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A DIFFERENTIAL DIAGNOSTICS OF THE RIGHT SHOULDER GIRDLE DEFORMITY IN THE SHANIDAR I NEANDERTHAL

ABSTRACT — This study presents a theoretical differential diagnostics of the etiology of the right shoulder girdle deformity in the Shanidar I Neanderthal specimen. The study was based on an examination of plaster cast and x — rays of Shanidar I right humerus and on the study of published literature.

The paper focuses on a comparative evaluation of the consequences of growth defects, palsies, and traumatic injuries in recent populations compared with the Shanidar I remains. More nosological units cannot be fully evaluated because of missing diagnostically important parts, especially of the axial skeleton.

The results revealed some discrete signs suggesting either a traumatic amputation or an intentional amputation in the fracture some years before the individual's death:

1. polytraumatic nature of the changes: fractures of the right humerus, of the left orbit's lateral wall and of the V. metatarsus, an injury to the frontal bone, osteomyelitis of the right clavicle;

2. partly preserved mobility of the right humerus documented by:

a) proximal diminution of atrophic alteration in separate bones of the right shoulder girdle;

b) a better preserved architecture of bone beams in the proximal right humerus;

c) differences in the cortical wall thickness of the right humeral diaphysis, very likely due to toning effects of intact muscle groups;

3. an atypical left tibia configuration as a result of the organism restructuring in its maladaptation to the altered biostatics.

To verify the amputation possibilities several practical amputation trials were performed with original stone tools and their experimental imitations.

The resulting amputation time ranged within 25—30 minutes. The results have comfirmed that the determining factors in amputation are not the tools employed but rather the grade of necessary medical practise in performing intervention or in treating injury.

The shape and surface of the bone breakage experimentally produced proves that the Shanidar I amputation could not be done by sawing, the method usual nowadays; some other mechanisms were possibly used.

A reason for the amputation could have been an ischaemisation of the right forearm after double fracture of the humerus.

KEY WORDS: Homo sapiens neanderthalensis — Shanidar I — Right shoulder girdle deformity — Differential diagnostics — Experimental amputation.

INTRODUCTION

Amputational interventions performed in prehistoric times are rare palaeopathological findings. In Palaeolithic skeletal remains this may be due to a lower number of finds , especially from earlier periods or, on the other hand, due to presumably lower level of medical knowledge needed for operative interventions.

The find of the Shanidar I Neanderthal with deformed right shoulder girdle and a missing right forearm was unexpected from the viewpoint of the supposed origins of orthopaedics, and opened broad field of speculations. In spite of the justly cautious opinion of the specialists, the missing parts of the right upper extremity indicate the possible amputation.

Comtemporary physician accustomed to operation room technology and extensive pharmaceutic background finds it difficult to accept the idea of both indicated and successful arm amputation in Middle Palaeolithic. The idea of growth deffect with similar pathological-anatomical picture seems to be more probable.

The resembling appearance and simultaneous discrepancy between the shoulder girdle deformity and the possible forearm amputation, and the resulting shoulder girdle deformity resembling a congenital defect or a juvenile trauma consequence, led us to the theoretical study of the pathological processes in the brachial region, and to an experimental verification of amputation possiblilities.

The study comprises therefore two parts. The first, theoretical one, based on the research results of specialists describing the Shanidar I osteological material with the author's own diagnostical analysis.

The second, experimental part, contains the results of amputations performed with original stone tools and with their imitations to verify the resulting appearance of bone amputation surfaces and to determine the time factor.

Summary: The presented study provides a diffential diagnostics of nosological units which in recent populations result in a picture similar to Shanidar I find, and gives the results of experimental amputations performed with stone tools

THEORETICAL PART

The circumstances of the discovery

The Solecki's Shanidar I Neanderthal, from the Shanidar cave (North-East of Iraq), dates back to the period of 46 900 + 1 500 years B.C. (Solecki, 1957 Vogel etWaterbolk, 1963;).

The find was made in the depth of 4.34 m, inside a mousterian layer.

The skeleton lay on its back, twisted partially to the right, with the head and the trunk building a non-physiological angle, which led Solecki (1960) to speculate on sudden death under a stone avalanche. The left side of the skeleton had suffered more damage than the right one; the lower extremities exhibited an evident detachment of the feet with distal part of the shank from the rest of the limb (Solecki, 1972).

The remains belonged to a 40—45 years old man, whose height was estimated on 173 cm according Trotter and Gleser's regression formula for the Euro-Americans. Typologically they were close to the classical type of H. sapiens neanderthlensis /Trinkaus, 1983/.

The osteopathological findings

Except of peri- and postmortal changes, the skeletal remains bear traces of a multiple traumatic insult with subsequent asymmetry reflecting an adaptation or maladaptation to the disturbed biomechanical statics of the posture.

A brief summary of pathological changes in craniocaudal direction gives a review of findings

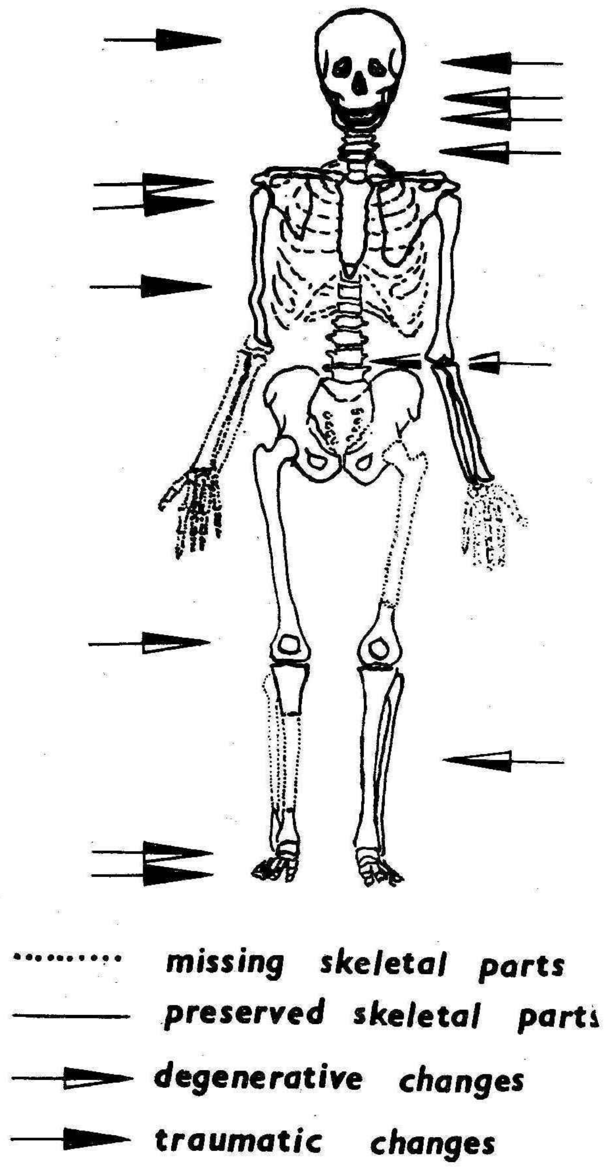


FIGURE 1. *Skeletal condition and review of pathological changes in Shanidar I.*

which form the essence of the Shanidar I's clinical picture (see *Fig. 1*). The sources used are cited in the Refferences.

The skull. In the area of the right frontal tuber there is a scar due to a blunt injury, with no signs of lamina externa fracture. The splanchnocranium exhibits a crushing fracture of the left orbit's lateral wall interferring with the frontal process of the zygomatic bone and zygomatic process of the frontal bone. The fracture was fully healed intra vitam with the remaining deformity and the narrowing of the left orbit's lateral wall.

The Shanidar I exhibits atypically worn teeth with maximal changes on the incisors, minimal inflammation changes on the alveolar bone and with no carries or apical granulomas.

The left mandibular condyle was affected by degenerative disease with outlined flattening of capitulum.

The vertebrae. Despite the fragmentary condition of the vertebrae, we can detect osteophytes on the antero-inferior edge of the C5 vertebral body and an ossification in the ligamentum intervertebrale inf. sin. of L3.

The shoulder girdle. The most pronounced pathological anomalies are found on the skeleton of the right shoulder girdle which is clearly reduced as compared to the opposite side.

A) The humerus. It is characterized by flattened head, a widened capitodiaphyseal angle and a reduced canelled diaphysis with missing condyles; the diaphysis is shortened by about 10 % compared to the left side.

The diaphysis bears marks of two fractures: a proximal fracture, localized 130 mm below the collum chirurgicum, has a 40 mm long callus with unsharply defined 33 mm long breakage line spreading from the medial side in distal and lateral direction. Evidently, the proximal fracture had healed per primam (see *x-ray 2*).

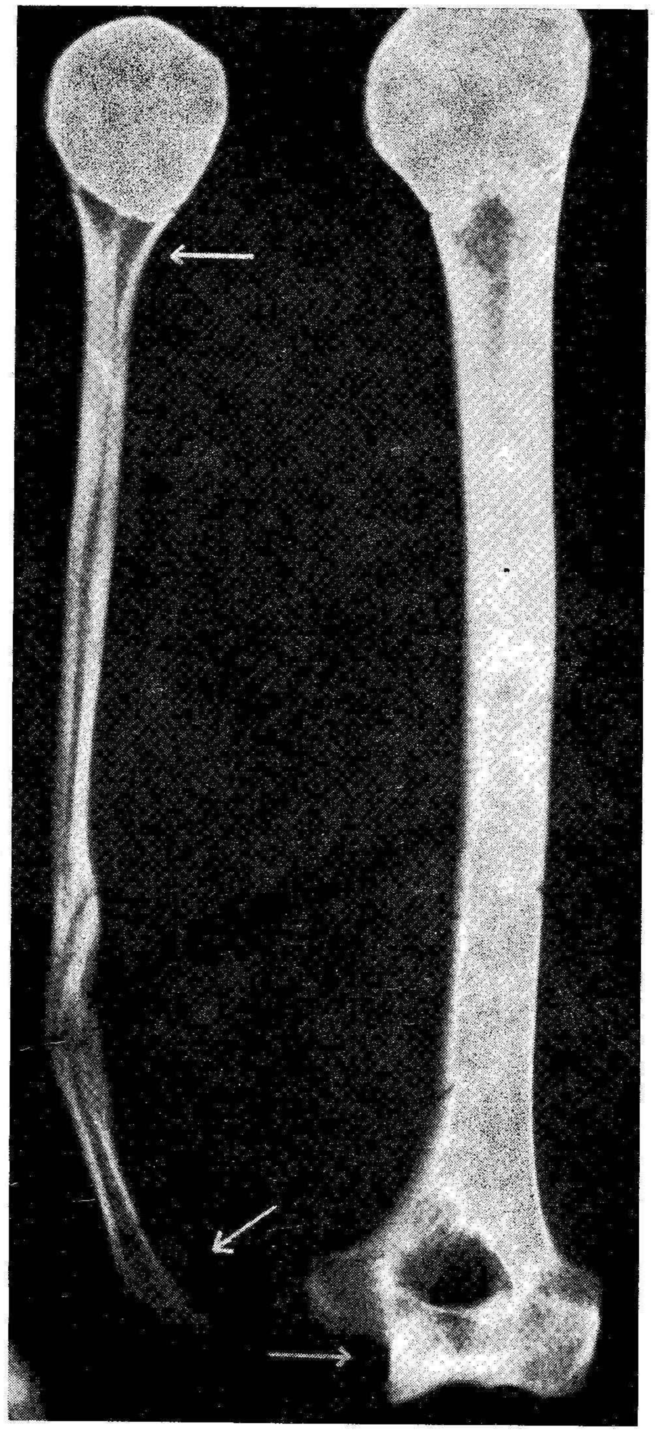
The intermediary fragment, as a section between the proximal fracture and distal one, deviates by 25—30° medially from the physiological axis and rotates round the lengthwise axis by 30° in clockwise direction.

The humerus is terminated by a distal fracture which forms a sharp point with a mild antero-dorsal flattening (author's opinion, according to plaster cast).

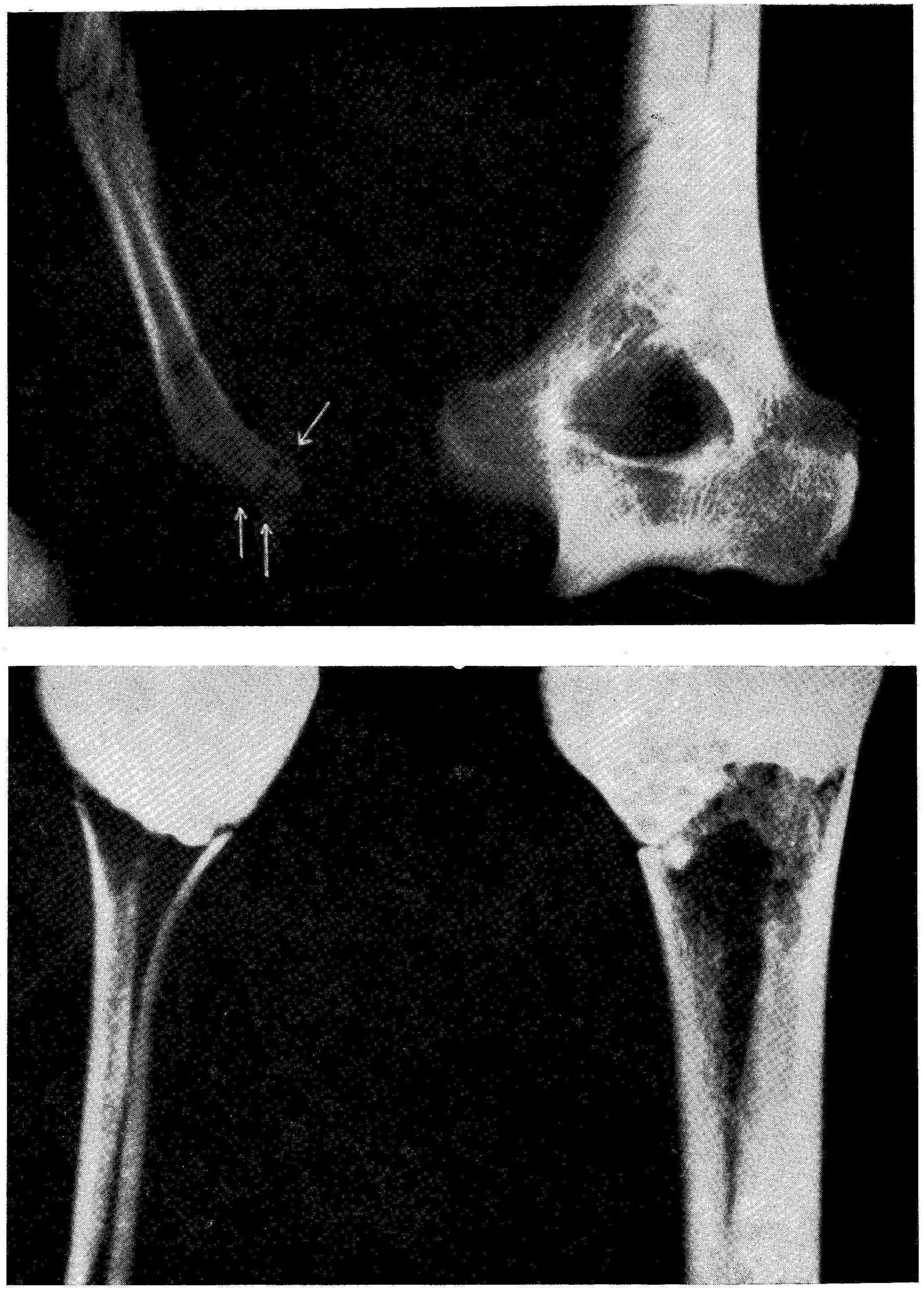
A maximal difference in contralateral quantitative parameters of bone thickness may be noted when comparing analogical distal parts of both the humeri, where the cross-section of the right one reaches only 55 % of that of the left one (*x-ray 1*). The cavities exhibit even more differences: in the proximal part, the antero-posterior as well as the medio-lateral cavity diameter of the right humerus makes only about 36 % of the left one. Relatively smaller are the disproportions in the thickness of the compact bone, where can be seen an excentric thinning with a slightly thicker postero-medial wall: *P* — 73 %, *M* — 88 %, *A* — 55 % , *L* — 40 % of the wall thickness on the contralateral limb.

B) The clavicle and scapula. Following the proximal direction the difference between the bones diminishes, and between the right and the left clavicles it makes cca 10 % . The clavicle dystrophy or hypotrophy presents a picture of a more proportional reduction of the medullary cavity diameter and of the cortical bone thickness. The quantitative indicators of the scapula reduction lie between the clavicle and humerus parameters.

The lateral clavicle around the tuberositas coracoides had been affected by an osteomyelitis which drained through an orifice on the upper surface



X — ray 1. The Shanidar I right and left humerus.



of the diaphysis medially from the tuberculum conoideum. The remission process is documented by the callus surrounding the cloaca.

The lower limbs. The right knee is affected by a degenerative joint disease manifested through exostosis on the femoral condylae and on the patella. The later, morover, is also enlarged and exhibits signs of remodelling.

The left tibial shaft is pathologically bent, with the convexity in anterior and medial direction.

The right talocrural joint and metatarsal I and II joints exhibit exostoses with an evident talar remodelling. On the right fifth metatarsus there was diagnosed a diaphyseal fracture healed ad integrum. (Solecki, 1960, 1972: Stewart, 1958, 1959, 1962, 1977: Trinkaus, 1978, 1983: Trinkaus et Zimmermann, 1979, 1982).

Physical reconstruction of the Shanidar I

The several pathological features make it possible to reconstruct a physical profile of the individual which is necessarily limited due to actual level of medical knowledge and to subjective interpretation.

This is a case of an individual which is severely handicapped by polytraumatism and degenerative alterations of the articular system.

The most severe affection was the right arm deformity, with which the man had lived long enough to develop reparation processes. The developed muscular attachments on the left upper limb bones and the pronouced trabecular architecture of the humerus (see x-ray 2B) prove a left- sided compensation of the right-sided manual insufficiency. The unusually abraded teeth support the idea of futher compensation of the defect by teeth use (Korobkov, 1963; Stewart, 1977; Wallace, 1983).

The fracture of the left orbit's lateral wall and the orbit's narrowing justify the assumption that the man should have been blind in his left eye (Trinkaus, 1983). A doubtless effect of the defective lower limb biomechanics was limping, although it is difficult to hypothesize a traumatic cause or restructuring as a result of disproportions in the global biostatics.

More evidence on the grade of the disorder would be obtained from the condition of the axial skeleton and when comparing the absolute length of extremities, but the fragmentary preservation of the vertebrae and the missing parts of the lower extremities preclude an estimation of the asymmetry extent.

The potrait of the Shanidar I individual can be completed by Trinkaus' hypothesis (1983) which, on the basis of an uncommon skull configuration, anticipates an artificial deformation.

X — ray 2. *A/Cystical clearings on the right distal humerus. B/ Partially preserved architecture of spongy bone structure in the right proximal humerus*

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The differential diagnostics

The objective finding suggests a primary importance of a correct diagnosis and differential diagnosis of the etiology of the right shoulder girdle deformity in distinguishing 1. an inborn dysplasia or dystrophy in contrast to 2. atrophy due to trauma suffered in adult or juvenile age.

If we accept the first alternative, then the healed fracture of the shoulder in an almost physiological position with a common malregeneration associated with dystrophic proccesses is an unusual find, and a considerable concern of the social community in the survival of a motorically affected individual may be assumed.

TABLE 1. *Nosological units affecting the brachial region analogically with the Shanidar I picture*

PRIMARY DEFORMITY

1. Congenital defects

A. Dysmelia of humerus and forearm (peromelia, ektromelia

B. Dysplasia of humerus or shoulder girdle
— Achondroplasia (chondrodystrophia fetalis)
— Chondrodysplasia punctata (chondroangiopathia punctata)
— Metaphyseal chondrodysplasias
— Fibrous dysplasia
— Metaphyseal dysplasia (familiar)
— Enchondromatosis (dyschondroplasia — M. Ollier)

C. Dysostoses
— Dysostosis multiplex and other polytopic diaphyseal polytopic dysostoses
— Dysostoses in mucopolysaccharidoses
— Dysostoses in neurofibromatosis

D. Ossification disorders
— Osteogenesis imperfecta

E. Congenital luxation/subluxation of art. humeri
— Scapula alata

2. Palsies

A. Congenital
— postnatal palsy of Erb-Duchenne type
— aplasia of separate muscle groups
— palsies of separate muscles — m. deltoideus
m. biceps brachii
m. triceps brachii

B. Acquired
— Poliomyelitis anterior acuta

C. Idiopathic
— Poliomyelitis anterior chronica

3. Juvenile trauma

A. Fracture

B. Amputation, traumatic amputation

C. Supporting factors

PRIMARY TRAUMA

1. Fracture and its complications

A. Dislocation of fragments

B. Inmobilization

C. Demineralization and osteoporosis

D. Disorders of innervation
of trophy — Volkman contracture

E. Algodystrophic syndrome (M. Sudeck)

F. Pseudoarthrosis

2. Amputation

As to the trauma and the loss of the intact antebrachium in adult age, the grade of dystrophic changes of the right humerus, of the scapula and clavicle seems to be too high.

An attempt to a medical analysis and a differential diagnostics may be carried out from two principal aspects:

a) progression of the anatomical-pathological picture in a primary deformity of the right shoulder girdle in juvenile age with subsequent secondary trauma;

b) progression of the anatomical-pathological picture in a trauma on an intact humerus with associated secondary complications in adult age or adolescence.

Possible nosological units are adduced in *Table 1*.

PRIMARY DEFORMITY

1. Congenital defects

They are carefully reviewed in medical literature due to uncertain pacient's prognosis and to restricted intervention possibilities. They were virtually irreversible up to the time of modern surgery. In etiologies we find chromosome and gene aberrations, toxic effects, and often idiopathic genesis, i.e. factors which in the given case cannot be detected, for which reason a morphological and rentgenological viewpoints have been preferred in the present itemization.

A. Dysmelias (peromelia, ektromelia). They represent a relevant grade of dysgenesis with a global growth disorder, and a hypoplasia of several cortical bones, deformities of the vertebrae and the lumbar joint, anomalies of cranial configuration or, as the case may be, microphthalmia (Störing, 1968).

B. Dysplasia. Severe forms are diagnosed as part of generalised affection of the organism, with growth retardation and a pronounced skeletal deformity (achondroplasia, dyschondroplasia punctata, metaphyseal chondrodysplasias and its subtypes) (Spranger et al., 1974; Weil, 1982).

In some nosological units (enchondromatosis, fibrous osteodysplasia), a lighter form of dysplasia may exceptionally proceed in a monostotic or leastways unilateral manner (Blažek, 1980; Stryhal, 1982) and is accompanied by changes in the shoulder girdle region: hypoplastic changes in articulating bones, subluxation of humeral head with resulting varus position (Weil, 1959).

The Shanidar I lacks a typical dysplasia x-ray finding of limited bone erosion with thinned compact bone and eventual sclerotic or cystic changes in the affected region (Beighton et Cremin, 1980).

C. Dysostoses. This type of congenital defect is characterized by ossification disorders in the epiphyseal and subchondral areas, hypoplasias of humeral head and lumbar joint, changes in the joints of hands and foots, a mild trunk growth retardation. The shoulder girdle is usually affected only in severe case, when there are clearly seen global changes (Cotta et Rautenberg, 1982).

Dysostoses in mucopolysacharidoses and neurofibromatoses are combined with typical severe growth disorders as in various forms of polytopic epiphyseal dysostoses. In lighter form of disostosis we find predilection of ossification disorders on epiphyses of hand and foot bones, less often of long bones, with shortening and broadening of diaphysis and a spongy bone remodelling. The affection is symmetrical (Marquardt, 1968; Spranger, 1983; Uehlinger, 1968) and this is not the case in Shanidar I.

D. Ossification disorder. The osteogenesis imperfecta (Vrolik, Lobstein) in an x-ray picture shows a typical gracile bone structure with numerous foci of defective ossification which are a source of pathological fractures. Predominating is the tendency to generalised affection (McKusick, 1966). Despite the outer appearence of bone post-traumatic deformities, the x-ray evidence diametrically differs from the Shanidar I finding.

Congenital luxation/sulbuxation of art. humeri, scapula alata

Both a congenital and a long-term post-traumatic affection of the shoulder girdle with a given effect leads to a similar picture — a malfunctioned articulation with a flattening of the humeral head with dysplastic and/or dystrophic changes of diaphysis, a varus position of humerus, unevennesses of the surface of compact bone, affection of humeral growth plates, and the development of compensation changes of the axial skeleton (Bernbeck et Dahmen, 1983; Fiddian et King, 1984).

2. Palsies

A. Congenital. A postnatal palsy of Erb-Duchenne type arises due to damage to the fibers of C5 and C6 roots in the plexus brachialis ensuing paralysis of important muscles of the shoulder girdle: m. deltoideus, m. biceps, m. coracobrachialis, m. teres maior (Kaiser, 1982). The limb hangs lamely alongside the body in the adduction position with forearm pronation and an inner rotation in the humeral joint. During an incorrected development the muscle contractures arise and the limb growth is hampered. Hypodynamics of the limb ensues insufficient deposition of minerals in the increasingly thinning compact bone. The disordered biostatics is compensated by the spine scoliosis (Hipp et Zielke, 1981). A differentiation of congenital or traumatic damage of the brachial plexus in Shanidar I case seems to be beyond possibilities of a theoretical analysis.

Muscle aplasias. Aplasias relatively often affect the shoulder region. In most cases, the right m. pectoralis lat. is absent, which is accompanied by a scapular or a clavicular hypoplasia, by changes in the shoulder girdle, flattening of the thorax, and by costal hypoplasias on the affected side (Unger, 1982).

Isolated muscles palsies. Their origin is heterogeneous, ranging from congenital defects up to post-traumatic insufficiency. The resulting picture depends on the size of the handicap and on the extent of compensatory changes through intact muscle groups (Witt et al., 1982; Hipp et Zielke, 1981).

Due to the postmortem destruction of the majority of ribs it is impossible to pronounce upon a possibility of isolated palsy or muscle aplasia in the Shanidar I.

B. Acquired. Poliomyelitis anterior acuta. Poliomyelitis is ascribed among more sporadic osteological findings that date from Neolithic to the present epoch (see Rida, 1962; Wells, 1964). As to affection of limb, the most incidence is due to monoparesis or paraparesis of lower limbs; yet there is also evidence of monoparetic damage to upper limbs (Wickman, 1913).

In the x-ray picture of recent population predominates an evolving "atrophia ex inactivitatem", demineralization, suppression of bone growth in children both lengthwise and breadthwise, due to premature closing of the growth plates (Greinacher, 1983; Currarino, 1966), and in general we see gradually evolving maladaptive deformities of the spine, ribs, shoulderblades and clavicles. Decreased bone growth is due to more factors: absence of load stimuli, frequent muscle contractures, loss of central control of trophics, and circulation disorders (Bernbeck et Dahmen, 1983). Pathological fractures are frequent.

Calcium losses and general demineralization increases in parallel with persisting limb immobility, the medullary cavity enlarges at the expense of the compact bone (Eichler, 1970; Lindholm, 1961).

The resulting thickness of bone depends on the tone of muscles and the grade of locomotor activity (Johnson, 1964). i.e. factors that are difficult to establish for Neanderthal community and can be only roughly estimated. With this regard it is interesting to compare analogous osteometric parameters and indices of the affected and healthy limbs in the Shanidar I and in an adult Japanese affected by juvenile poliomyelitis ant. ac. (Ishida et Suzuki, 1985), *table 2*.

Comparing the Shanidar I contralateral indices available in the literature (Solecki 1960, Stewart 1977, Trinkaus, Zimmermann 1982) with well documented recent case exhibiting a paralysis of the left body side shows a worse motoric stimulation in the Japanese case with the known diagnosis. The result of this simple comparison cannot be taken as absolute and considered as pathognomonic, as information, however, it has some utterance validity.

TABLE 2. *Osteometric humeral and clavicle indices in the Shanidar I and a recent Japanese individual — comparison of the affected and healthy side*

Measurement acc. to Martin		Index ratio of affected and healthy side [%]	
		Japanese	Shanidar I
clavicle	M4	62.5	95.4
	M5	90.9	82.6
	M6	68.6	87.4
humerus	M5	50.0	56.7
	M6	46.6	52.4

It may be stated that in spite of the visual resemblance of both humeri there is a difference in parameters characterizing the build and thickness of bones, and the result prove a better preserved shoulder motoric activity in the Neanderthal man.

C. Idiopathic. Poliomyelitis anterior chronica. This disorder shows a similar pathological-anatomical scheme as Heine-Medin disease. The affection starts in 25—30 years old men, with palsies affecting primary the upper limbs, hypotrophic and atrophic changes begin acrally (ape's hand) and proceed proximally (Bartko, 1982). The typical bilateral progression of affection is not conform with the unilateral stigmatization in the Shanidar I.

Juvenile trauma

A. Fracture. The progression of complications and consequences due to the fracture has received a closer description in the second part of our analysis. At this point we only remind that pathological processes, having negative influence on healing are fully manifested in younger age as well (only perhaps with the exception of the algodystrophic syndrome (Blumensaat, 1956).

Fracture healing during the period of the skeleton growth has a better prognosis due to increased regenerative capacity of the young organism; on the other side, damage to the growth plates cause growth retardation in the limbs and in younger age there may occur more expressive maladaptation changes (Tošovský et al., 1967).

B. Amputation. According to the Soviet orthopaedists Volkov and Dedova (1983), the main defect in an amputation stump (in the case of amputation in juvenile age) is its conical shape (age conicity). Amongst other particularities of later postamputation period, a slower growth of soft tissue in comparison with the bone stump is dominant and also the lower growth intensity in the amputated shoulder due to specifically lower epiphyseal growth intensity, and disproportional growth of the lower limbs must be mentioned.

The discrepancy in the biostatics becomes evident by the asymmetry of overall growth in sagittal plane and through spine scoliosis. Significant are the shoulder girdle joint articulation disorders as well as the frequent deformity of the scapulae, clavicles, or of the thorax (Vojnova, 1978).

The given changes are analogical to the palaeopathological finding and are of interest.

C. Supporting factors. The compressive syndromes (scalenus, costoclavicular ones) causing innervation and blood supply disorders, if not therapeutically influenced, may induce soft tissue atrophy, seldom in bone tissue, depending upon the extent of the lesion and duration of nutrition insufficiency of the limb (Hipp et Zielke, 1981; Bartko, 1982).

In the Shanidar case, the osteomyelitis of the right clavicle indicates a traumatic insult, and the compressive syndrome might have evolved as a direct result due to an inflammatory process. In any case, the consideration of the compressive syndrome can be real only as a supporting factor of bone atrophy during unfolding bone changes (Kaiser, 1982).

PRIMARY TRAUMA, SECONDARY ATROPHY

1. Fracture and its complications

Complicated or multiple fractures of long bones at present period are dealt with mostly by surgical treatment to prevent a deformity or a dysfunction of limb. During a therapeutically untouched fracture the healing of the limb is potentially endangered by complications, even in case of some aid. The result is doubtful without proper medication and expert knowledge. Despite the fact that reposition and fixation are not "conditio sine qua non restitutio", yet in the past the ratio of healed to complicated fractures was more unfavourable than today. The therapeutic drawback is proved by the sceptical attitude of ancient and medieval physicians toward open fracture therapy (review by Rohde et al., 1972).

A Dislocation of fragments. Dislocation belongs to the most frequent fracture complications. From the introductory description we see that in the proximal fracture there was only minimum shift by 5 mm ad latum which may be assessed as a physiological position and an intermediary fragment rotation around the long axis of the humerus by about 30° in clockwise direction. The position of the peripheral stub cannot be determined. The placing of muscle attachments on separate fragments and the vector analysis of the pulling direction of appropriate muscles permits at least an orientative understanding of the resulting status.

In the fracture, the huge m. biceps pulls the forearm cranially and posteriorly; the m. biceps, the m. brachialis and m. brachioradialis form a muscle corset enveloping the distal fracture. The sharp ends of the distal fracture and condyles endanger the neurovascular supply in the elbow.

The proximal attachment of the m. brachialis, the medial head of m. triceps and the proximal attachment of the m. brachioradialis should stabilize the proximal fracture.

B. C. Immobilization, demineralization and osteoporosis. A pain stimulus due to fracture produces in recent Mediterranean population reflexive immobilization with subsequent osteoporosis and a demineralization up to 80 % local calcium losses which in an uncomplicated course normalizes itself within a few months (Lemperg, 1957). While the demineralization process in the initial stages of the "atrophia ex inactivitatem" advances from the spongy bone towards the endosteum with subsequent cavitation (Eichler, 1970), the subperiostal resorption, which sets in during prolonged duration, causes bone diameter reduction (Meema, 1962).

D. a) Innervation disorder. Disorders of innervation lead to farther immobilization and trophic control disorder. (Rorabeck, 1980). The healing complications accompaning the innervation damage are determined by the height and character of the lesion. The more proximally the lesion localizes, the more pronounced the symptoms are manifested. Osteoporosis is more distinct in an incomplete damage of the nerve than in its complete crosscut (Rochlin et Zeitler, 1968), with reparative processes starting in extreme cases within up to 2.5 to 3 years (Heuck, 1970).

D. b) Trophic disorders. The strong a. brachialis in the supracondylar region passes from the medial arm side to the ventral wall into the fossa cubiti. In the fracture localized here the artery is endangered either directly or through compression. This results in a different degree of limb ischaemisation with a possibility of an origin of ischaemic Volkman contracture. The process starts by decomposition of muscle fibres with subsequent reparative scar wrinkling and stops by the progressing flexed position of the forearm, its pronation, claw-like fingers and the immobile limb (Kroupa, 1973; Popelka, 1982). The pronating forearm position links with mild intrarotation in the humeral joint.

The ischaemic limb shows increased senzitivity to infections, and — even now in an era of antibiotics — it presents an association of inflammation and perfusion disorder being in individual cases an indication for amputation (Burri, 1979).

E. Algodystrophic syndrome (M. Sudeck). This complication frequently occurs in a fracture. Lanšakov et al. (1982) report in selected patients up to 27 % of its incidence in humeral fractures. The leading subjective symptome is an intensive pain with subsequent reflexive immobilization of the limb (Benz, 1983). The objective evidence shows a predomination of circulation disorders with subsequent dystrophic changes in skin, muscles and bones: with maximal changes on acral parts of limbs, and a gradual proximal retreat of changes (Bircher, 1978; Rejholec, 1982; Vitjugov et Kotenko, 1980). The extent and character of the changes depends on the stage of affection.

The *x-ray* picture of the M. Sudeck's III. stage displays with marks of hypertrophic bone atrophy ("Glassknochen") with thinnish trabeculation and a clearly defined compact bone (Birzle et al., 1985; Blažek, 1980; Knobloch, 1975). Reparative processes set in late, and demineralization persists as long as 1.5 years (Heuck, 1970). The limb with atrophied muscles looks like an inborn hypotrophic one (Typovský, 1981), frequent is an affection of the joint resulting in a malfunctioned position and limited mobility (Huraj, 1981).

F. Pseudoarthrosis. The continuity and stability of the medullary vascular system is the main factor in regenerative processes and in callus formation during fracture healing (Mentzel et al., 1982). Negative factors as dislocation and insufficient immobilization of fragments are a serious obstacle to revascularization which, with respect to the known lower osteogenesis of cortical bone, lead to impeded fracture healing (Schoettle et al., 1980).

In the past, higher locomotor activity of the shoulder during acute healing stage of humeral fractures reflected in a higher incidence of pseudoarthroses. Bruns (1886) presumes that 1/3 of all humeral fractures in the last century resulted in pseudoarthroses.

A dislocation of fragments, and a vascularization disorder or an interposed muscle, induce hypotrophic, atrophic or avascular pseudoarthrosis. These synonyms all refer to a status characterized by the thinned compact bone, the distally thinning diameter of the bone and by pointed end (Beck, 1973; Bircher, 1978; Rehn et Lies, 1984). Evident articular surfaces do not form if both fragments do not come into direct contact.

2. Amputation

After an amputation the loosed forearm ceases to fulfil its tonizing function and several important muscles lose their distal attachments, the most important being the m. biceps, m. triceps brachii, the m. brachioradialis and m. brachialis. The predominance would fall to the m. coracobrachialis holding the limb in the intrarotated and adducted position together with the mm. humeri.

The loss of the attachments of the m. biceps brachii induces a gradual loosening of the humeral articulation in the glenoidal fossa and produces a malfunctional position (Bogojavlenskij, 1976).

The damaged muscle groups lose their functional importance and retract gradually, connective tissue modifications set in but, due to adaptation and the functional interplay with other muscle groups, the function does not fully disappear.

Change in the tonisation of the cortical bone becomes the most evident in the distal parts, where muscles suffer the most damage. This is confirmed radiologically by differences in the bone architecture of the distal right humerus showing chaotically arranged bone trabeculae and cystical changes in radiolucency suggesting to a decreased muscle tone and insufficient motoric stimulation as compared with the trabeculae in the proximal humerus which may also be thinned but may have an outlined correct trabeculation (see *x-rays 2*).

EXPERIMETAL PART

Several amputation experiments were performed with original stone tools and modern experimental ones. The trial embraces two parts. The aim of the preparatory phase was to determine an optimal working procedure and suitable instruments.

In this phase the first three amputations were performed on human cadavers, (experimental amputations on human cadavers were performed under grant and with active participation of Ass. Prof. Mirko Mego, M.D., CSc., Department of Forensic Medicine, Medical School of Comenius University, Bratislava, Czechoslovakia.) for other three experiments whole pork thighs were used.

Examinators (two physicians and one autopsy technician) could freely choose a working procedure and stone tools (see *Tab.* 3 for their list). The subjective evaluation was based on the agreement of all the examinators. We conclude:

1. Instruments of hard stone (flint, obsidian) were more suited to cut skin and soft tissue.
2. The original tools were considered more effective than recent ones.
3. Instruments of soft materials (lime-, sandstone) were more convenient for sawing bones.

TABLE 3. *List of instruments used in the preparatory phase of the amputation experiment*

Type of instrument	Material	Site of origin	Number	Culture
scraper	sandstone	Ivanovce (Czechoslovakia)	2	Mousterian
knife	obsidian	Mexico	1	Aztec cca 1300—1500 A. D.
blade	flint	Poland	1	Magdalenian
splinters	quartzite	Býčí skála (Czechoslovakia)	6	Magdalenian
splinters	limestone	Ivanovce	5	surface collecting

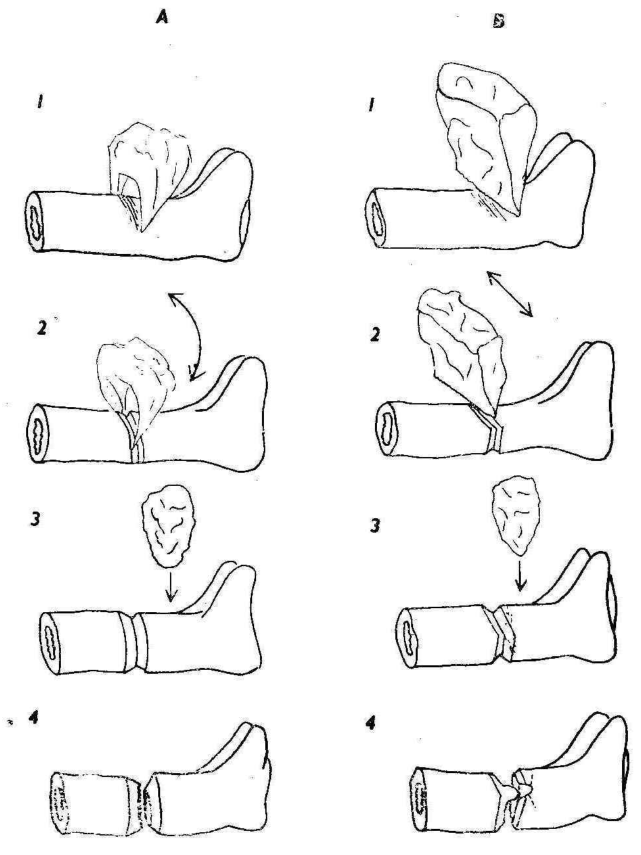


FIGURE 2. *Schematisation of two working procedures: A/ amputation by using instrument with reversed "V" cutting ridge; B/ amputation by sawing.*

4. The most suitable for efficient sawing proved to be instruments with the edge of at least 7—8 cm length, wedge-like in shape. The tools with shorter edges were too difficult to saw with.
   Another alternative was a tool of reverse "V" shape. Short semicircular movements along the bone circumference penetrated fast into the compact bone (see *Fig. 2*).
5. The empirical evidence revealed that the time-optimal mode of amputation was to incise 1,5—2 mm deep round the whole circumference and then by a light blow to detach the peripheral part of bone.
6. Cutting across the soft tissue took 3—6 minutes for untrained experimenter. Sawing fully across the bone lasted about 45—60 minutes. Procedure ascribed in item 5 almost doubled the speed of amputation.

The second part of the experiment ensued from the experiences of the preparatory one. Considering the minor labour during cutting of the soft tissue, the trial with cadavers and whole pork thighs was abandoned. Only raw pork thigh bones were used. Limestone fragments collected in a quarry served as tools, the only condition for selection being suitable working edge. The experiment was executed by only one examiner.

Results might be summed up briefly as follows:

1. The mean time to file through one bone is 20 minutes and 50 seconds. (*Table 4* shows time needed for filing through the bones, the parameters of the bone sawn, and the total number of tools used).

TABLE 4. *Characteristics of used osteological material and results*

Number of trial	Time (min.)	Circumference (mm)	AP dimension (mm)	ML dimension (mm)	Maximal thickness		Number of tools
					A — wall (mm)	M — wall (mm)	
1.	26	86	33	18	4	3.5	5
2.	19	79	28	18	3.5	2.25	3
3.	17	80	27	19	2.5	3.25	4
4.	21	77	22,5	18	4.5	3.25	4
5.	27	85	30	20	3.2	2.5	6
6.	25	80	27	18	3.5	2.5	4
7.	20	81	28	18	3.25	2.25	3
8.	18	78	25	18	3.75	2.5	4
9.	19	82	29	20	4.0	3.2	5
10.	22	84	30	19	3.5	3.75	4
11.	17	74	25	18	3.25	2.25	3
12.	20	85	32	20	4.0	3.5	5
13.	21	82	30	18	3.5	2.5	4
14.	20	81	33	21	3.75	3.0	4
15.	21	84	31	22	3.5	2.75	3

2. The proposed mode of amputation — incision and breaking off the epiphysis by blow — produced smooth breakage surfaces perpendicular to the long axis of the diaphysis. The edges of the breakage surface were finally serrated.
3. As number of amputations increased, the sawn circumference of 3.6 mm/min grew larger to 4.0 mm/min.

Discussion to the experimental part

The performed experiment was subconsciously influenced by the modern medical apprehension of considerate amputation. The differenciated choise of tools and the gradual crosscutting of the soft tissue and the bone reflects the knowledge of today's specialists and may diametrically differ from the methods used by Palaeolithic man. The obtained results are valid only with respect to this limitation.

Conclusion: The different condition of the Shanidar I right humerus substantially limits possible consideration of the sawing mechanism and intentional intervention could be explained only by different amputation procedures (hacking?) or by amputation inside fracture or pseudoarthrosis.

From the analysis of the time factor it follows that filing through soft tissues and bone in the supracondylar area of the humerus takes about half an hour. Shorter amputation time depends on the experience and choise of optimal tools, as well as on higher skill.

DISCUSSION

The palaeopathological collections only sporadically provide, materials comparable with the Shanidar I right shoulder girdle deformity, and materials proving uncontested amputation or orthopaedic interventions are also very rare.

The oldest known amputation is the intervention performed on a woman from Murzak-Koba (Crimea, UdSSR) dating back to 9 000 to 10 000 years B.C. (Bibikov, 1940). The symmetrical bilateral removal of parts of the fifth finger phalanges testifies to an artificial intervention, and the absence of secondary complications suggests a post-operational treatment (Rochlin, 1965).

Gorjanovič—Kramberger (1906) described a fragment of the right ulna from Krapina (No. 180) with pronouced shortening and atrophy. He ascribed this to the consequences of arthritis deformans. More realistic seems to accept the diagnosic of a post-traumatic pseudoarthrosis (Trinkaus, 1978).

The process of atrophy/dystrophy affected the left humerus of the La Quina 5 specimen, although to a lesser extent than in Shanidar I. The finding is v.s. of traumatic origin (Martin, 1925).

The Rüchendorf find (Nürnberg, Germany) dating back to 800—900 years B.C. documents a shoulder bone amputation. The presence of plant fibres and grain flour remaiders confirms post-operation/post-traumatic care (Grüss, 1937). The extensive suppurative changes in the scapula and the stub do not permit a comparison of the extent of bone changes with the Shanidar I case.

The skeleton of an Anglo-Saxon man from grave No. 38 in Worthy Park (Kingsworthy, Hampshire, England) dating back to 500—600 A.D. lacks the left upper limp bones, scapula and clavicle. Futher, there is a clear asymmetry of the axial skeleton with thoracal spine scoliosis, rib changes, an asymmetry of the pelvis and acetabulum and ossifications on the lig. sacroiliacum ant. dexter. The lost cranium is reported to bear marks of a healed left mandible fracture and of a cut on the left parietal bone. Wells ascribed the resultant state to an "inborn absence of limb" with the axial adaptation (Hawkes et Wells, 1976).

Grave No. 2. of an Aborigine from Roonka (Australia) dating back to the 19-th century contained the remains of a man with his left humerus amputated in the middle diaphysis. Striking was the advanced grade of atrophy and a conus-like thinning of the bone diameter into a three-canted canelled humerus end. The changes of the humerus are associated with a thinning of the left clavicle. Even if this amputation is suspected to have been done by an European, there are indications proving subsequent coexistence of the individual with the Aborigines (Prokopec, 1979; Prokopec, personal letter).

Described as a case of amputation was the distal right forearm from Sedment dated to 2 000 B.C. (Sedment, Egypt, IX. dynasty). The stub consists of the remains of the ulna and radius connected by a bone bridge (Brothwell et Møller-Christensen, 1963). The doubts about an amputation origin claimed by Stewart (1977) attest the difficulty with differential diagnosis between amputation and pseudoarthrosis.

Reasons for the intervention can be only rarely deduced from an amputation. An example offers the skeleton 78/IV from the Salvic cemetery at Mikulčice (Mikulčice, Czechoslovakia) dated to the 9-th century A.D. with an amputated right forearm and left foot just above the ankle. The nature of this amputation suggests punitive reasons (Stloukal et Vyhnánek. 1976).

ETHNOGRAPHIC OBSERVATIONS

There is generally accepted axioma that ethnographic parallels in works concerning Palaeolithic are at best debatable. Since the application of historical notes and of ethnographic observations in recent primitive peoples is doubtful for Palaeolithic populations living in different social and natural conditions and since the choise of casuistics is often subjectively determined by study purposes, we have decided not to adduce separate positive or negative references but to generalize from the accesible literature the response to following questions:

1. What were the indications for amputation in the past?
2. What instruments were used to carry them out?
3. How was the post-operational care?

A fleeting review fully confirms the mentioned doubts about possibilities of comparisons between the cultures of different historical epochs.

1. Amputation indications range widely from ritual amputations of fingers spread over the world, in the sense of punitive amputations like in North-American Seneca Indians, up to rationally indicated removal of unhealing complicated limb fractures among African Massai tribes and resection of frozen limbs in Arctic nations.
2. Choise of amputation instruments presents as well a wide variety of materials and shapes ranging from the stone tools — flint, obsidian, quarzite — over bambus knives through to metal ones.
3. Post-operational care in several nations differs strongly and comprimes clearly rational measures as injury ligature, bleed stopping, dressing, hygienic care, maintaining injury purity; also common practises directly or indirectly endangering patient's life such as laying on feaces, massive cauterization of injuries, premature mobilization ... (Ackerknecht, 1967; Fortuine, 1985; Grapow, 1956; Hamada et Rida, 1972; Hofschlaeger, 1939; Janssens, 1970; Siegel, 1973; Taubner, 1973; Terry, 1926; Wells, 1964; and others).

The current pragmatical aproach to therapy is not only a result of a long-term empirical selection of knowledge: mainly it is a consequence of evolving rational medicinal thought. The documented survival after amputation, often carried very drastically and made under septical conditions by primitive instruments, indicates that the basic problem of survival was not only the process of limb ablation itself, but mainly the question of individual resistence of the organism to operational stress and the grade of conscious prevention of possible complications.

Decisive for preserving life is basic knowledge of inevitable therapeutic and aseptic measures, i.e. factors which are impredictable for a Neanderthal community.

CONCLUSION

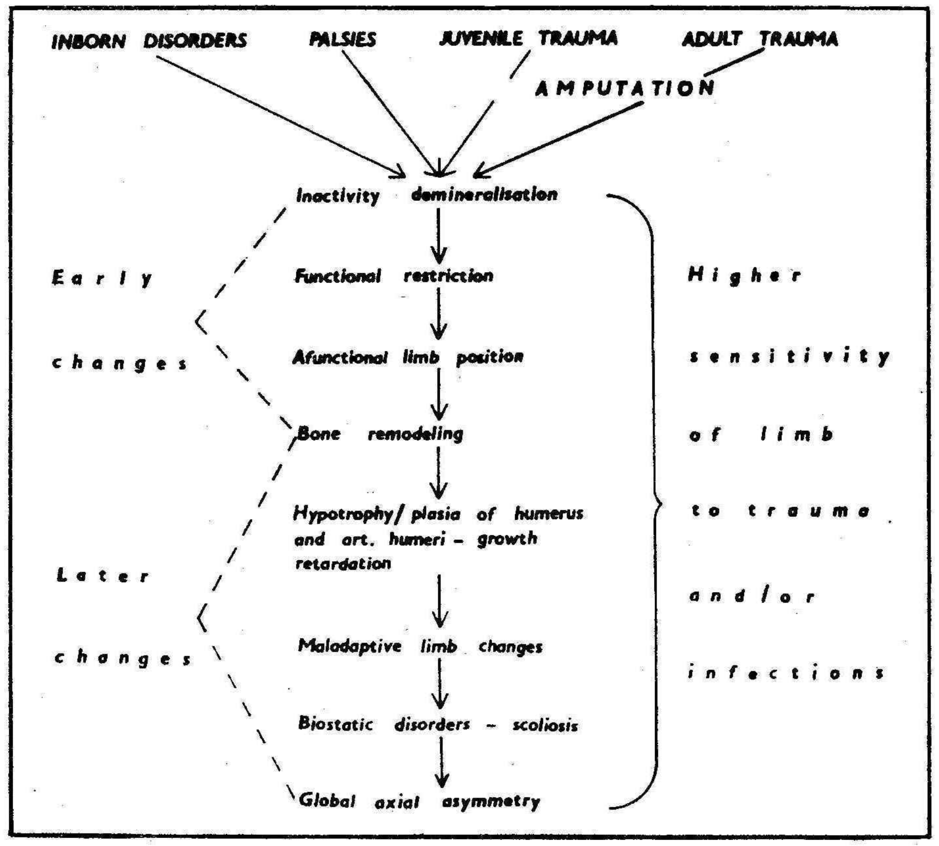
We have discussed the examples of survival following palaeopathological amputations or severe disorders of the integrity of upper limbs.

The high incidence of trauma during Palaeolithic period (see Roper, 1969) is generaly accepted by majority of scholars.

Both this realities from the viewpoint of the primarily set question about the etiology of the right shoulder girdle deformity in Shanidar I — i.e. differential diagnosis of inborn defect of trauma, support the latter variant.

Table 5 shows a generalized scheme of the organism reaction to pathological stimuli in the shoulder girdle. The Table is composed with regard to the above separate alternatives/nosological or morphological units. From here ensues the fact that every more serious disorder of limb development or trophics entails analogical effects bearing only discrete pathognomonic signs.

TABLE 5. *Scheme of unfolding changes in the organism*



A prevailing portion of congenital diseases mentioned in the review are accompanied by univocal organic changes (Ortner et Putschar, 1981).

Poliomyelitic affection is characterized by a thinned cortical bone and broadened medullary cavity which is in direct variance with the Shanidar I find as shown by Trinkaus (1983). Healing of the fracture in almost physiological position is extremely improbable without a specialist's intervention, because the muscle corset is reduced. Moreover, there is a negative coaction of an atypical muscle tone incapable to stabilize the thinned bone. Recent analogies point out a larger extent of atrophy but in the Shanidar I case we ignore the exposition time and appropriate basic level of motoric activity determining the rate of bone metabolism (Trueta, 1964).

Muscle palsies/dysplasias are difficult to diagnose because of the fragmentary condition of the axial skeleton; moreover they are contradicted/limited by partially maintained shoulder motoric activity.

The extensive polytraumatic affection points to a traumatic genesis. Attractive is the possibility of fracture complications, i.e. Sudeck's disease. The objective evidence displays some basic differences in comparison with its course in recent populations. Stage II of the disease is manifested by typical cystic radiolucency in the x-ray picture appearing months after the trauma. This is accompanied by decomposition of the fibres of the cortical bone, but the cortex is clearly manifested in Shanidar 1 (see *x-ray 2*). Atrophic changes and thinning of the compact bone (stage III) come some years later and they are not accompanied by cystic changes that otherwise occur on the right distal humerus of the Shanidar 1.

From among the presented alternatives the least contradicting one to known facts is the hypothesis of a traumatic amputation or an amputation inside the fracture. A double humerus fracture may quickly induce ischaemisation of the forearm requiring an amputation. Futher process of adaptative changes has been already proposed.

Regardless of the origin of the amputation, the healing of the right arm trauma(s) indicates an existence of some social relations allowing survival of life-threatening injury (ies), and perhaps, also suggests presence of some therapeutical knowledge.

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