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FORENSIC ANTHROPOLOGY TECHNICAL ADVISORY GROUP

Guideline for Best Practice Skeletal Trauma Analysis and Interpretation

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A document prepared by the Australia New Zealand Forensic Science Community

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Introduction

The aim of this document is to provide forensic anthropologists with a guide on how to examine and interpret skeletal trauma. This guideline should be considered in conjunction with the ANZPAA NIFS 'Guidelines for Forensic Anthropology Practitioners'¹.

Skeletal trauma is defined by Davidson *et al.*² as a modification, and ultimately the failure, of bone at the macro and/or microscopic level in cortical and/or trabecular bone because of a slow or rapid-loaded impact with an object. When asked to provide an opinion on skeletal trauma, the forensic anthropologist's role is to identify and describe skeletal defects, establish they are the result of trauma (as opposed to taphonomy, anatomical variation and/or pathology) and, where possible, explain when and how that trauma occurred relative to the individual's death. Such analyses may be done as part of a general anthropological examination, or to address specific questions asked by the pathologist, coroner and/or police. In some cases, trauma analysis and interpretation may be pivotal to a case, in other circumstances, such analyses may be complementary or exclusionary.

Trauma analysis relies on the anthropologist having a comprehensive understanding of bone biomechanics, the extrinsic and intrinsic variables that influence trauma, and the bony features characteristic of different loads.

Modalities to use for trauma analysis

The choice of which modality/ies to use for an examination depends on where the analysis is being undertaken, the context of the case and the question/s being asked. Examination of the gross bone is always the first preference and should involve macroscopic and microscopic inspections. High resolution computed tomography (CT) scans are acceptable to use in lieu of the gross bone, given the existing empirical evidence base that supports their reliability (e.g.,³⁻⁵). The exceptions to this are:

- Hospital grade CT images – this low resolution is insufficient for trauma analysis
- Sharp force trauma cases – CT may not provide sufficient detail of cut mark features. Micro-CT scans may be considered in addition to the gross bone for these types of cases.

Digital or plain film radiographs and photographs of the gross bone should be used to complement, not replace, a gross bone examination. Should medical images or photographs be used in lieu of gross bone, caveats must be provided that articulate the limitations of such an examination in that some details are not possible to assess. These will include, but are not limited to, inadequate detail of fracture margins, bone colour, and other preservation characteristics.

Processing and preparing trauma cases

Maceration / cleaning

Processing that involves the removal of soft tissue may aid the documentation of skeletal trauma. Prior to consideration of cleaning and maceration, trace evidence sampling should be considered and undertaken as required. In cases with suspicious circumstances (e.g., homicide) where soft tissue is adhered to the bone, maceration for skeletal trauma analysis may aid the examination. In cases with non-suspicious circumstances, it is inappropriate to macerate the whole body for an anthropology examination, taking into account ethical, religious and cultural considerations. In these cases, imaging should be done first to assess if an area of the skeleton exhibits trauma. The palpation method is not suitable to use to indicate which anatomical areas have trauma as many subtle fractures are missed in palpation. Anatomical regions identified as having trauma should then be macerated for examination, especially if post-mortem CT (PMCT) is not available.

The approach to maceration is made in consultation with the case pathologist and the method used may depend on the available resources and time. Any of the standard maceration techniques are acceptable to use for

traumatised remains (e.g., King and Birch ⁶). When possible, preference should be given to cold-water bacterial immersion over hot-water immersion to avoid bone alterations occurring if immersed for too long. In cases where the remains are fragmented and require maceration:

- Bone fragments should be placed in a mesh bag before immersion to ensure the fragments are kept together during processing, and
- Maceration should be monitored, and a conservative approach taken, to ensure exposed trabeculae does not soften or other damage occur.

In cases where there is complex preservation (e.g., burnt bone), immersion methods should be assessed on a case-by-case basis.

Use of medical imaging

Medical images (i.e., radiographs or CT scans) should be used to direct the maceration / cleaning process in non-suspicious cases (as detailed above). Imaging should also be used to indicate the severity of trauma (e.g., extent of fragmentation) so that the maceration process may be tailored to the trauma.

Documenting skeletal trauma

If time allows, it is advised that skeletal trauma be documented and then reviewed again after a few days. Re-examination of skeletal trauma after a short period of time allows the anthropologist to consider and review the basis of their initial description and interpretation.

Terminology

The following terminology is specific to the discipline of anthropology. As such, these terms should be defined in the forensic anthropology report, either within the body of the report, or in an annexure.

General descriptive terms:

- *Defect*: a change/alteration/imperfection in the bone.
 - This term should be used in the description of all bone alterations.
- *Fracture*: a traumatic rupture of the integrity of the bone.
 - This term should be used in the interpretation that the defect is the result of ante- or peri-mortem trauma.
- *Damage/breakage*: fragmentation and modification of bone when it is in a dry state.
 - These terms should be used in the interpretation that the defect occurred in the post-mortem period.

Describing the timing of trauma:

- *Ante-mortem*: an impact or modification to the bone that exhibits remodelling at the macroscopic or microscopic level
- *Peri-mortem*: an impact or modification to the bone that occurred when the bone was wet/fresh/green and there is no evidence of healing
- *Post-mortem*: an impact or modification to the bone that occurred when the bone was dry/dehydrated (see comment below on the effects of fire).

The alterations to bone from heat (i.e., the effects of fire) should be described as post-mortem characteristics and not trauma.

Describing the mechanism/s of trauma:

- *Blunt force trauma*: slow-loaded impact of a blunt object or surface on bone
- *Sharp force trauma*: slow-loaded impact of a sharp or bevelled implement on bone
- *Projectile trauma*: either rapid- or slow-loaded impact of a projectile on bone.

Trauma resulting from blast forces is a combination of the above mechanisms and is typically informed by the context and soft tissue modifications. These descriptors of mechanism are to be used in broad relative terms. When describing the mechanism in reference to a bony defect, terms such as velocity and speed are not appropriate to use.

The term ‘circumstance’ or ‘event’ should be used to describe the type of event where the mechanism occurred. For example, the event was a fall that resulted in the individual sustaining blunt force trauma.

Reconstruction of fragmented bone

The decision to reconstruct bone fragments depends on the complexity of the fragmentation and context of the case. Fragmented bones should be reconstructed when:

- The fragmentation is extensive and/or involves the skull,
- The information about trauma is not possible to obtain from the fragments separately, and/or
- Circumstances indicate the fragmentation was likely the result of trauma.

Reconstruction should be done with a glue that is able to be dissolve (e.g., imedio™), or is not so strong that the fragments may be disassembled later (e.g., thermoplastic adhesive). Such adhesives allow for the reconstruction to be undone if required. Reconstruction should only be undertaken at the mortuary/laboratory, not at the scene, and only after the remains have been processed and appropriately documented.

In cases with complex preservation (e.g., burning), consideration may be given to digital options for reconstruction, such as photogrammetry.

Describing skeletal defects

Currently there is no standard recording form for skeletal defects. Plain/lined paper with blank schematics (i.e., outlines of individual skeletal elements and the whole skeleton) is best for annotating descriptions. These may form part of a standard laboratory recording proforma.

The recording form/ blank paper should be titled ‘Changes to the skeleton’ or ‘Skeletal defects’. There should be no reference to ‘trauma’ at the descriptive stage. Description of each defect, either written or illustrated in a schematic, should include the following:

- Anatomical location of the defect
- Features of the defect
 - Shape
 - In cases where the defect is interpreted as a fracture, morphological and biomechanical references should be used to describe the shape. The defect should not be described using clinical orthopaedic names.
 - Margin characteristics
 - Length (and width and depth where applicable)
 - Number of fragments (where applicable)
- Description of how the defect does, or does not, interact with other defects

The description should also include all the characteristics that would then inform the interpretation of the defect being the result of trauma. These comprise:

- Features of timing
 - Example: colour, plastic deformation, fracture morphology

- Features of trauma type
 - Example: kerf wall and floor (sharp load), fracture margin (blunt load)
- Features of trajectory/direction
 - Example: bevelling distribution, margin angles

To avoid potential bias, no contextual details, or as little as possible, should be known prior to describing defects.

In cases where the defect exhibits remodelling, the following should be considered:

- Only broad descriptive stages of remodelling (i.e., ‘callus formation’ or ‘early/late-stage callus formation’) should be noted
- When callus is present, there should be no description of the underlying fracture.

Photography

All defects, whether taphonomy or trauma, should be photographed pre- and post-processing. This ensures complete documentation and provide a means to justify how taphonomic defects were differentiated from trauma in the peer-review process. The photography process for each defect should be:

- Overall bone
- Broad area of interest
- Specific area of interest/defect without aids (e.g., scale, pointer, knitting needles)
- Specific area of interest/defect with relevant aids.

If reconstruction of fragmented bone is required, the photograph process should be:

- All fragments (both sides) and their margins
- Each stage of the fragment reconstruction (i.e., after every few fragments have been reconstructed)
- Final reconstructed bone (in the standard anatomical views).

Use of scientific techniques, imaging and microscopy

Magnification should be used for every defect that is considered to be the result of trauma as part of a gross bone examination. Ideally this should be high-powered (i.e., stereo microscope), however in cases where such equipment is not available, a low-powered microscope or high-powered light source is acceptable.

Scientific techniques (e.g., scanning electron microscope (SEM), histology, x-ray fluorescence), medical imaging modalities (e.g., X-ray, PMCT, micro-CT, MRI) and photography modalities (e.g., photogrammetry) may be applied if they value add to the question being asked. Examples include (but are not limited to):

- Timing of fracture - histology and SEM
- Mineral composition associated with a defect - X-ray fluorescence
- Fracture margins to indicate direction of load – micro-CT.

The application of these technologies must be approved by the forensic pathologist and these examinations must be done by the relevant qualified expert/s who has skills in histology, mineral composition, radiology or photogrammetry.

Taking casts of traumatic defects

Casting is a complementary technique to the descriptive process. A cast should be created if a tool mark examination is required (done by the police), or if a permanent record of the defect is required. Casting should be done using a polyvinyl siloxane material impressed into the feature of interest (e.g., cut mark or fracture margin). Casting should be done after the anthropology examination and collection of any trace evidence.

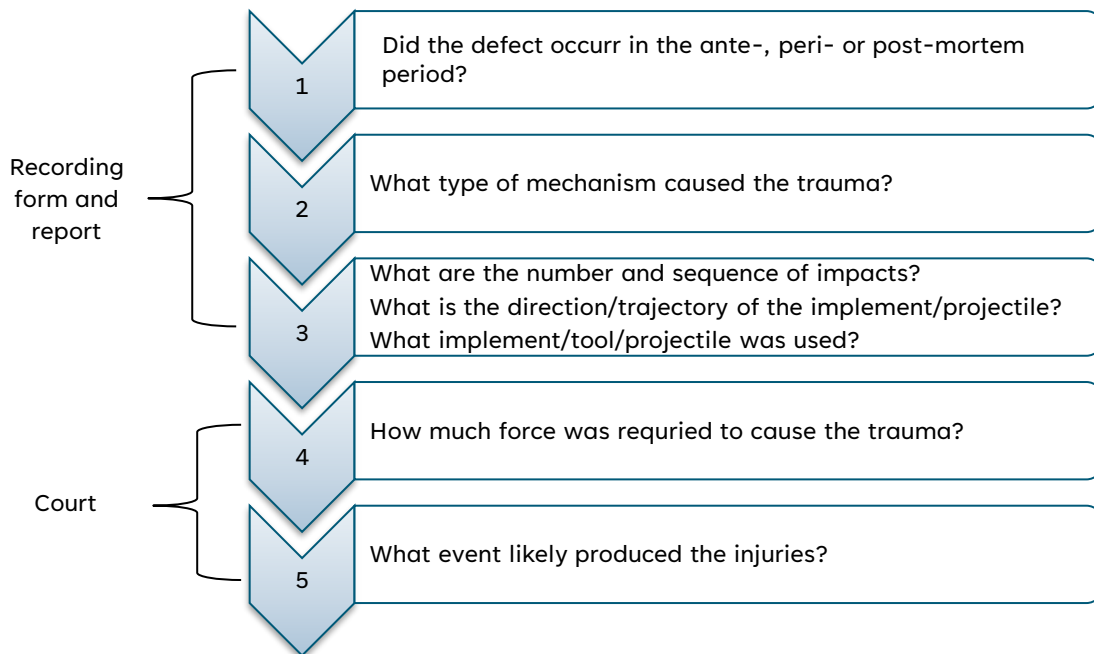
Interpreting skeletal trauma

The interpretation of skeletal trauma is the anthropologist’s opinion on what caused the defect (i.e., change to the bone) based on the descriptive features identified. The interpretation is one of the most important contributions an anthropologist may provide to a trauma case.

The level of detail in an interpretation

The level of detail in an interpretation will depend on the preservation of the remains and the quality and extent of contextual information available to the anthropologist. Consequently, an interpretation may be limited or comprehensive.

There are five levels of interpretation. Levels 2-5 are only relevant when Level 1 is interpreted as peri-mortem trauma.



Level 1: This is the standard interpretation expected of the anthropologist. It is not always possible to interpret the timing of a defect (i.e., poor preservation), but when it is possible, it should be reported.

- *Ante-mortem:* In cases where a defect exhibits callus formation, no comment on the defect characteristics should be given and no precise remodelling timeframes (e.g. weeks/months) should be provided. If specific timeframes are required, histology, SEM or micro-CT should be employed and reported by the relevant specialist. In cases where a defect has occurred over an area of bone remodelling, caveats should be provided that the interpretation is complex because the bone has been compromised.
- *Peri-mortem:* In cases where a defect has characteristics of peri-mortem trauma, levels 2-5 of interpretation should be considered.
- *Post-mortem:* In cases where a defect has characteristics of post-mortem damage, levels 2-5 of interpretation are not necessary.

Level 2: Interpreting the type of mechanism that caused the peri-mortem trauma is a standard request of the anthropologist. When possible, this should be reported.

Level 3: These questions are more complex as they rely on interpretations of detailed bone characteristics to make some inferences on the circumstances of the event. In some cases, depending on context and preservation, it may be possible to answer these questions.

- The interpretation of minimum number of traumatic events and sequencing will depend on the type and distribution of traumatic defects. If trauma is distributed to more than one bone and it is the result of a blunt load, it may not be appropriate to comment on minimum number of impacts (MNI)/sequence. However, if the trauma is the result of a sharp load then it would be appropriate to comment. If traumatic defects interact with each other (e.g., multiple fracture across the cranium) then it is appropriate to comment on the MNI and sequence, however there should be a caveat that, once a bone has been traumatised, it is difficult to interpret subsequent impacts because the bone has been compromised.
- Trajectory/direction for sharp force and projectile trauma should be provided in general anatomical terms. That is; superior-inferior, anterior-posterior and left-right. For blunt force trauma, direction should only be commented on if the fracture is depressed. Interpreting direction from other fracture types should be done with caution and in relation to the evidence base.
- The interpretation of a specific implement or tool is not possible. In cases of blunt and projectile trauma, where the size and shape of the implement does not reliably correlate with the characteristics seen on bone, it is not appropriate to interpret the tool/calibre from the bone features. Only broad comments may be provided (e.g., a flat blunt object). In cases of sharp trauma, if sufficient bone features are present, an interpretation of the class of tool may be possible.

Level 4: Answers to this question should be reserved for the court room and not included in reports or mortuary/laboratory recording forms. The degree or severity of force is not appropriate to comment on as it is not possible for an anthropologist to accurately assess. An anthropologist may only comment on the relative nature of the force. Questions regarding force should be referred for a biomechanical assessment.

Level 5: The interpretation of a specific event should be based on the features of the trauma, an understanding of biomechanics and contextualised to published literature on the traumatic defects resulting from such events (i.e., the evidence base). If presented with a specific event in court, it is appropriate to say that event is 'a possibility' or 'unlikely'. A definitive answer should not be given. Terms such as 'consistent with' or 'in keeping with' should be avoided.

To make any interpretation (Level 1 to Level 5), two or three skeletal characteristics that support the interpretation should be provided. For example, two features that indicate the event occurred in the peri-mortem period may be plastic deformation and the fracture margin morphology.

The interpretation should be conservative and within the area of an anthropologist's expertise. Where appropriate, the interpretation should have caveats to explain any limitations.

Accounting for variables and contextual information

Intrinsic and extrinsic variables will influence how trauma is interpreted. It is appropriate and necessary for the anthropologist to know such contextual details to inform their interpretation. It is, however, not possible to account for all variables in the report and it is not necessary to list every relevant variable. Variables should be anecdotally incorporated into the interpretation discussion in the report when relevant (e.g., neck of femur fracture and the individual was elderly), or provide caveats in the report when it is not possible to account for variables. Scene attendance will assist in obtaining some extrinsic variables (e.g., potential environmental processes that have occurred).

To mitigate contextual bias in cases where variable information is known, in accordance with the ANZPAA NIFS Contextual and Cognitive Bias Position Statement ⁷, the anthropologist should take steps to avoid or minimise contextual information until the description component has been completed, declare any contextual information known in the report, and have the case blindly peer-reviewed.

Report content

In the report, preservation should always be described prior to trauma and the description and interpretation of trauma should be combined. That is, sub-headings that are the timing of trauma (ante-mortem, peri-mortem) or taphonomic alterations (post-mortem) should be used. If multiple mechanisms of trauma are present, subheadings of 'Blunt force trauma', 'Sharp force trauma' etc, should then be used.

As the report is initially written for the forensic pathologist, the report section on skeletal trauma should use technical and anatomical terminology and the terminology should be related to trauma (i.e., no longer referred to as 'defects' but rather fractures, incisions, etc). The level of detail for each traumatic defect should be consistent, regardless of the number of defects (i.e., one or 20). Schematics of traumatic defects (and taphonomic defects if relevant) should be included in the report as these support and further clarify the terminology used to describe and interpret the defects.

All interpretations should be referenced, where possible, with peer-reviewed published empirical studies.

The report should include a glossary / annexure of lay descriptions of any anthropology-specific terms, for the benefit of the pathologist, and any complex terms, for the benefit of defence and prosecution council should the case go to trial.

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The Forensic Anthropology Technical Advisory Group members involved in the preparation of this report were:

- Dr Samantha Rowbotham (Victorian Institute of Forensic Medicine, VIC)
- Dr Ellie Simpson (Forensic Science South Australia, SA)
- Dr Alanah Buck (PathWest, WA)
- Dr Denise Donlon (University of Sydney/ Department of Forensic Medicine, NSW)
- Donna MacGregor (Queensland Police, QLD)
- Dr Anne-Marie Williams (University of Tasmania/Department of Health and Human Services, TAS)
- Adj/Prof Soren Blau (International Commission on Missing Persons)

The Forensic Anthropology Technical Advisory Group observers involved in the preparation of this report were:

- Dr Penny McCardle (Department of Forensic Medicine, Newcastle, NSW)
- Dr Angela Clark (University of Otago, NZ)

ANZPAA
Australia New Zealand
Policing Advisory Agency



Victoria Police Centre
Level 24, 311 Spencer Street
DOCKLANDS VIC 3008

T +61 3 9606 4515

E secretariat.nifs@anzpaa.org.au

Web: www.anzpaa.org.au/nifs