Otitis Media, Mastoiditis, and Infracranial Lesions In Two Plains Indian Children

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One disease condition that is common to nearly all children is otitis media, also known as middle ear disease. Although most people speak of it as a middle ear "infection," other causes such as neoplasm (tumor) can result in manifestations and symptoms mimicking an infectious process. This paper presents findings related to osseous lesions in two Indian children, approximately three to five years of age, who died with otitis media and infracranial lesions. Through macroscopic and radiographic analysis, it is possible to show that one child probably suffered from tuberculosis and the other from histiocytosis X. From an epidemiological and historical perspective, these determinations in skeletons from the Plains contribute to improved understanding of the evolution of infectious and tumorous diseases in North America.

The two children reflect different skeletal manifestations of otitis media and infracranial lesions. Although the differential diagnosis of disease in archaeological skeletons must be tempered with caution, the morphology and distribution of bone lesions in these children provide evidence for distinguishing infectious from tumorous disease. These cases serve two basic purposes: first, to provide detailed descriptions of the lesions, and second, to stimulate new thought and perspectives on the epidemiology, history, and geographic distribution of infectious and tumorous diseases in the Plains. In addition, these unusual examples demonstrate the contribution of skeletal remains to improved understanding of disease in prehistoric populations.

**Otitis Media**

Otitis media is a disease of the middle ear that commonly occurs secondary to an infectious process (frequently during the winter) in the upper respiratory tract (Casselbrant et al. 1985; Henderson et al. 1982). Clinical studies have shown that susceptibility varies by age and racial affiliation. Otitis media is common in infants after the neonatal period (birth to 28 days), with declining incidence after the first year of life. A study of 2,565 children living in Boston, Massachusetts, revealed that 9 percent had at least one episode of otitis media by age three months, and 65 percent experienced the condition by 24 months of age (Teele et al. 1984). Using otoscopy
In the past, the condition seems to have been demonstrated to have a relationship between the prevalence of otitis media and medical treatment, better general health, improved social conditions, lower virulence of responsible organisms, and treatment with antibiotics (Phelps and Lloyd 1990; Scott and Jackler 1989). In the past, the condition seems to have been more severe and frequently complicated by acute labyrinthitis, acute mastoiditis (inflammation often followed by destruction of the mastoid antrum or process), or intracranial sepsis (Phelps and Lloyd 1990). A 10-year (1974 to 1983) study in Israel found that, although still a serious and potentially lethal disease, acute mastoiditis is an infrequent complication of acute otitis media (Rosen, Ophir, and Marshak 1986).

The pathogenesis of otitis media usually follows an event, such as allergy or infection, that causes congestion of the respiratory mucosa, obstruction of the isthmus, and accumulation of mucosal secretions of the middle ear (Bluestone and Klein 1988). In individuals with low resistance or in whom the infection has reached a state of high virulence, the disease quickly spreads throughout the temporal bone, resulting in a local inflammatory response and generalized systemic changes (Pendergrass, Parsons, and Hodes 1956). Proliferation of bacteria in the middle ear leads to suppurative (producing pus) and symptomatic otitis media. Mastoid disease, a possible sequela to otitis media, has been associated with pneumonia, influenza, tuberculosis, and exanthemata. The spread of bacteria (e.g., Staphylococcus aureus) may result in hearing loss, osseous lesions, and rapid destruction of the mastoid antrum and air cells (mastoiditis), tegmen tympani, and surrounding bone within a few days. Perforation of the tegmen or pyramid may lead to epidural abscess and death despite antibiotic therapy (Stanievich et al. 1981).

Prehistoric and historic archaeological examples of otitis media have been reported from Egypt (Moodie 1931), Iran (Rathbun and Mallin 1977), Arizona (Titche et al. 1981), Tennessee (Dowd 1989), and North and South Dakota (Gregg, Steele, and Halzhueter 1965). Gregg and colleagues (1965) found evidence of altered pneumatization in approximately 47 percent of 417 temporal bones (dry specimens) from South Dakota. This frequency suggests a high infection rate during infancy and early childhood.

**Histiocytosis X**

Histiocytosis X (the X signifying of unknown origin) is the terminology used as a comprehensive category for three conditions: eosinophilic granuloma, Hand-Schuller-Christian disease, and Letterer-Siwe disease. These conditions are commonly believed to be expressions of the same basic pathologic process. Eosinophilic granuloma is the mildest form of the disease, which may present as single or multiple osseous lesions. Hand-Schuller-Christian disease is the most varied form, presenting as chronic disseminated osseous lesions seen predominantly in children, although it may be found in adolescents and, rarely, adults. Letterer-Siwe disease is the acute form and has a poor prognosis (Resnick and Niwayama 1988). It is most commonly seen in children below the age of three years. Histiocytosis X occurs primarily in infants, children, and young adults and is more common in males by a ratio of nearly 2:1 (Barnes and Peel 1990). Aural and temporal bone involvement are common during the course of the disease.

**Tuberculosis**

Tuberculosis is disseminated by two sources of infection: inhalation or ingestion of the human (Mycobacterium tuberculosis) or bovine (Mycobacterium bovis) form of the tubercle bacillus. In the past, the second form was responsible for approximately 20 percent of all skeletal cases, especially in children (Resnick and Niwayama 1988). Skeletal tuberculosis (Pott's disease of the spine), a condition most familiar to paleopathologists, is one manifestation of the disease. Invasion
of the temporal bone by tubercle bacilli may result in tuberculous otitis media, a condition rarely encountered in modern groups (only 10 cases in children were reported between 1960 and 1977; MacAdam and Rubio 1977). The tubercle bacillus is present universally and, although everyone is exposed to it at one time or another, not everyone contracts the disease. Factors including host immunity, age, general hygiene, nutrition, sanitation, population size (e.g., crowding), and geography affect the incidence and virulence of tuberculosis (Buikstra 1981; Daniel 1981).

The frequency of tuberculosis, although disproportionately distributed throughout the world, has declined dramatically with the advent of chemotherapy. The rate of tuberculosis in the United States decreased steadily until 1985, at which time it leveled off, but in 1986, the trend reversed (Rieder et al. 1989). Incidences of smear-positive pulmonary tuberculosis by continent are highest for Africa (165/100,000) and Asia (110/100,000) and lowest for North America (7/100,000) (Styblo and Rouillon 1981). Nearly four million new infectious cases of tuberculosis develop worldwide each year. Although skeletal tuberculosis can affect individuals at any age, it is rare in the first year of life. The interval between 5 and 14 years is the "favored age" for tuberculosis in children (Smith and Marquis 1987).

In 1985, of 1,261 patients in the United States with childhood tuberculosis, 36.2 percent were Black, 27.3 percent were Hispanic White, 20.1 percent were non-Hispanic White, 12.7 percent were Asian or Pacific Islander, and 3.7 percent were Native American (Hayden, Bloch, and Snider 1987). Of the 22,170 known-race patients with tuberculosis in the United States, 397 (2%) were Indians and Eskimos. The incidence for this group was 25 per 100,000, or 4.4 times the rate for Whites (5.7 per 100,000) (Gregg 1987). Although Native Americans accounted for high frequencies of reported tuberculosis cases in Alaska (71%) and South Dakota (62%), these groups comprise only 14 percent and 7 percent of the Alaska and South Dakota populations, respectively. Lester (1986) reports that tuberculosis has an inverse relationship to the standard of living within a society. The frequency of the disease increases during times of social catastrophe and decreases with improvements in the standard of living and nutrition. Historically, Indian and Eskimo children have been at high risk for contracting tuberculosis.

Mycobacterial tuberculosis of the musculoskeletal system occurs from hematogenous (blood stream) spread and usually involves the spine (Pott's disease) or a single bone or joint (Day et al. 1991). The joints of the lower limb are more commonly affected than those of the upper limb. Examples of skeletal tuberculosis have been reported from prehistoric and historic archaeological sites in North America (Buikstra 1981).

**Sites Represented by the Two Skeletons**

The 25DK10 cemetery was located on a 300-foot high bluff overlooking the floodplain of the Missouri River one mile northwest of the Big Village site (25DK5) in Dakota county, Nebraska. Looters discovered this and other Omaha cemeteries and were collecting burial artifacts. University of Nebraska archaeologists alerted to this destruction organized two salvage crews in the late 1930s and early 1940s to excavate burials and preserve skeletal remains and artifacts from further plundering (Reinhard et al. 1990). The more than 60 skeletons recovered represented historic Omahas of both sexes and all ages buried about 1780 to 1820. Bone preservation was excellent, although many burials had been disturbed by previous excavations and by burrowing animals. One of the examples described in this report, a child aged 4.5 to 5.5 years and designated Individual 1 (Burial 47), came from this site.

The child was buried in an extended, supine position and shared a single burial pit with another subadult. The burial pit, which had been disturbed by looters, measured 26 inches long and 16 inches wide. The skeleton, found 68 inches below surface, is nearly complete (missing only portions of the hands and feet) and well preserved. Staining resulting from copper salts is visible on both temporals and on most of the long bones of the arms and the fibulae. Green staining on the temporal bones and mummified adhering soft tissue (portions of the ears) resulted from copper coil ear ornaments. As was typical of many Omaha burials from 25DK10, a large number of burial objects were placed with this individual, including seven copper bracelets, 14 copper pendants, one silver pendant, five copper coils, one lead band, one iron handle, a pail lid, and trade beads.

Age was determined by the degree of dental development (Moorrees, Fanning, and Hunt 1963a, 1963b) and lengths of the long bones (Merchant and Ubelaker 1977). The crowns of the first permanent molars are complete and the roots are approximately half developed, suggesting 4.5 to 5.5 years of age. A maximum length measurement of the right femur is 180 millimeters, which is consistent with the estimated age based on the dentition.

During a salvage operation at the Cotter-Hutson site (34CU41) in Custer County, Oklahoma, Don G. Wyckoff of the Oklahoma archaeological Survey recovered the skeleton of a child of 2.5 to 3.5 years of age (Burial 2, designated
Individual 2 in this report). Artifacts from the surface and associated refuse pits included cordmarked and plain pottery with caliche and grit temper, grinding stones and milling basins, shell disk beads, and small projectile points of the Young, Scallorn, Washita, Fresno, and Harrel types (Keith, Snow, and Snow 1971). The site was occupied by people of the Custer focus, a prehistoric farming and hunting-gathering culture of western Oklahoma (Bell and Baerris 1951; Buck 1959). Radiocarbon dates for other Custer focus sites indicate dates between A.D. 800 and 1100 (Bell 1968; Brooks 1989). The flexed burial was found lying on its left side in a small circular refuse pit. All major bones were recovered with the exception of the hands and feet.

An age estimate was based on the stage of dental development of both the deciduous and permanent teeth. Complete crown and partial root formation of the permanent first molars (6-year molars) suggest an age of 2.5 to 3.5 years (Moorrees et al. 1963a, 1963b). These teeth are still within their bony crypts and have not fully erupted through the jaw. The deciduous teeth show mild attrition and no carious lesions.

**Skeletal Pathology of Individual 1**

Individual 1 exhibits mixed lesions in the cranium, mandible, ribs, vertebrae, and long bones. The temporals have resorptive lesions that had caused considerable erosion of both ear canals (fig. 1). The left temporal bone has a resorptive defect measuring 34 by 14 millimeters involving the petrous process (tympanic plate and antrum entirely destroyed) and mastoid process, with destruction of the bone superior and posterior to the external auditory meatus (fig. 1, bottom). The ectocranial margin of the defect is remodeled, beveled, and ringed with irregular scar tissue that is radiographically visible as sclerosis. Internally, there is evidence of mild osseous remodeling in the form of irregular scar tissue along the margin of the defect. Radiographs of the mastoid process exhibit coalescence of the air cells. There is no endocranial or ectocranial evidence of active fibrous bone. The extent of osseous remodeling (healing) indicates a prolonged condition. The squamosal suture is nearly completely obliterated, a condition possibly related to infection.

The right temporal bone also shows resorption of the petrous process, with complete destruction (by otitis media) of the tympanic plate and mastoid antrum. The external auditory meatus is eroded and the meatal opening is enlarged superiorly. The defect measures 24 by 10 millimeters, with an irregular, porous margin of reactive bone superior and poste-
rior to the external auditory meatus. The mastoid process is not noticeably affected. The squamosal suture is completely obliterated.

The occipital exhibits marrow hyperplasia (porotic hyperostosis), which is commonly attributed to anemia (Angel 1964, 1966; Macadam 1989). The right parietal exhibits what superficially appears to be asymmetrically positioned porotic hyperostosis. The “spongy” lesions are most pronounced in the occipital and right parietal, with mild involvement along the lambdoidal suture. The right parietal also exhibits a small perforating lesion (fig. 2), measuring 12 by 6 millimeters (outer cortex) and 4 by 2 millimeters (inner cortex), located near the vertex, approximately 3 centimeters lateral to the sagittal suture. This ovoidal lesion has a mildly raised external margin of reactive bone, sclerosis, and is bounded anteriorly by an irregularly shaped but well-demarcated mound of spongy bone. When viewed ectocranially, the defect is inwardly beveled and exhibits mild vascularization (tiny pits reflecting an increase in the number of blood vessels).

A radiograph (fig. 3) of the right parietal reveals that the outer table of bone beneath the spongy bone is intact, and there is no evidence of diploic expansion (that is, porotic hyperostosis). Macroscopic and radiographic examination of the right parietal indicates that the area of raised bone is more consistent with a periosteal (inflammatory), rather than a diploic, reaction to the adjacent lytic lesion, possibly reflecting a hemangioma. The orbital plates exhibit mild cribra orbitalia, a pitting and thickening condition frequently attributed to anemia. Mild porosity is also visible on both cheekbones.

In regard to the mandible, the right condyloid process is slightly larger than the left and exhibits a small resorptive lesion (probably healed) at the anterior margin of the articular capsule. The circular lesion measures 4 by 3 millimeters, lacks sclerosis, and has a well-defined margin and a smooth floor. The depth of the lesion measures 2 millimeters and is confined to the cortex. The neck of the right ramus is thicker (healed periostitis) mediolaterally than the left neck.

The infracranial skeleton exhibits numerous active focal areas of osteolysis and laminated (“onionskin”) periosteal new bone. Laminated reactive bone is created by concentric planes of ossification beyond the cortex interspersed with radiographically lucent zones between the new bone lamellae (Ragsdale, Madewell, and Sweet 1981). Affected bones are the tibiae, fibulae, ulnae, right humerus and radius, left ribs 4, 7, 9, and 10, and right ribs 2, 4, 7, 8, 11, and 12. Vertebrae C6, T12, L1, and the arches of three lower thoracic vertebrae (numbers unknown) also exhibit lesions. The ribs and tibiae best represent laminated new bone. The scapulae, clavicles, os coxae, and hands and feet were unaffected as were the epiphyseal plates.

Ten left and nine right ribs are present for examination. Of these, four left (nos. 4, 7, 9, and 10) and six right ribs (nos. 2, 4, 7, 9, 11, and 12) (fig. 4) exhibit active periostitis and/or multiple lytic, expansile lesions. The lesions affect both the inner (visceral) and outer surfaces of the ribs, with perforation mostly confined to the outer surfaces. Laminated new bone has resulted in mediolateral thickening and “clubbing” of the vertebral segments of three left (nos. 7, 9, and 10) and three right (nos. 8, 11, and 12) ribs.

Most affected is the fourth right rib, which exhibits five ovoidal cortical perforations, four of which are in the inner surface, confined to a 12-millimeter area and a small sequestrum (loose dead-bone fragment) in the medullary cavity. The smallest perforation is on the outer surface, which lacks evidence of periostitis. The perforations are associated with active
periostitis, in some instances resulting in eccentric expansion of the outer cortex, with concomitant perforation of the inner surfaces in the right fourth rib and eleventh left rib. The lytic lesions in the cortex range in size from 3 to 7 millimeters.

The right seventh rib also exhibits a large resorptive lesion situated a few centimeters posterior to its midshaft. The rib is broken and missing bone (postmortem) at the posterior margin of the lesion. The ovoidal expansile lesion is located along the inferior half of the outer surface of the rib, measures 13 by 8 millimeters, and is surrounded by a narrow "capsule" of cortical bone. The medial cortex exhibits 2 millimeters of laminated new bone. The lesion has a smooth, dense floor, and the inner cortex opposite the larger lesion exhibits an ovoidal resorptive lesion measuring 5 by 3 millimeters. The macroscopic appearance of the defect indicates osteolysis, originating either in the medullary cavity or on the inner cortex, followed by outer involvement of the rib cortices.

Seven vertebrae exhibit resorptive lesions of either the centrum or arch (fig. 5). Of 18 vertebrae present for examination, three exhibit moderate to severe destruction of the bodies, and four have lytic lesions in the arches. Lytic lesions are present in the cervical, thoracic, and lumbar vertebrae.

Of the cervical vertebrae, only C6 shows destruction of the anterior body. The lesion, which was confined largely to the right half, destroyed approximately half the body. The margins of the defect are irregular, with little evidence of remodeling. Approximately 6 millimeters of bone remain along the posterior centrum.

Three lower thoracic vertebrae (numbers indeterminate) present lytic lesions in the vertebral arches. Lesions are visible in two right vertebral arches and one left. One vertebra shows destruction of the right superior articular facet; the right inferior articular facet is destroyed in a second vertebra. The twelfth thoracic vertebra shows extensive destruction and flattening (vertebra plana) of the inferior body and mild cortical resorption of the pedicles (the superior end-plate of the opposing first lumbar vertebra also exhibits mild destruction). The bodies present no evidence of sclerosis. The lesion resulted in a groove extending anteroposteriorly that would have involved the posterior longitudinal ligament and, possibly, the spinal cord.
Lumbar vertebra 1 shows mild destruction of the superior end-plate and reactive bone encircling the left Hahn’s cleft, the vascular opening in children’s vertebral bodies. A cauliflower-shaped extension of bone measuring 3 millimeters is located anterior to this cleft. The right inferior vertebral arch exhibits active periostitis. The third lumbar vertebra has a small perforation with an irregular and raised margin in the inferior surface of the arch near its convergence.

The cortex of the right tibia is thickened anteriorly and exhibits vascularization and laminated periosteal new bone. Macroscopically, the outer cortex suggests only a mild, active periosteal response; however, radiographs reveal an ill-defined intramedullary lucency (early-stage lesion) bounded laterally by laminated new bone in the proximal third of the shaft. The lesion exhibits minimal sclerosis, has mildly eroded the endosteum (that is, scalloping), and does not communicate with the outer cortex. The lucency measures 20 by 12 millimeters and is oriented along the long axis of the shaft. The left tibia exhibits an ill-defined intramedullary radiolucency near the midshaft, periosteal new bone, and increased vascularization, also confined to the anterior shaft.

The diaphyses of both humeri show active periostitis along the posterior and lateral surfaces of the distal shafts. The pattern of periosteal new bone is symmetrical, and the new bone is loosely attached, pitted, and darker in color than the surrounding normal cortex. There is a separate island of periostitis on the medial portion of the diaphysis of the right humerus immediately above its midshaft. This new bone is also immature and easily flakes away from the underlying cortex. The circumference of the left humeral diaphysis is smaller than that of the right humerus (most visible on radiograph). Radiographic examination reveals an ovoidal, eccentric, intramedullary resorptive lesion measuring 15 by 6 millimeters near the medial cortex of the left humerus (fig. 6). The lesion has a narrow radiopaque margin, with a narrow sclerotic band encircling the defect.

The proximal diaphysis of both ulnae and anterior midshaft of the right radius (in supination) are thickened and exhibit localized periostitis and vascularization. The margin of periosteal new bone on the right radius has remodeled and is indistinct (healed and faded), whereas those on the ulnae are distinct from the surrounding bone. The radius and ulnae exhibit eccentric (that is, confined to one surface) thickening and expansion of their diaphyses. A radiograph of the right radius reveals two resorptive intramedullary lesions measuring 8 by 5 millimeters and 8 by 2 millimeters at the midshaft (fig. 7). The lesions exhibit no sclerosis beneath the areas of periosteal new bone. The lesions resulted in focal resorption of both the medullary cavity and endosteal surface (scalloping) of the diaphysis. Neither lesion perforated the outer cortex. The bones of the right forearm (radius = 114 millimeters, ulna = 115 millimeters) are longer than those of the left forearm (radius = 111 millimeters, ulna = 113 millimeters), and the humeri are equal in length. The left radius and both ulnae present no evidence of resorptive lesions.
The distal halves of the fibulae are thickened and porous. Involvement of the diaphyses is eccentric, with no evidence of draining sinuses. The pattern of periostitis is symmetrical and confined to the medial surfaces opposing the tibiae. Radiographs reveal no evidence of resorptive lesions.

CORTICAL THICKNESS AND BONE DENSITOMETRY

Plain-film radiographic examination of the long bones for pathological features gave the impression of some cortical thinning (osteopenia). Therefore, the possibility of decreased bone mass was assessed quantitatively through measurements of cortical thickness and densitometry of the femur.

Densitometric measurements of certain appendicular bones are often used as a means of identifying osteoporosis. Osteoporosis is a condition of decreased bone mass as a result of any of a number of metabolic, disease, or nutritional factors. Loss of the bone in the axial skeleton is disproportionately greater than in the appendicular skeleton (Frost 1963). Thus, if visible changes are evident in the long bones, the loss of volume is more dramatic in other areas of the skeleton.

Table 1 presents radiographically determined measurements of cortical thickness for the 25DK10 child and for nine other children from three protohistoric Northern Plains village sites. These children were selected for comparison solely on the basis of age and comparability of femur length (an approximate diaphyseal length of 177 millimeters). Standardized posterior-anterior and lateral views were taken of each femur using a Kodak, Lanex, fine, single-screen cassette and Kodak single-emulsion ortho M film. Three measurements were determined for each view: T (total subperiosteal diameter), M (medullary cavity width), and C (cortical thickness calculated as $C = T - M$) (after Garn 1970). The medullary cavity width at midshaft is absolutely and relatively larger in both projections compared to the reference sample. The average cortical thickness of the control sample in both dimensions is exactly 1 millimeter larger than noted for Individual 1.

Measurements of bone mineral content (BMC) were determined for each femur at the midshaft and the femoral neck using a digital bone densitometer (table 2) (Norland Corporation Model 1768, with collimator #4 and a bone edge search threshold setting of 75%; Norland Corporation 1986). The densitometer determines bone mineral content using a single photon absorption technique. A collimated beam of monoenergetic photons passes through the bone, and the resulting transmission attenuation is monitored with a photon detector. The absorption curve is integrated to obtain a value related to the total bone mineral per unit length of the bone being scanned. The data reported in the printout are the bone width (BW), the bone mineral content in grams per centimeter (BMC), and the ratio BMC/BW (grams/cm²). The BW measurement represents the width dimension of the bone being scanned and is approximately equivalent to the value of $T$, as measured in the posterior-anterior view with plain-film radiography. The ratio BMC/BW is a measure of density of the bone. The densitometer was calibrated by scanning a calibration phantom having a known BMC.

Four scans were taken at each site and averaged to obtain the best estimates for the two sites on each femur. The values
Table 1. Femoral Cortical Thickness and Mineral Content Measured by Radiography

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<tr>
<th>N</th>
<th>Femur Length Mean (mm)</th>
<th>T Mean (mm)</th>
<th>M Mean (mm)</th>
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Midshaft Radiography

Posterior-Anterior View

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Medio-Lateral View

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Table 2. Femoral Cortical Thickness and Mineral Content Measured by Densitometry

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<th>BMC Mean (g/cm)</th>
<th>BMW/BW Mean (g/cm²)</th>
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Midshaft Densitometry

Femoral Neck Densitometry

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<th>BMW Mean (g/cm)</th>
<th>BMC/BW Mean (g/cm²)</th>
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</table>
for Individual 1 appear in table 1, compared to the overall mean values for the nine reference femora. (No femoral neck scan was taken for one control specimen because of post-mortem breakage in the neck region.)

As table 2 shows, the midshaft and femoral neck values for BMC and BMC/BW of Individual 1 are nearly two standard deviations less than the age-matched reference sample. In fact, for both scan sites, Individual 1 has the lowest values recorded in this series. The range varied between a low of 0.62 (midshaft BMC/BW for Individual 1) and a high of 0.92; the femoral neck low was 0.37 (BMC/BW for Individual 1), compared to a high of 0.70. These density measurements parallel the pattern described for the cortical thickness data. Figure 8 shows a midshaft scan of the 25DK10 femur and four reference specimens using computed tomography. The two-dimensional images of the tomogram illustrate individual differences in cross-sectional areas of the cortical bone and the medullary cavity. Note that the 25DK10 femur is completely circular, lacking development of the linea aspera, a prominent muscle attachment site on the posterior femur.

The femur of this child exhibits a thinner cortex, sparse trabeculae, and diminished mineral content relative to other children of similar age and stature. These physical signs reflect osteoporosis of the skeleton. This condition can be attributed to several factors related to the disease process including poor nutrition and inactivity. As the disease progressed, the child experienced a loss of appetite resulting in reduced nutritional intake and increased immobility. Reduced cortical thickness and enlarged medullary cavities due to increased endosteal resorption are characteristic of malnutrition and malabsorption (Garn 1970). Furthermore, histomorphometric and bone densitometry studies of paraplegics and bedridden patients have demonstrated significant losses of trabecular and cortical bone within relatively short periods of time (Chantraine, Nusgens, and Lapiere 1986; Mazess and Whedon 1983; Stout 1982). Immobilization results in muscle atrophy, lower bone mineral density, cortical porosity, and greater endosteal diameters (Doyle, Brown, and Lachance 1970; Smith and Gilligan 1989). Loss of compact bone occurs at a slower rate than for trabecular bone. Both increased osteoclastic resorption and decreased bone formation are responsible for bone loss with immobilization.

**Skeletal Pathology of Individual 2**

The skull exhibits a resorptive defect (that is, exaural abscess) measuring 5 by 4 millimeters in the outer temporal cortex immediately superior to the right mastoid process (illustrated in Owsley 1989:132). This lesion communicates with a second perforating lesion in the tegmen and the mastoid process, signifying mastoiditis. The defect in the outer vault has an irregular margin and is bordered by porous reactive bone measuring approximately 1.5 centimeters in diameter (some bone may have been destroyed postmortem). A radiograph reveals a lucency in the mastoid antrum surrounded by dense (sclerotic) bone. The mandible is macroscopically normal.

A gross pathologic and radiographic examination (Keith, Snow, and Snow 1971) suggests that the premortem changes in the right temporal bone could have resulted from a coalescent mastoiditis or a cholesteatoma, leading to an epidural abscess. Meningitis and subdural empyema frequently accompany epidural abscesses, each of which usually causes the death of the untreated patient. Any of these complications could have resulted in death.

The distal left humerus exhibits a large resorptive lesion in the metaphysis and coronoid and radial fossae (fig. 9). The defect is roughly confined to the area within the articular capsule, measures 17 by 14 millimeters, and has smooth, sloping borders. When viewed from below, the lesion has an irregular and porous floor of reactive bone with perforation into the medullary cavity. The cortex superior to the lesion is healed and thickened anteroposteriorly (2.5 millimeters thicker than the right humerus). Radiographs reveal regional sclerosis (thickened reactive bone) associated with the resorptive lesion (fig. 10).

The proximal left ulna exhibits two ovoidal resorptive lesions measuring 9 by 6 millimeters and 8 by 5 millimeters. The larger (cortical) defect is situated immediately superior to the radial notch, and the smaller defect is on the semilunar notch. The smaller lesion has eroded the subchondral bone (the articular surface) and exposed the trabeculae. There is no evidence of inflammation or sclerosis associated with the defects. Although the lesion above the radial notch was con-

![Fig. 8. Computerized tomogram of the midshafts of five length-matched femora including Individual 1 (25DK10). The femora are in a prone position.](image-url)
fined to the cortex, the subchondral lesion may have communicated with the medullary cavity.

The left fifth rib (fig. 11), although fragmentary, has subperiosteal new bone (periostitis) along its inferior (visceral) surface. The immature new bone is situated approximately 3.5 centimeters from the vertebral end and is porous and loosely attached to the underlying cortex.

Two vertebrae (probably thoracic) exhibit nearly complete destruction of the bodies. The trabeculae are thickened, and all that remains of the bodies are thin end-plates (one each). The pattern and extent of osseous destruction are nearly identical. It is likely that these were opposing vertebrae.

The remainder of the skeleton revealed no other lesions, although this child also shows pronounced osteoporosis. The approximate length of the femur was 165 millimeters (estimated because of postmortem breakage). Posterior-anterior and lateral radiographs were taken of the femora of Individual 2 and of four Plains Village children (three from South Dakota and one from Oklahoma, with an average femur length of 160 millimeters). The midshaft measurements are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Posterior-Anterior View</th>
<th>Lateral View</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>M</td>
</tr>
<tr>
<td>Individual 2</td>
<td>10.6</td>
<td>8.6</td>
</tr>
<tr>
<td>Reference (n = 4)</td>
<td>11.8</td>
<td>7.4</td>
</tr>
</tbody>
</table>
Fig. 11. Patchy periostitis (arrows) along the visceral surface of the left fifth rib (Individual 2).

Individual 2 has smaller total subperiosteal diameters (T), especially as measured in the lateral view, and a proportionately larger medullary cavity (M). The cortical thickness (C) is less than half that of the reference sample.

Interpretation of Skeletal Lesions

For Individual 1, the gross and radiographic features include a smooth-walled, beveled, lytic lesion in the right parietal, vertebra plana of the twelfth thoracic vertebra, multifocal lytic lesions, with minimal sclerosis of the ribs and long bones, laminated periosteal new bone formation, and otitis media. The amount of temporal destruction indicates that the child was deaf. The distribution and appearance of the lesions strongly suggest disseminated histiocytosis X (Langerhans cell histiocytosis), frequently referred to as Hand-Schuller-Christian disease when observed in children more than two years old. Involvement of the temporals, resulting in otitis media, could reflect aural histiocytoisis, cholesteatoma, or other infection (Dorfman 1989). The presence of minimal sclerosis and rapid periosteal new bone suggests that the disease process was, at the minimum, of a few months' duration. Although disseminated histiocytosis X is the preferred diagnosis, metastatic neuroblastoma, lymphoma, and osteomyelitis (pyogenic, salmonella, or spirochetal) are other possibilities in young children with multiple lytic lesions of bone.

The lesions in Individual 2 consist of otitis media in the right temporal bone, multiple resorptive lesions in the left humerus and ulna, and periosteal new bone along the left fifth rib. Erosion of the lateral cortex of the mastoid and petrous processes, combined with sclerosis of the mastoid antrum, indicates a chronic infectious process such as a cholesteatoma rather than coalescent mastoiditis (Keith, Snow, and Snow 1971). The proliferation of stratified squamous epithelium (skin) in the middle ear forms a cholesteatoma. Accumulation of the cholesteatoma gives rise to an enlarged mass capable of producing osseous erosion, labyrinthitis, facial paralysis, intracranial suppuration, and death.

Resorptive lesions in the left elbow, left fifth rib, and two vertebrae suggest a disseminated infection consistent with tuberculosis. According to Steindler (1952), the focus of tuberculosis of the elbow joint is frequently located at the upper end of the ulna, around the olecranon fossa. A focus in the articular surface of the humerus is less common, and in the radius it is the exception. Reportedly, tuberculosis of the elbow is prevalent in adults, with less than one third of 19 clinical cases (elbow tuberculosis) from early twentieth-century North America being noted in children under 15 years of age (Steindler 1952). Because of similar radiographic features, and in the absence of biopsy, chronic pyogenic osteomyelitis of the elbow must also be considered (Silverman 1985).

The periosteal rib lesion provides further evidence to suggest that the child suffered from tuberculosis rather than a nonspecific osteomyelitis. Rib lesions of the kind seen in this child strongly suggest pulmonary tuberculosis, as similar rib lesions are rarely associated with pneumonia (Kelley and Micozzi 1984). Pneumonia is more prevalent in the right lung and tuberculosis in the left lung ("Respiratory Disease Among Protohistoric and Early Historic Plains Indians," this vol.) (as is the case for Individual 2). Tuberculous otitis media has been found to occur clinically as a complication of the pulmonary infection (Pendergrass, Parsons, and Hodes 1956).

It is difficult to ascertain the sequence of infection in this child. The first question one might ask is whether the infracranial lesions were primary or secondary sites of infection. That is, which lesions occurred first, those in the left forearm, the rib, or the temporal bone? Both the mastoid disease and the lesions in the left arm represent longstanding conditions in that both sites exhibit considerable remodeling (compared with that of known duration in other dry-bone specimens). The child was able to mount an immune response to the infection for a period of at least a few months.

The rib lesion, although seemingly of more recent origin than the other skeletal lesions, might represent an early response to pulmonary tuberculosis. Periosteal lesions on the visceral surface of the uppermost ribs may be the first discernible evidence of tuberculosis ("Respiratory Disease Among Protohistoric and Early Historic Plains Indians," this vol.). The rib lesion in this child might represent an early site of
pulmonary inflammation, with involvement of the right temporal bone and left elbow following. Two observations support this hypothesis: tuberculous otitis media is more likely to be secondary to a pulmonary lesion, rather than isolated (not pulmonary) (Phelps and Lloyd 1990), and tuberculous otitis media has a tendency to cause less sclerosis than chronic mastoiditis of non-specific origin (Pendergrass, Parsons, and Hodes 1956).

**Conclusion**

The two children described in this report serve as examples of the variability and “natural” course of untreated otitis media, tuberculosis, and tumor in prehistoric and historic North America. Individual 1 probably suffered from several disorders. Histiocytosis X affected many elements in the cranial and infracranial skeleton. The otitis media resulted either from the histiocytosis X or some infectious process involving viral or bacterial agents. Whatever the cause of otitis media in this individual, the child became deaf. Periostitis present on many bones could represent another infection, although such an infection cannot be determined unambiguously from dry specimens. The presence of cribra orbitalia and porotic hyperostosis is indicative of anemia. Finally, the loss of cortical bone suggests that the child suffered from reduced food intake and immobility for a period before death.

For the contemporary Omaha, who encouraged and permitted this analysis, the examination of ancestral remains is important in tracing the origin of disease conditions still present in the tribe. This study, for example, not only documents otitis media, a problem that persists among modern Native Americans, but also demonstrates that the problem is of long standing, among both the Omaha and preceding peoples.

The finding of both otitis media and histiocytosis X in Individual 1 has implications for the reconstruction of the Omaha health care system of 200 years ago. The skeletal collections from Omaha cemeteries contain cases of both trauma-induced pathology, such as fractures and gunshot wounds, and conditions of infectious etiology, such as osteomyelitis. Although individuals who suffered trauma often survived and healed well (as shown by skeletal remains), lesions of infectious origin appear to have been active at death, as in the case of Individual 1. This finding suggests that certain infectious conditions could not be treated so effectively as trauma. Individual 1 suffered from a tumorous condition, probably complicated by bacterial infection. That the osteolytic activity in Individual 1 progressed to the extreme shows that long-term care for sick and dying individuals was available, in spite of overwhelming odds against recovery.

The pattern of osseous lesions in Individual 2 strongly suggests tuberculosis and provides evidence for comparison with other skeletons from the New World. When first examined in 1971, both the otitis media (infectious) and resorptive (tubercular) lesions in the elbow were described using radiography and gross examination. The resulting report, combining the expertise of both physician and anthropologist, did not suggest tuberculosis in the differential diagnosis, although much was known about skeletal tuberculosis at that time. Two observations are relevant to the revised interpretation presented here: (1) identification of periosteal rib lesions often associated with tuberculosis, and (2) presence of two vertebrae with severe erosion of the centra (Pott's disease) that were previously overlooked. Both findings led to reevaluation of disease possibilities. Omission of the vertebral data by the previous researchers does not reflect neglect or lack of expertise, but instead subsequent diagnostic advances developed by both the clinical and anthropological communities. Keith, Snow, and Snow (1971:125) were cognizant of the importance of a comprehensive skeletal analysis when they wrote: “For this reason, the authors have attempted to make this particular analysis as comprehensive as time and space allowed. The desirability of more complete skeletal studies is quite evident, for these studies are the bases of paleodemography which endeavors to reconstruct the population picture of prehistoric man.” Twenty years later, researchers had the opportunity to gain additional information. This example highlights the importance of long-term curation of large and diverse skeletal samples as a basis for increased understanding of morbidity and mortality among peoples of North America in the preantibiotic era.

Mark Kransdorf, Therese Bocklage, and Jeno I. Sebes provided opinions on differential diagnosis and confirmation of the diseases. Alison Galloway and Rachel Power provided background information and determined the femur mineral content of Individual 1 using the densitometer. Fran Albrecht was responsible for the radiographs. The CT scan was provided by the University of Iowa Hospitals and Clinics. Examination of the skeleton from 34CU41 was made possible by Julie Droke, Collections Manager for the Oklahoma Museum of Natural History, University of Oklahoma. The research was facilitated by the Omaha tribe.

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