, chronological age and living stature [1]. From this information, termed a biological profile, the pool of potential identities from documented missing persons may be reduced. While the biological profile may be relatively easy to deduce from remains recovered in a relatively intact state, the

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absence of certain skeletal elements, particularly the skull, pelvis and long bones increases the complexity of this process.

The discovery of human remains, in various states of decomposition, is a relatively regular occurrence; however there appears to be a bias in the anatomical areas recovered, as the lower limb, and in particular the foot, tends to be discovered in isolation, with at least 9 incidents recorded in the United Kingdom (UK) since 2003 [2–5]. This is not specific to the UK and the recovery of isolated pedal remains was brought to the attention of the media by a spate of incidents in the Straights of Georgia, located on the border between Canada and the United States of America, where 14 feet were recovered between 2007 and 2012 [6,7]. More recently, two incidents occurred in New Jersey and San Francisco in a four-week period of 2013 [8,9]. The expanse of territories over which these incidents have occurred highlights the prevalence of cases such as these. It should be noted however that the majority of incidents in which a foot has been recovered in isolation, have been found contained within items of footwear and have been associated with either marine or fluvial biomes [2–7,10]. The presence of the foot within a shoe contains the pedal elements, thus preventing disassociation of the individual bones. In addition, the type of shoe in which the foot is encased may alter the buoyancy characteristics of the foot, and thereby affect the likelihood that the foot will become stranded on the tide line. Within terrestrial biomes, the protective nature of footwear may prevent dissociation of the individual tarsal elements, prevent some aspects of taphonomic alteration, such as animal scavenging and add a degree of protection to the remains, thus preserving the integrity of the pedal skeleton [11–13].

The dissociation of the foot from the remainder of the body may occur through a variety of scenarios, including the normal sequence of post-mortem disarticulation which occurs in terrestrial or aqueous environments; scavenging behaviours of carnivorous fauna; and traumatic amputation, such as may occur during aviation or road traffic accidents or as a result of collision with a ship's propeller [14]. Although the mechanisms by which feet may become dissociated from the remainder of the lower limb may be diverse, a factor common to almost all recorded incidents of isolated recovery of a foot in the UK since 2003 is the presence of the foot within an article of footwear, for example training shoes or work boots [2,4–7,10]. In addition, the robust nature of the tarsal bones makes them more likely to survive inhumation and other taphonomic influences than other, more fragile, elements of the skeleton [13,15,16].

Despite the apparent frequency of the discovery of isolated feet, there is a paucity of literature relating to the role of the foot and ankle in forensic human identification. The disarticulation of human remains presents certain challenges relating to establishing the identity of an individual including a reduction in the quantity of information pertaining to identification that can be deduced [17]. It is therefore imperative that the method chosen is appropriate to the context and the anatomical region under examination [18]. This short communication will present a review of the current trends in the examination of the foot in the context of forensic human identification.

2. Choice of methods

The methods used in the examination of the foot for the purposes of identification will vary depending on whether presumptive identification of the remains has already taken place, such as may have occurred during a closed mass disaster incident where the identities of the individuals involved is known. In such circumstances, the comparison of ante-mortem and post-mortem radiographs of the foot has been used in attempt to support the suspected identification [14]. This approach to identification however is contingent upon the presence of recent ante-mortem records relating to the foot and ankle; a source of information which may not be present for every individual. In addition, the comparison of ante-mortem podiatric records with lesions or pathological changes noted in recovered feet may be used to support an identification [19]. In the case of a mass disaster where fragmentation of remains has occurred, it may also be possible to re-associate isolated feet with their corresponding limb through anatomical matching with a leg or body with a pedal amputation [20]. This approach was used during the triage phase of the identification process that followed the attacks on the World Trade Centre in 2001 and resulted in a reduction in the number of DNA tests required as without anatomical matching of fragmented remains, protocol would have dictated that each fragment be subject to DNA testing [20].

2.1. DNA

In the absence of a presumptive identification it may be necessary to establish a biological profile, which, when compared with ante-mortem information may narrow the pool of potential identifications, making the use of alternative primary identifiers such as DNA testing feasible. The current recommendations pertaining to DNA analysis include obtaining a mid-shaft femoral bone sample; however this site is secondary in preference to an intact, multi-root tooth [21]. There is however some evidence that certain tarsal elements, in particular the talus, calcaneus and cuneiforms may provide a higher yield of genetic material than may be extracted from other skeletal elements, including the long bones of the upper and lower limbs [21,22]. As a result of this research, the bones of the foot should be considered as a source of genetic material for the purposes of DNA analysis of unidentified remains and may facilitate the reconciliation of disassociated anatomical regions. The ability to recover useable DNA is however dependent on a number of factors including the bone structure, the post-mortem interval, the biome(s) in which the remains have existed since death (i.e. marine, fluvial or terrestrial) and other taphonomic influences [22].

Although the successful use of DNA analysis in human identification is largely restricted to cases where a putative identity is suspected, it may be a useful tool in the re-association of remains recovered in different temporal and spatial locations. This approach has been utilised in both North America and Europe in cases where individual feet, which became disassociated through natural post-mortem disarticulation, were recovered in similar footwear and were subsequently re-united through DNA matching [23,24]. The use of DNA matching in the re-association of human remains has been of particular use in scenarios where substantial fragmentation and commingling of remains has occurred [25]. The importance of DNA analysis from the foot and ankle is also highlighted by the use of Improvised Explosive Devices (IEDs) in modern theatres of warfare. As a result of the technologies involved in the manufacture of tactical footwear, the potential recovery of an intact foot may be greater than that of other anatomical areas in the aftermath of an explosive incident [26].

The recovery of isolated feet, particularly in fluvial or marine biomes, may require the origin of the foot to be established as the remains be transported a considerable distance from the point at which they entered the specific environment [27]. Although estimation of the point of origin of remains may be possible to some extent in riverine systems, the effect of ocean currents on the path of disarticulated remains is less predictable. It may therefore be necessary to use alternative methods, such as stable isotope analysis, to determine those geographical areas in which the decedent resided prior to their death. The protective nature of footwear in such circumstances renders stable isotope analysis of keratinised tissue from the toenails a viable option [28]. As a result of the relationship between diet, geographical location and the isotopic

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