A PRELIMINARY DISCUSSION OF TRAUMA IN THE HUMAN SKELETONS FROM BAN CHIANG, NORTHEAST THAILAND

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ABSTRACT

A complete re-examination has been conducted on skeletal material excavated from the site of Ban Chiang, in northeastern Thailand in 1974 and 1975. This paper describes and enumerates traumatic injuries to the 140 human skeletons examined. The natures and extents of such injuries were found to be consistent with accidental injury during the course of daily living, rather than attributable to warfare.

INTRODUCTION

In 1974 the Thai Fine Arts Department and the University Museum of the University of Pennsylvania, under the direction of Pisit Charoenwongsa and the late Chester Gorman, began excavation in the center of the village of Ban Chiang in the northeast of Thailand (Gorman and Charoenwongsa 1976). The excavation was to push known occupation of the area back three thousand years and bring to world attention the antiquity of bronze metalworking and the beauty of Ban Chiang pottery. In the course of two seasons of excavation in 1974 and 1975, 140 human skeletons were recovered. Beginning in 1974 the remains were examined by Michael Pietrusewsky and his students at the University of Hawai'i, where they are now curated (Pietrusewsky 1980, 1982). Due to the untimely death of the co-principal archaeologist, Chester Gorman, final reports of the archaeological and osteological analyses were never published.

Prompted by Dr. Joyce White's revision of the Ban Chiang chronology (White 1986) and with the support of the University Museum, a complete re-examination of the skeletal material was undertaken by Pietrusewsky and myself this past year. In addition, this skeletal population forms the backbone of my doctoral dissertation examining the palaeopathology in Bronze and Iron age populations of northeastern Thailand. Measurements and nonmetric traits in the skull, teeth and infracranial skeleton were collected, along with observations, both qualitative and quantitative, on cranial vault thickening and porosis, *cribra orbitalia*, dental pathology including caries, abscessing, dental wear and dental enamel hypoplasia. Degenerative changes such as osteoarthritis, occupational changes and other indications of pathology were recorded as well. Although most of the data analysis is not yet completed, this paper reports preliminary observations on the type and extent of traumatic injury in the human skeletal remains found in the two seasons of excavations at Ban Chiang.

TRAUMA

Although a highly static organ, the human skeleton is resistant to most disease entities, which leave no mark upon the dry bones. Trauma includes evidence of perimortem violence, or injury sustained at the time of death, as well as healed fracture, dislocation or sprain. Interpreted on an individual level, we can draw conclusions about the risks of everyday life (Steinbock 1976, Ortner and Putschar 1981). The presence, type and frequency of traumatic injury within a population and its distribution by age and sex, provide evidence for inferences on the extent of medical knowledge and the caretaking capacity of the population (Merbs 1989). Traumatic injury may also provide evidence of interpersonal violence or warfare, in contrast to accidental injury which should, ordinarily, be random (Walker 1989).

The skeletal remains from Ban Chiang represent a village cemetery with individuals of both sexes and all

ages represented. Any interpretation of the occurrence of trauma in a skeletal population is dependent upon the age and sex structure of that population. A benefit of the twenty years of research in forensic osteology and skeletal biology since 1975 has been an improvement in ageing methodologies, allowing improved age estimates with respect to more individuals than was the case in the first analysis. Unfortunately, the presence of only the lower legs of some individuals in the excavation area and the failure to excavate the remainder of the burial still results in our ability to place about one-third of the burials in only the wide categories of young, middle and old adults, or just adults.

The sex ratio for the site is nearly equal. Thirty-four individuals are between birth and 15 years of age (10%), an under-representation. Average age at death is 24.27 years. The age distribution is bimodal with a peak between the ages of 2 and 4 years and a second peak at 40 to 49 years of age. Examination of the age-at-death distribution by sex also reveals a bimodal form. In females the highest number of deaths occurs at 35-40 years, while in males the greatest number of deaths occur in the 45-50 year age range.

In this discussion of the evidence for trauma, individuals recovered in the first excavation season (1974) will be designated with a "1/" before the burial number, and those excavated in the second season as "2/". Although not common, healed fractures of the bones of the skull, vertebrae, ribs, clavicles, humerus, radius, femur and the hands and feet, were observed in the skeletal remains from Ban Chiang.

Perimortem Trauma

There is a single case of possible perimortem trauma in the skeletal remains from Ban Chiang. In Burial 2/50, a male aged 25-30 years, the left lateral frontal bone, above the supraorbital ridge, has a depressed, circular breakage which appears old and stained, but has been complicated by recent damage. The skull is reconstructed. There is no reactive bone surrounding the lesion. The left zygoma is missing and the exposed maxilla is darkly stained. The dark staining of these broken areas suggests either that breakage occurred near the time of skeletonization or that there was *in situ* breakage in the ground. The hardness of the earth, multiple disturbances of the graves at the site and the depth and weight of the overlying earth, all contribute to a large amount of old breakage at the site. Bone fracture at the time of death is very difficult to infer during archaeological excavation in the absence of an injuring weapon.

Skull Fractures

Two fractures of the bones of the skull are noted in the Ban Chiang series. Burial 1/20, a young adult male, has a healed depressed defect of the right frontal bone. The frontal bone has been reconstructed but the defect is visible on the right temporal area of the frontal bone. The defect is oval shaped (32 x 23 mm) and slopes inward to a single bone layer (20 x 13 mm) which does not completely cover the defect. The defect is well healed; the cortical bone is smooth. Postdepositional damage to the cranium makes it difficult to evaluate this fracture but it appears that a circular piece of the cranium was removed or lost and healing occurred secondarily from the anterior side of the defect. The size of the healed extension and the absence of any fresh periosteal bone suggests that the individual lived a significant period of time after the injury.

The second skull fracture occurs in Burial 2/73, a male aged 35-40 years, with a healed fracture of the (?right) hyoid horn, the bone of the throat. Only a single horn was recovered. The fracture occurred at the distal shaft and there is a slight distortion of the greater horn indicating some displacement of the fragment. There is slight cortical expansion but the area is completely remodeled. This bone is typically fractured by a blow to the neck or in strangulation.

Vertebral Fractures

A vertebra may fracture at any one of its three component parts: the body, the processes or the lamina. Fractures of the vertebral body are typically sustained in falling or jumping from a height, while fractures of the processes of the vertebra or the lamina may be the result of sudden severe or sustained muscle action. Two kinds of vertebral fractures are found in the Ban Chiang skeletal series: stress fracture of the vertebral lamina, also called *spondylolysis*, and fracture of the spinous process.

Two males have fractures of the spinous processes of the lower cervical vertebrae. Burial 1/20, a male aged 35-40 years, has a flattened and porotic spinous process of the seventh cervical vertebra. The area is mushroomed outward with a coarse porotic bone surface. Burial 2/50, a male aged 25-30 years, has flattening of the spinous processes of the seventh and sixth cervical vertebrae. These spinous process avulsion fractures are called *clay shoveler's* fractures, first described as a consequence of lifting shovelfuls of heavy clay during the 1932 depression in Australia (Bedbrook 1982).

Spondylolysis, a fracture of the neural arch of the vertebra at the *pars interarticularis*, the narrow area below the superior articular facet, occurs typically in the

lower lumbar elements. The separation may occur on only one side (*hemi-*) or it may occur bilaterally (complete), effectively separating the inferior facets from the vertebral body. *Spondylolysis* is noted in three females and one male from Ban Chiang.

Burial 1/8, a female aged 35-40 years, has *spondylolysis* of both the fourth and fifth lumbar vertebrae. The lumbar vertebrae are fragmentary and the arches could not be restored to the vertebral bodies. Burial 1/48, a female aged 35-45 years, has *spondylolysis* of one of the lumbar vertebrae, the exact element is undetermined because the lower vertebrae are represented by the fifth lumbar vertebra and a few vertebral facets. The inferior portion of the superior articular facet in the fifth lumbar vertebra is coarse, pitted bone which appears remodelled, and consistent with *spondylolysis*. Burial 2/30, a female aged 20-25 years, has complete separation of the arch of the fifth lumbar vertebra. The vertebral body and the superior facets are present but the neural arch fragment was not recovered. The centrum is extremely compressed posteriorly: posterior height 16 mm and anterior height 23 mm, and the left *pars interarticularis* has two osteophytes extending inferiorly, while on the right side the articulation has a concave porotic appearance.

Spondylolysis occurs in a single male, Burial 2/65, aged 40-45 years, who has a fracture of the fifth lumbar vertebra. The neural arch was not recovered. There is a complete separation at the *pars intrarticularis*, with compression of the height of the posterior centrum and degenerative changes to both the inferior and superior end-plates.

Spondylolysis is most common in the fifth lumbar vertebra because 70-75% of the flexion of the spine occurs at the fifth lumbar-first sacral segment (Rothman and Simeone 1982). The frequency of *spondylolysis* in the lumbar vertebrae from Ban Chiang is 3.1% (6/191). In females the frequency is 6.5% (5/77), and in males 0.9% (1/108). The occurrence of *spondylolysis* has a genetic component but is also directly related to activities of daily life. In our modern society, gymnasts and weight lifters have a high frequency of this vertebral fracture.

Rib Fractures

There is an interesting cluster of healed rib fractures in the skeletal remains from Ban Chiang. Although ribs are often poorly preserved and fragmented in archaeological material, a great many of the burials had large numbers of ribs recovered.

Five individuals from Ban Chiang had healed rib fractures. In the 1974 series, Burial 1/8, a female aged 35-40 years has a healed fracture of the left twelfth rib, with circumferential swelling of the body near the axial end. The bone is well-healed without angulation or overlap of the segments. Four individuals, three males and a female, from the 1975 excavation have healed rib fractures. All of these burials have an estimated age-at-death of 45-50 years, and all have multiple fractures of the left ribs. Burial 2/40, a male has healed fractures of the apex of the left ?ninth, tenth and eleventh ribs. The ninth rib is thickened circumferentially with a slight anterior shift of the sternal fragment. The left tenth and eleventh ribs, fractured slightly posteriorly to the apex, have less callus formation and are not displaced. Burial 2/45, a male, has a healed fracture of the body of the left ?sixth rib, with circumferential thickening and some depression of the sternal rib fragment, and a healed fracture of the left twelfth rib at the head. Burial 2/47, a male, has healed fractures of the left ninth and tenth ribs. The ribs have fractures at the apex, with circumferential thickening and no angulation or deformity. The angulation in the tenth rib is sharp suggesting incomplete fracture of the posterior surface of the rib.

Burial 2/46, the single female, has healed fractures of two of the middle left ribs (5-9). Bone preservation is poor in this individual so the ribs are incomplete and many of the heads and most sternal ends are missing. Two rib fragments have healed fractures of the apex with circumferential thickening, anterior expansion of the apex, without displacement.

Ribs are typically fractured in multiples, unless there is a puncture or stab wound when a single rib may be affected. The cause of these multiple rib fractures, all on the left side, at this point remains a mystery.

Clavicle Fractures

The clavicle is the most frequently fractured bone in the human skeleton (Connolly 1981). Fractures of this bone are typically grouped according to location: middle third, outer third and inner third. There are two individuals in the Ban Chiang series with possible clavicle fractures, one infant and one child. The evidence is circumstantial: differences in shape and length of the clavicles which are suggestive of healed fracture. In children, where much of the energy of the body is utilized in growth, bone remodels at an astonishing rate and is capable of complete restoration of the original bone morphology after fracture (Hensinger 1977). In Burial 2/12, an infant aged 9-12 months, both of the clavicles are present. The left is complete but the right is missing the distal end, just after the conoid tubercle. The right clavicle is asymmetric to the left. It appears to be flattened in the anterior-posterior direction near the medial end and there is a raised ridge

on the inferior surface just distal to the midshaft. There is no sign of callus formation or circumferential thickening but the height is increased. There is a slightly greater degree of curvature on the right side than on the left. In Burial 2/44, a child aged 2-4 years, there is substantial size difference between the clavicles which cannot be documented in the other arm long limb bones.

Humerus Fractures

Evidence for fractures of the humerus in the Ban Chiang skeletal series is, again, circumstantial. One individual, Burial 2/53, a young adult male, has marked lateral bowing (apex medial) of the right humerus. There is no anterior-posterior rotation, the deltoid tuberosity is strongly marked and the bicipital groove is quite deep. There is no sign of thickening. This marked bowing, unilaterally, in the humerus may be the result of differential muscle use in the right humerus, or may be the result of a healed fracture of the humeral midshaft during childhood (Epps 1975).

Radius Fractures

Two burials from Ban Chiang have fractures of the radius. Because of the extended range of motion of the forearm and the wrist, fractures of the forearm bones can be complicated. Normally, there is approximately 9° of lateral curve over the length of the radius to allow clearance of the soft tissue of the forearm during rotation (Connolly 1981). Any disruption of this curvature will result in impingement of the full range of motion of the forearm (Anderson 1975). Burial 2/35, a male aged 45-50 years, has a healed fracture of the upper third of the left radius, below the biceps tubercle. There is slight circumferential thickening of the shaft, but all surfaces are smooth cortical bone. There is angulation of the shaft, apex medial, of less than 10° , with no apparent rotational deformity. The left ulna is not broken but is considerably reduced in robusticity with a nearly round shaft and reduction of the inter-osseous crest. The hand bones on the left side appear smaller in size than those on the right. Fracture of the proximal radial shaft is not common and may be caused by a direct force, such as a blow to the forearm, or an indirect force, such as in a fall on the extended hand. Proximal radial fractures usually result in movement of the proximal fragment anteriorly and the distal fragment medially or toward the ulna (Connolly 1981, Anderson 1975). This movement is the result of muscle action on the unanchored fracture segments and is responsible for the angulation seen in this individual.

The second radius fracture is found in Burial 1/31, a female aged 50-60 years. The right distal radius is expanded and mis-shapened with 30° angulation, apex dorsal, of the distal end indicating anterior movement of the distal fragment. The cortex is completely remodelled, but there is a slight residual ridging of bone across the posterior shaft. There are several large osteophytes on the posterior lateral surface of the bone. The right ulna has a slightly flattened distal articular facet, with the styloid process missing post-depositionally. The right lunate and scaphoid are normal in size and shape although the lunate has a small osteophytes along the posterior scaphoid facet. Fracture of the distal radius or wrist, is typically caused by a fall on the outstretched hand, or forced hyperextension of the wrist with the forearm and wrist pronated (Dobyns and Linscheid 1975). A Smith's fracture, in which the distal fragment is displaced volarly, or toward the anterior surface of the forearm, as is the case in Burial 1/31, is less common than displacement posteriorly (Connolly 1981).

Metacarpal Fractures

Fractures of the bones of the hand are uncommon in the Ban Chiang skeletal series. Burial 2/24, a 30-35 year old male, has a healed fracture of the proximal shaft of the right fifth metacarpal, just distal to the articular surface. There is significant dorso-volar angulation (22° apex dorsal), no apparent rotation, and completely remodeled cortex. Burial 2/76, a male aged 25-30 years, has a healed fracture of the proximal shaft of the left fourth metacarpal with dorsovolar angulation of 38 (apex dorsal) and no rotation. A small osteophyte has formed on the dorso-lateral side of the well-remodelled cortex.

Metacarpal fractures typically result from direct blows to the hand, such as hitting an object with a clenched fist, or from a crushing injury to the hand (typically multiple metacarpal fractures) (Connolly 1981, Barton 1982, Green and Rowland 1975). The most common metacarpal fracture is that of the head or neck of the fifth metacarpal (Boxer's fracture).

Femur Fractures

Femur fractures are one of the most dangerous fractures that may be sustained because of the large amounts of blood which can be lost into the muscle of the thigh. In contrast to fractures of the upper limb, fracture of the femur is a "high impact" fracture, requiring significant force such as a fall from a height (Connolly 1981). Two healed femur fractures are found in the Ban Chiang skeletal series, one male and one female. In the female, Burial 2/30, aged 20-25 years, the right femur is missing the proximal end but there is a healed fracture of the distal third of the femoral shaft with 25° of angulation,

apex anteriorly. There is well remodelled cortex in the area without thickening in the medial-lateral direction, but a well-demarcated ridge-like extension anteriorly, just above the lateral condylar line. The extension measures 10 x 56 mm and follows the long axis of the bone. The posterior intercondylar area has two raised (3 mm) osteophytes above the medial and central area of the condyle. Bone preservation is not adequate enough to evaluate loss of the bone mass in the lower leg, but there would have been significant leg length discrepancy resulting in a substantial limp.

In Burial 1/5, a middle-aged ?male, there is a large protruding ridge of dense cortical bone extending obliquely across the anterior shaft of the right femoral midshaft fragment. The femoral shaft fragment includes the shaft below the lesser trochanter to the distal end above the bifurcation of the *linea aspera* (250 mm in length). In the anterior view the ridge is situated on the lateral surface of the bone, with no apparent angulation in the lateral direction. In the lateral view, the posterior contour of the femur appears quite normal, but the ridge gives the anterior surface a "bowed" appearance and increases the anterior-posterior diameter of the bone. The medullary cavity is intact and there appears to be no angulation of the distal end of the femur either anteriorly or laterally.

Neither of the femora in these cases are complete enough to assess rotational deformity in the fracture healing or to make deductions about the method of treatment. Typically the injured person would be bedridden with the leg outstretched, a position which encourages lateral rotation of the leg, along with the distal fragment. After healing, the lower femur will be rotated outward while the upper femur will be fixed in an anterior position.

Metatarsal Fracture

The only fracture of a bone of the foot in the Ban Chiang skeletal series, the fifth metatarsal, is found in Burial 2/73, a male aged 35-40 years. The left fifth metatarsal has an enlarged, flattened, and porotic tubercle. The articular facet appears intact and with slight arthritic lipping. The cuboid is not present on this side. The fifth metatarsal tuberosity is for attachment of the *peroneus brevis* muscle, which acts to extend the foot. Textbooks differ in their descriptions of this fracture, some calling it a Jones' fracture, after Sir Robert Jones who broke his foot while ballroom dancing, and others saying it is not a true Jones' fracture (Sammarco 1982, Connolly 1981, Wilson 1982). At any rate, the most common injury to the fifth metatarsal is an avulsion fracture of the tuberosity caused by excessive inversion of the foot (Connolly 1981).

Dislocation

A unique observation in the skeletal remains from Ban Chiang is found in Burial 2/73, a 35-40 year old male, with a possible chronic dislocation of the left shoulder. Unfortunately, this burial was disturbed by a large trench feature and only the scapulae, right humerus, clavicles and vertebrae are present. The left scapula is complete, except for the acromion process and a small amount of the blade in the center and along the vertebral border. The anterior edge of the glenoid is eroded and flattened, and a semi-circular area on the anterior surface of the body of the scapula is porotic and lipped. The remainder of the glenoid fossa is normal without evidence of osteoarthritic lipping, while the porotic area on the anterior scapula has evidence of remodelling periosteal bone.

The bony configuration of the shoulder joint is by its nature unstable, as the joint has a wide range of motion which is constricted only by the joint capsule and the muscles of the shoulder. An anterior dislocation of the shoulder, the most common type, is typically sustained by young, active people (Connolly 1981). While there are three kinds of anterior dislocation, the most common is a subcoracoid where the humeral head becomes lodged beneath the coracoid process and in front of the glenoid, as is the case in Burial 2/73. An individual with a dislocation of the shoulder will carry the affected arm in slight abduction, with the shoulder flattened, the elbow flexed and the forearm rotated internally. Old dislocations which are not reduced may be painless and afford some degree of function. The presence of erosion of the proximal scapula in Burial 2/73 suggests a chronic dislocation of the shoulder with some degree of function of the arm. If the left humerus were preserved, we would expect to see a flattening of the posterior aspect of the humeral head.

Periosteal Contusions

Sometimes there may be trauma to the periosteum of a bone which lies near the surface of the skin (Ortner and Putschar 1981). Because the anterior tibial spine lies directly beneath the subcutaneous tissue, it is a common site for this type of trauma, the so called "bark" of the shin. Two individuals in the Ban Chiang skeletal series have healed cortical expansions of the anterior tibial spine. Burial 1/2, a young adult ?female, has a smooth, elongated cortical lump (48 x 18 mm) on the medial side of the proximal anterior crest of the right tibial shaft fragment, just below the level of the *nutrient foramen.*

There is no fresh reactive bone and the edges of the apposition are smoothly graded into the cortex. The right fibular shaft appears lumpy and swollen but there has been preservative applied so it is difficult to evaluate. The opposite side appears normal.

Burial 2/65, a male aged 40-45 years has a well healed "bump" of the anterior spine of the left tibia, just distal to the midshaft. The swelling is 40 x 19 mm in size. There is a clean transition to cortical bone at the edges of the swelling and no sign of infection, cloaca or fracture.

DISCUSSION AND CONCLUSIONS

None of the fractures described in the Ban Chiang skeletons can be directly attributed to warfare following the reasonable criteria of frequent occurrence and a patterning in location, age and sex. Other than the cluster of left rib fractures and *spondylolysis*, there are no apparent patterns of fracture related to age or sex. It is also important to note that the frequency of bone fractures over the relatively long chronology of the site is quite low. Most of the fractures described in this series are likely to have been the result of accidental injury during the course of daily living. Certainly the raised platform house provides an adequate height for a fall which could fracture the femur and the residents of Ban Chiang were likely to be dependent upon fruit and other tree products, also providing an opportunity for injury.

The number of fractures found in the Ban Chiang series is quite large when compared to other large skeletal series from Thailand. However, differences in sample size, temporal sequence and preservation complicate any attempts at comparison. The single fracture reported in the small sample of 31 skeletons recovered from Ban Kao in the Kanchanaburi Province (Sangvichien *et al.* 1969), was a compression fracture of the first lumbar vertebra in an adult male. Excavations at Ban Na Di, located 24 kilometers from Ban Chiang, recovered the remains of 73 individuals ranging in age from fetal to over 50 years (Wiriyaromp 1984). Two cases of trauma are noted: a healed fracture of the first metatarsal in an adult male, and a thickened interior aspect of the left tibia of an adult of unknown sex. No healed fractures are reported in the series of 83 skeletons recovered in 1966 from Non Nok Tha, northeastern Thailand, examined by Pietrusewsky (1974). Recent excavations at a former coastal site, Khok Phanom Di, near the present city of Bangkok, disinterred 154 skeletons with a demographic profile skewed toward children (Tayles, 1992). Fractures in this series were infrequent: two left clavicle fractures, both females; a fifth metacarpal in a 45 year old male, and a fourth metacarpal in a young adult male. These are very commonly fractured bones and offer some suggestion of relatively small degree of risk of accidental injury in this population. The lack of healed fracture of any of the major long limb bones of the lower leg in other skeletal samples from Thailand is quite interesting and perhaps suggestive of a riskier lifestyle in the uplands of the Khorat Plateau.

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