J Forensic Sci, Nov. 2002, Vol. 47, No. 6
Paper ID JFS2002116_476
Available online at: www.astm.org

TECHNICAL NOTE

Jeremy Rich,[1] D.P.M.; Nancy E. Tatarek,[2] Ph.D.; Robert H. Powers,[3] Ph.D.; B.G. Brogdon,[4] M.D.; Bradley J. Lewis,[5] M.D.; and Dorothy E. Dean,[5] M.D.

Using Pre- and Post-Surgical Foot and Ankle Radiographs for Identification*

ABSTRACT: An evaluation of the effect of surgical intervention on foot and ankle radiographic comparisons was performed. In this study, 34 sets of pre-surgical ("premortem") and post-surgical ("postmortem") foot and ankle radiographs were retrospectively evaluated simulating a postmortem identification. In each radiographic set, the films were separated by a surgical event to reproduce the effects of an alteration in the anatomy. The radiographs included both matches and mismatches. This study also presents a numerical representation of the reliability of a radiographic match following a surgical procedure. Results indicate that surgical intervention with subsequent healing does not preclude positive identification in foot and ankle radiographic comparisons.

KEYWORDS: forensic science, forensic pathology, radiographs, human identification, surgical modification, ankle, foot

Foot and ankle radiographs can establish positive identification in forensic investigations involving decomposed, mutilated, incinerated, or fragmented remains (1–7). Given the protective nature of footwear, the foot and ankle may be better preserved than other anatomical elements (8). The structural complexity of the foot and ankle facilitates identification by providing potentially unique skeletal features and configurations. Radiographic comparisons offer an objective means for establishing positive identification. Skeletal features such as total configuration, trabecular patterns, enostoses, osteophytes, foreign bodies, and anomalous development may establish identification when compared with antemortem radiographs.

A few case reports in the forensic literature have used surgically modified (anatomically altered) foot and ankle radiographs to establish a presumptive or positive identification (3,5,7). To our knowledge, there is a paucity of research in the literature evaluating the potential effects of surgical intervention with subsequent healing on radiographic comparisons.

Furthermore, the process of radiographic comparisons for human identification is intuitively understood, but not easily represented in an algorithmic fashion. While the result of the comparative evaluation may be represented as a binary result, either "match" or "no match," the process by which that determination is made may not be as easily described. An expression of a qualitative factor addressing the reliability of that match may also be difficult to convey.

The purpose of this study is twofold. First, an evaluation of surgical intervention on foot and ankle radiographic comparisons is presented. Secondly, the authors developed a numerical representation of the reliability of a radiographic match following surgical intervention. A radiograph scoring system is described allowing a quantitative variable to be considered in addition to a binary match result with regard to forensic investigations.

Materials and Methods

Thirty-four sets of pre-surgical ("premortem") and post-surgical ("postmortem") radiographs of the foot and ankle simulating a postmortem identification were retrospectively evaluated from a tertiary care medical center. The radiographs represented both in-patient and out-patient surgical procedures. Surgical interventions in the study sets included debridements, joint resections, amputations, arthroplasties, osteotomies, and fusions. The surgical procedures were proper standard of care and deemed medically necessary. Radiographs were separated by time to allow for further potential alteration due to the healing process. The time lapse between pre- and post-surgical radiographs ranged from 2 to 48 months. The age range of the individuals in this study was 25 to 78 years. Seventeen subjects were male and seventeen were female.

In the present study, up to three different radiographic views were used, including anteroposterior (AP), medial oblique (MO),

[1] Clinical fellow in surgery, Harvard Medical School, Beth Israel Deaconess Medical Center, 330 Brookline Avenue, Boston, MA.
[2] Physical anthropologist, Ohio University, 293 Lindley Hall, Athens, OH.
[3] Chief toxicologist, Hamilton County Coroner's Office, 3159 Eden Avenue, Cincinnati, OH.
[4] University distinguished professor emeritus of radiology, University of South Alabama Medical Center, 2451 Fillingim Street, Mobile, AL.
[5] Coroner and forensic pathologist, respectively, Franklin County Coroner's Office, 520 King Avenue, Columbus, OH.

* Presented in poster form at the 54th Annual Meeting, American Academy of Forensic Sciences, Atlanta, GA, February 2002.
* This project was supported by the Forensic Sciences Foundation in the form of a Lucas Research Grant.
Received 6 April 2002; and in revised form 15 June 2002; accepted 21 June 2002; published 16 Oct. 2002.

TABLE 1—*Spearman correlations of the skeletal characteristics total score, and match or no match.*

Skeletal Characteristic	Total Score	Identification Score
Overall shape of the foot and ankle bones	0.79	0.93
Surgical modification to the skeletal elements and/or soft tissue	0.63	0.33
Plates, screws, pins, or other orthopaedic devices	0.54	0.34
Degenerative joint changes	0.55	0.40
Soft tissue calcification	0.47	0.31
Trabecular pattern	0.79	0.93
Osteophytes	0.66	0.68
Additional sesamoids or absence of sesamoids	0.36	0.38
Enostoses	0.48	0.63
Supernumerary bones	0.00	0.00
Identification	0.70	1.00

and lateral projections. All the radiographic sets were randomly selected by one author (JR) and included both matches and mismatches. The radiographic sets were separated by time and thereby analogous to forensic contexts.

The authors described 10 characteristic skeletal features in the post-surgical radiographs (9) (Table 1). The same radiographic features were then evaluated in the pre-surgical films. All 34 radiograph sets were assigned a value for every characteristic feature (hereafter called feature score) and the resulting 10 numbers were added for a total score. The following scoring system was used for each of the 10 skeletal features with a possible total score ranging from −10 to +10.

+1: if the skeletal feature was present and matched.
0: if the skeletal feature was either not present or its presence could not be determined.
−1: if the skeletal feature was present but did not match, or if the trait was present in either the pre- or post-surgical radiograph but not both.

A forensic pathologist, a physical anthropologist, and a forensic radiologist compared pre-surgical and post-surgical radiographs independently for identification of simulated unknown human remains. Available epidemiological information included age, gender, and past medical history.

Separate from the score, authors NET, BGB, and DED independently compared the skeletal characteristics of each set for positive identification. The radiographic sets were evaluated according to the medicolegal standard, "with a reasonable degree of medical certainty, these radiographs came from or did not come from the same individual." Positive identification was scored as a "1" and no identification was scored as a "0" (called identification score). Cases in which a positive or negative identification were not possible due to insufficient features or inadequate radiographs were given a "missing" identification score (neither scored as "1" nor "0"). Spearman correlation coefficients were calculated from raw data consisting of the feature scores, the total score, and the identification score (10).

Results

Of the 34 sets of radiographs evaluated, ten were correctly assessed as not having come from the same individual (not a match, exclusion, or negative identification) and 23 sets as having come from the same person (match or positive identification) (Figs. 1*a*, 1*b*, and 2*a*, 2*b*). An example of feature scores for the radiograph set represented by Figs. 1*a* and 1*b* were as follows (in the same order as Table 1): 1,−1,0,1,1,1,1,0,0,0. The total score was four and the identification score was one. Useful skeletal features that assisted in establishing a match included the trabecular pattern in the calcaneus, the hook-shaped osteophyte on the calcaneus, and the presence of a small calcification under the fifth metatarsal. The set represented by Figs. 2*a* and 2*b* was scored as follows: −1,−1,−1,0,0,−1,−1,0,0 with a total score of −6 and an identification score of 0. Similarly, the trabecular pattern of the calcaneus was a useful feature in making the differentiation between the radiographs and thereby yielded a mismatch.

Radiograph set #23 could not be evaluated because the pre- and post-surgical films were from contralateral feet. Each radiograph was evaluated for 10 skeletal characteristics and scored. In every instance, positive scores (ranging from 2 to 6) correlated with a match and negative scores (ranging from −2 to −7) correlated with exclusions (Fig. 3).

The overall shape of each bone and trabecular patterns were used with greater frequency than other skeletal features. Specifically, the most diagnostic features for positive identification were the shape of the calcaneus, shape of the cortical bone of the metatarsals, and trabecular bone patterns of the calcaneus. Overall bone shape and trabecular patterns can be used to make a positive identification,

FIG. 1a—*Pre-surgical radiograph from a study set.*

FIG. 1b—*Post-surgical radiograph of a hallux amputation. This radiograph matches Fig. 1*a *and represents a positive identification.*

FIG. 2a—*Pre-surgical radiograph from a study set.*

FIG. 2b—*Post-surgical radiograph with an orthopaedic plate and screws at the first metatarsophalangeal joint. This radiograph does not match Fig. 2*a *and therefore is not a positive identification.*

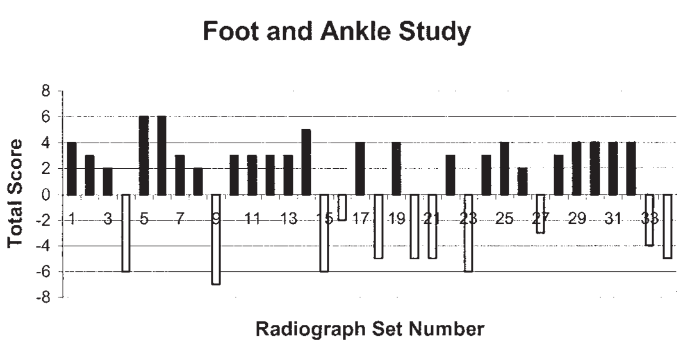

FIG. 3—*Total score for each radiograph set. Black rectangles indicate a match and white rectangles represent a no match. Set #23 could not be evaluated for a potential match because the pre- and post-surgical films were from contralateral feet.*

even when considered alone. Spearman coefficients of the 10 skeletal characteristics, total score, and identification score resulted in high correlations for overall shape and trabecular pattern (Table 1).

Discussion

The purpose of this study is to document that positive identification can be rendered even if the deceased had surgery with subsequent healing of the foot and ankle region. Thirty-four radiographic sets were evaluated for 10 skeletal characteristics and whether or not they came from the same individual. Of the 10 characteristics, osteophytes, enostoses, and orthopaedic devices are visually easy to recognize and are extremely useful to critique individual cases. Statistically these skeletal features appear to be only moderately useful for the study population probably because they occurred infrequently in the study set (Table 1). Supernumerary bones did not correlate because this skeletal characteristic was absent in the study sample.

Of the 10 skeletal features evaluated, overall shape, and trabecular patterns can be used to make a positive identification, even when considered alone. However, the presence of osteophytes when considered alone may result in a false positive identification and should only be considered in conjunction with other skeletal features. When the overall shape of individual bones and/or the trabecular patterns do not match, it can be concluded that the radiographs have not come from the same individual. These findings support previous studies in the forensic literature with regard to trabecular patterns establishing positive identification (11,12).

In this study, potential limitations include lack of antemortem foot and ankle radiographs for comparison. Presumptive identification must be established initially, which may involve procuring medical records from a variety of sources. A false negative evaluation may be rendered when the quality of the radiographs is poor or the angle of incidence is not the same for each film.

Additionally, the extent of surgical intervention to the foot and ankle could potentially remove identifying skeletal characteristics and exclusionary features. Skeletal changes occurring after surgery such as arthridites, metabolic bone diseases, and heterotropic bone growth may sometimes be so drastic that a false negative evaluation is rendered. For example, the presence of Charcot osteoarthropathy can dramatically change the skeletal architecture and may prevent an accurate evaluation with the pre-surgical radiograph. Moreover, in the recovery process of decomposed and fragmented remains, sesamoid bones and phalanges can be easily lost, possibly causing a negative radiographic evaluation. For these cases, we recommend additional postmortem radiographs of the same region or postponing identification until further medical information can be procured.

Conclusions

Positive identification from radiographic comparisons can be made despite surgical intervention of the foot and ankle region. Surgical modifications and subsequent healing alter the anatomy yet unique skeletal characteristics remain and can be useful in forensic contexts. A systematic approach is beneficial for quantifying "reasonable medical certainty" when potential limitations are recognized. This study provides a recognizable standard that can be used in many forensic contexts, including cases involving decomposed remains, mass fatalities, and human rights investigations.

Acknowledgments

The authors gratefully acknowledge the Department of Radiology, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston MA, for technical assistance.

References

1. Singleton AC. The roentgenological identification of victims of the "Noronic" disaster. Am J Roentgenol Radiat Ther 1951;66(3):375– 84.
2. Eckert WG. The medicolegal autopsy. In: forensic medicine. A study in trauma and environmental hazards. Tedeschi WG, Eckert WG, Tedeschi LG, eds. Philadelphia: W.B. Saunders Co. 1977:995–1014.
3. Sivaloganathan S, Butt WP. A foot in the yard. Med Sci Law 1988; 28(2):150–6.
4. Owsley DW, Mann RW. Positive identification based on radiographic examination of the leg and foot. J Am Podiatr Med Assoc 1989; 79(10):511–3.
5. Brogdon BG. Radiological identification of individual remains. In: forensic radiology. Brogdon BG, ed. Boca Raton, CRC Press, 1998: 149–87.

6. Nye PJ, Tytle TL, Jarman RN, Eaton BG. The role of radiology in the Oklahoma City bombing. Radiology 1996;200(2):541–3.
7. Sudimack JR, Lewis BJ, Rich J, Dean DE, Fardal PM. Identification of decomposed human remains from radiographic comparisons of an unusual foot deformity. J Forensic Sci 2002;47(1):218–20.
8. Haglund WD. Disappearance of soft tissues and the disarticulation of human beings from aqueous environments. J Forensic Sci 1993;38(4): 806–15.
9. Hogge JP, Messmer JM, Doan QN. Radiographic identification of unknown human remains and interpreter experience level. J Forensic Sci 1994;39(2):373–7.
10. Hintz J. Number cruncher statistical system (NCSS), 2000.
11. Kahana T, Hiss J. Positive identification by means of trabecular bone pattern comparison. J Forensic Sci 1994;39(5):1325–30.
12. Mann RW. Use of bone trabeculae to establish positive identification. Forensic Sci Int 1998;30:98(1–2):91–9.

Additional information and reprint requests:
Dorothy E. Dean, M.D.
Franklin County Coroner's Office
520 King Avenue
Columbus, OH 43201