Forensic anthropology population data

Practical relevance of prescribing superimposition for determining a frontal sinus pattern match

Natassha Hashim [a], Narayanasamy Hemalatha [b], Karuppaiah Thangaraj [b], Abdul Kareem [c], Arefuddin Ahmed [d,1], Nik Fakhuruddin Nik Hassan [e], Paul T. Jayaprakash [e,*]

[a] Forensic Science, Chemistry Department of Malaysia, Kuala Lumpur, Malaysia
[b] Forensic Medicine Department, SRM Medical College and Research Centre, Potheri, Kattangulathur (PO), Kanchipuram Dist., Tamil Nadu 603203, India
[c] Department of Radiology, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian, 16150, Kelantan, Malaysia
[d] Medical Radiation Program, School of Health Sciences, Universiti Sains Malaysia, Kubang Kerian, 16150, Kelantan, Malaysia
[e] Forensic Science Program, School of Health Sciences, Universiti Sains Malaysia, Kubang Kerian, 16150, Kelantan, Malaysia

ABSTRACT

A research that tested the methods suitable for comparing ante- and post-mortem radiographic patterns of frontal sinuses concluded that superimposition should be followed as a stringent method for establishing individual identification. We verified the practical relevance of prescribing superimposition by superimposing ante- and post-mortem frontal sinus patterns recorded in case situations as well as simulated ante- and post-mortem of frontal sinus patterns recorded using archived skulls. For superimposition, the wipe facility available in the vision mixer was employed in addition to the mix mode. Ante- and post-mortem radiographic patterns that were available in two earlier cases were not superimposable. Related simulated ante- and post-mortem radiographic patterns of frontal sinuses are superimposable only when the skull that is initially oriented for recording the ante-mortem radiograph is retained in the same posture for recording the post-mortem radiograph also. Once the skull has been removed from the X-ray table, after recording the simulated ante-mortem radiograph, and repositioned for the simulated post-mortem radiograph, even when the intervening time is 1 min, the sinus patterns in these radiographs are not superimposable. Superimposition cannot be used as a conditional requirement for side-by-side comparison of radiographic patterns of frontal sinuses.

© 2015 Elsevier Ireland Ltd. All rights reserved.

1. Introduction

Ever because the work of Culbert and Law [1], radiographic patterns of frontal sinuses have been widely used for identifying skulls retrieved from unidentified human remains whenever ante-mortem X-rays of the putative victims are available [2–12]. The popular use of frontal sinus patterns is attributed to the acceptance of these patterns as unique for an individual [2–11,13–22]. The uniqueness in the morphology of the frontal sinus patterns is ascribed to the influence of complex factors that include stresses, such as masticatory and hormonal levels, that prevail in an individual during development to which the sinuses respond [23]. After adulthood, the sinus anatomy remains stable throughout life unless it is affected by pathological changes or artifacts during

radiography [18]. Reports on identification with the comparison of radiographic patterns of frontal sinuses have relied on side-by-side comparison of these patterns [1–5,9,13,17,24–30], while some have mentioned superimposition in addition to morphological comparison [2,4,5,9,25,30].

Citing the requirements from the Canadian and United States courts that prescribe standards for admitting scientific evidence, Besana and Rogers [11] tested three methods for comparing and evaluating frontal sinus patterns, viz., metric studies, including the use of discrete trait combinations and superimposition. They recommended superimposition *as the standard methodology when trying to obtain an individual identification using the frontal sinuses*, which should be used as a *stringent* requirement [11]. These authors overlaid two possible matching X-rays on a light box and superimposed the frontal sinus patterns to generate a 100% positive match [11]. The present research verified the practical relevance of prescribing superimposition by overlaying ante- and post-mortem radiographic patterns of frontal sinuses as the stringent method for concluding a match.

2. Methodology

The research design included three sets of experiments. The first set of experiments used ante- and post-mortem radiographic patterns of frontal sinuses that were recorded in two cases of homicide, wherein identification was established by the corresponding author both on the basis of the frontal sinus pattern match as well as on a match during skull-photo superimposition. The testimony was accepted in the trial courts. The ante- and post-mortem patterns that are available on record were verified for ascertaining whether the process of superimposition revealed a match that would convincingly demonstrate the conclusion for identity on a definite basis.

The second set of experiments used 10 skulls from the Universiti Sains Malaysia archive. Each skull was radiographed in two sessions. One skull in each session was radiographed twice, first to simulate the ante-mortem record and second to simulate the post-mortem record. In the first session, the same orientation, albeit by the same technician, for the simulated ante- and post-mortem radiographic exposures was achieved in two independent events. In this session, after radiographing a skull to simulate the ante-mortem record, the skull was removed from the X-ray table and, to simulate the post-mortem record, the same technician oriented the skull in a posture that was estimated to be as close to the previous posture as possible. The intervening time was approximately 1 min. Here, the orientation of the skull for the simulated post-mortem X-ray was achieved as an independent event in the same way that a skull is oriented for post-mortem radiography in real life scenarios. However, the technician knew the preceding orientation unlike the real life scenario where the position in the ante-mortem X-ray would alone be relied on for orienting the skull post-mortem on a trial and error basis. In the second session, the orientation initially obtained for recording the simulated ante-mortem radiograph was maintained unaltered while recording the simulated post-mortem radiograph. This was accomplished by ensuring the retention of the same orientation of the skull through securing the initially oriented skull with the X-ray table with cellophane tape.

The third set of experiments was carried out by an independent group of researchers using two skulls archived in Sri Ramachandra University, Tamil Nadu, India and followed the same procedure as described for the second set of experiments. The X-ray machine used to obtain the post-mortem radiographs in the first set of experiments was Elpro-Collmex and the X-ray units in the second and third sets of experiments, respectively, were Philip Optimus and DX 525 Simplex, GE brand.

The digital images of the frontal sinus patterns from the simulated ante- and post-mortem radiographs were cropped and processed using Adobe Photoshop® CS3, maintaining the relative magnification for further morphological comparison and superimposition. The steps during processing involved changing the images to gray mode, ensuring auto level brightness and contrast and inverting one of the ante- or post-mortem images for obtaining black and white prints of 1200 resolution in A4 size paper using HP Laser Jet P2015 PCL6 printer.

The related ante- and post-mortem radiographic patterns of frontal sinuses were compared side-by-side to assess the morphological similarity. During the process of superimposition, the print outs of the ante- and post-mortem frontal sinus patterns were fixed on cork panels that were affixed on two vertical boards, which were supported on stable wooden stands, and their images were independently captured with two similar high resolution (600 pixels) CCD video cameras (Bosch) fitted with manual zoom lenses (Fuginon). The cameras produced images of equal magnification. The captured images were fed into a digital video vision mixer (Panasonic-G-MX70E) and the mixed images were cast on a 32-in. LCD TV screen. The procedure followed during the superimposition involved the use of farthest point as the registering point for achieving an overlay. During this process, the farthest points in the left and right side could not be registered simultaneously. Subsequently, the image size of one of the sinus patterns was manipulated to achieve satisfactory overlay of the two farthest points in the sinus patterns. After achieving the match in relation to the farthest points in the width of the frontal sinus patterns, the remaining areas in the matching patterns were examined to verify whether the overlay indicates a superimposable match.

The best match between the ante- and post-mortem images was obtained in the mixed state of superimposition by adjusting one of the images that was fixed on the board, and both the fade and wipe facilities in the vision mixer were used to conclude whether the match was acceptable as the best. The congruence between the morphological features seen in the ante- and post-mortem sinus patterns was evaluated in the superimposed state using the fade and wipe facilities. The fade mode could be varied to obtain mix images of varying intensities, while the wipe mode enabled visualization of the pattern match on a point-by-point basis along the wipe lines in terms of the pixels permissible by the vision mixer in the desired plane viz. horizontal, vertical or oblique. The extent of the pattern match seen on the TV screen was photographed with a camera (Nikon D90) supported on a tripod. The digital images were stored and black and white printouts (HP Laser Jet P2015 PCL6) were obtained and examined.

3. Results

The ante- and post-mortem radiographic sinus patterns obtained in the two real life cases and studied in the first set of experiments were not superimposable, and the lack of a match between the contours of the ante- and post-mortem sinus patterns was apparent during examination in the wipe mode (Fig. 1). The results in the first session for both the second and third set of experiments also indicated that the 12 simulated ante- and post-mortem radiographic patterns of the sinus patterns in these experiments failed to match, especially when analyzed in the wipe mode (Figs. 2 and 4). The extent of non-concordance between the contours of the simulated ante- and post-mortem radiographic patterns of the sinus patterns that were revealed during examination in the wipe mode was measured and recorded. The results in the second session for both the second and third set of experiments indicated a perfect match between the images of the 12 simulated ante- and post-mortem radiographic patterns of the sinus patterns during both the mix and wipe modes in the superimposition process (Figs. 3 and 5).

4. Discussion

4.1. On the comparison methods used by practitioners

In the melodramatic first case of the frontal sinus pattern-based identification of one of the two human remains recovered in Kashmir, India as that of a white man who disappeared 260 days earlier, side-by-side comparison of the ante- and post-mortem X-rays enabled determining that, beyond any possibility of doubt, both the sets of roentgenograms were from the same individual [1]. In the above case, as well as in the cases that followed [2,3,5,9,13,17,24–26,29–31], comparison of the ante- and post-mortem frontal sinus patterns had been performed on a morphological basis by studying these patterns side-by-side. A few of the aforementioned authors have referred to superimposition in varying connotations [2,4,5,9,25,30]. Atkins and Potsaid displayed the ante- and post-mortem patterns side-by-side and