

MULTISYSTEMIC TUBERCULOSIS IN A PRE-COLUMBIAN PERUVIAN MUMMY: FOUR DIAGNOSTIC LEVELS, AND A PALEOEPIDEMIOLOGICAL HYPOTHESIS

Guido P. Lombardi*, Uriel García Cáceres**

We review the case of an adult male from the Nasca culture who lived in southern Perú about 900 A.D. (Code 67466, National Museum in Lima). Four diagnostic levels support its diagnosis of pleuro-pulmonar and osseous tuberculosis: anatomo-radiological, bacteriological, molecular, and paleoepidemiological. To the present, the most definite cases of pre-Columbian tuberculosis in the Americas proceed from coastal southern Perú and northern Chile, where five out of approximately 1000 mummies studied by different authors have been clearly diagnosed with Pott's disease. Today, this disease reflects $\pm 1\%$ of all tuberculosis cases. Appropriate calculations permit us to estimate a high prevalence of tuberculosis in this area during pre-Columbian times. We postulate that tuberculosis has existed in this area since the Early Intermediate period, and had pandemic levels around 900 A.D.

Key words: Mummies, tuberculosis, DNA, paleoepidemiology

Revisamos el caso de un varón adulto de la cultura Nazca que vivió en el sur del Perú alrededor del año 900 DC (Código 67466, Museo Nacional, Lima). Cuatro niveles analíticos apoyan su diagnóstico de tuberculosis pleuro-pulmonar y ósea: anatómo-radiológico, bacteriológico, molecular y paleoepidemiológico. Hasta ahora, los casos más claros de tuberculosis en América precolombina proceden de la costa sur peruana y norte chilena, donde cinco casos de unas mil momias estudiadas por diferentes autores han sido claramente diagnosticadas con Mal de Pott. En la actualidad este mal representa $\pm 1\%$ de todos los casos de tuberculosis. Mediante cálculos adecuados, estimamos una alta prevalencia de tuberculosis en esta área para tiempos precolombinos. Postulamos que la tuberculosis ha existido en esta región desde el periodo Intermedio Temprano, y que posiblemente tuvo niveles de pandemia alrededor del año 900 DC.

Palabras claves: Momias, tuberculosis, ADN, paleoepidemiología.

Tuberculosis is one of the main infectious diseases of the world. One third of the world population today is infected with *Mycobacterium tuberculosis*, especially among the Third World countries, where 95% of the deaths caused by TB occur (Ministerio de Salud, 1997).

From a historical perspective, there is evidence of osseous TB in human remains from both the Old and New worlds since pre-contact times (Morse 1967). Nevertheless, the spread of the disease is not well understood.

There has been a historical tendency to refuse the presence of pre-Columbian TB in the New World (Lombardi 1994). Some cases of Pott's disease diagnosed in mummies by different authors since 1939 (García-Frías 1940), were interpreted by others as post-humous contamination, misdiagnoses, not chronologically accurate, or being expression from different *Mycobacteria* other than *M. tuberculosis* (Allison et al. 1973; Morse 1967; Cockburn and Cockburn 1980; Salo et al. 1994).

The debate apparently ended with the description by Salo et al. of a Chiribaya mummy with hilar lymph node lesion from which a segment of DNA

unique to the *Mycobacterium tuberculosis* (Salo et al. 1994). Nevertheless, even this case has been subject of such tendency (Stead et al. 1995). For Stead et al. it appears more likely that the Chiribaya mummy had an 'uncommon' *Mycobacterium bovis* involvement, insisting in the post-contact arrival of *M. tuberculosis*.

The objective of this paper is to reevaluate the paleoepidemiological importance of the case that, as far as we know, represents the best-documented example of prehistoric TB of the New World.

The case

An adult male mummy (National Museum, Lima. Accession code 67466) approximately 50 years old, from Nasca (Late Nasca period, ± 900 AD, culturally dated; Figure 1). It was selected for study among 54 other human mummies, because of its fair degree of preservation and the presence of a slight dorsal angulation. Subsequent analyses following a non-destructive autopsy protocol revealed pleuro-pulmonar and spinal TB (Lombardi 1992 and 1994).

* Cátedra Pedro Weiss, Universidad Peruana Cayetano Heredia, Lima. Department of Anthropology, Tulane University, 1921 Audubon St., New Orleans, LA 70118 5936, U.S.A.

** Cátedra Pedro Weiss, Universidad Peruana Cayetano Heredia, Patología SRL, Clínica Javier Prado, Lima 3, Perú.

Recibido: marzo 1999. Aceptado: diciembre 2000.



Figure 1. Mummy 67466 (Museo Nacional, Lima)

Diagnosis levels:

1. Anatomico-radiological (Depts. of Radiology and Pathology, Clínica Javier Prado, Lima; Radiological Unit, Hospital Naval, Callao): a wedged pathologic fracture of T10 (kyphotic apex) was observed, secondary to a pure osteolytic lesion inside its body. This osteolytic lesion extended downward up to T12, associated to the collapse of the intervertebral spaces, and lacking any blastic reaction (Figure 2). Radiologically too, a fistular image demonstrated the involvement of the neural duct. During the subsequent non-destructive autopsy a 12 x 1 cm pleuro-pulmonar adherence was found on the right hemithorax (Figure 3). Also, evidence of a cold abscess was seen due to the detachment of the prevertebral anterior fascia down from the T10 level. These signs fulfilled the criteria of Pott's disease. In the absence of other demonstrable lesions, the cause of death of this person could have been related to the natural history of Pott's disease.

2. Bacteriological (Dept. of Pathology, University of Kansas, KMC; Dept. of Anatomy, Georg August University, Göttingen): numerous AFB on granulomatous-like lesions were found in subsamples taken from the pleuro-pulmonar adherence (Ziehl-Neelsen, BK Auramin, transmission electron microscopy: Figure 4). Scanning electron microscopy of samples of T10 revealed soft tissue accumulations between eroded trabeculae: possibly remains of caseum (Figure 5).

3. Molecular (Department of Pathology and Laboratory Medicine of the University of Minnesota at Duluth): 120 nucleotides from the *Mycobacterium tuberculosis complex* DNA marker IS6110 were sequenced from a sub-sample of the pleuro-pulmonar lesion, using nested PCR (Figure 6).

4. Paleoepidemiological: the most definite cases of TB from the Americas come from the Andean area, specifically from Southern Perú and Northern Chilean coastal sites. From there, at least 5 well-documented and generally accepted cases of Pott's disease in mummies have been reported, including ours (see below).

The evidence presented clearly identifies this entity as multisystemic tuberculosis, with compromise of the lungs, pleura, bone, and possibly the neural system. Further molecular analyses in course would probably confirm the *human* affiliation of the strain involved, that is *Mycobacterium tuberculosis*. Nevertheless, an epidemiological exercise using current data make this last possibility the most likely.

High Prevalence

A concentration of pre-Columbian pathological cases at the Peruvian-Chilean coast would be expected as an artifact from environmental origin: natural mummies are concentrated in this arid zone, the driest place on Earth. Nevertheless, our estimated pre-Columbian TB prevalence rate for the region appears to be extremely high.

During the last decades about 1000 mummies from this region have been autopsied by different authors (a comprehensive database on them is still a major need in Andean paleopathology); among them were at least five *clear* cases of Pott's disease documented by positive AFB and/or IS6110 (Allison et al. 1973; Allison et al. 1981; Arriaza et al. 1995; Lombardi 1994; Salo et al. 1994). Even this restrictive selection represents a high proportion of cases (5-6 / 1000), high enough to fit Morse's expected frequency



Figure 2. Coronal CT Scan: osteolytic lesion involving T10-T12

lumbian populations, since most of these mummies dated from 200 to 1400 AD (Early Intermediate period to Late horizon), especially in the Peruvian area. Interestingly enough, four of these cases are from or around the year 900 AD, a fact that could reduce somewhat the fuzziness of the time frame.

Today, Pott's disease reflects approximately 1% of all TB cases, proportion that was certainly higher in the pre-antibiotic era, when the disease followed its natural history. From such information, it is possible to extrapolate a high pre-Columbian TB prevalence: if

$$p = c / n$$



Figure 3. Autopsy: pleuro-pulmonary adherence in situ

(6.7/1000) for skeletal collections (Morse 1961; Buikstra 1981). Indeed, high frequencies have been found in skeletal series, both in North and South America, but always carrying the proper limitations of bone diagnosis: they were just tuberculosis-like lesions, amidst many differential diagnoses (Buikstra and Williams 1991). That was the main reason we had in order to make this very restrictive selection.

Under the logical constraints of paleoepidemiology, it is possible to consider those 1000 mummies as a *representative sample* of local pre-Co-



Figure 4. Transmission EM: Koch bacilli

where p : prevalence (in general).

c : cases.

n : representative sample size.

If we take p to represent a TB prevalence, then p' could represent Pott's disease prevalence as a function:

$$p' = k p$$

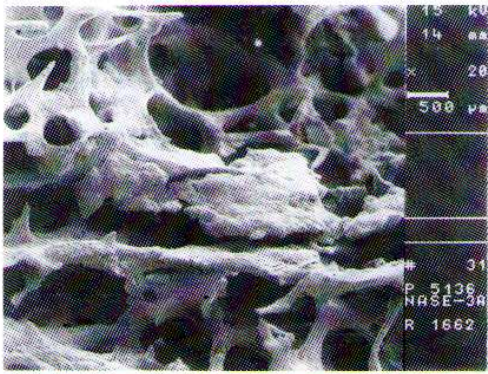


Figure 5. Surface EM: *caseum* amidst eroded trabeculae



Figure 6. Amplified IS6110 (8th column) from the mummy

where k : proportion of Pott's disease cases, today around 1%, and much probably higher in the past. Since we know $p' @ 0.5\%$ for this sample, the estimated pre-Columbian TB prevalence could be estimated as:

$$p = p' / k$$

If we assume k , being conservative, to be between 2 and 5%, the estimated pre-Columbian tuberculosis prevalence on the sample would oscillate between 10 and 25%. Although these figures appear exaggerated at first sight, they resemble contemporary TB rates of the third World. According to the Ministry of Health (Ministerio de Salud, 1997), TB has its highest prevalence levels in Lima, and the Peruvian Southern coast (1996 morbidity rates):

| | |
|----------|-----------------------------|
| Perú | 193.3 / 100.000 inhabitants |
| Ica | 272.1 / 100.000 inhabitants |
| Moquegua | 231.3 / 100.000 inhabitants |
| Tacna | 339.9 / 100.000 inhabitants |

Since morbidity, or incidence, depicts new cases diagnosed *per year*, it is clear that the prevalence (total number of cases at any particular moment) would be much higher: probably around 10% of the population (including healed cases). It has been argued that it is not appropriate to extrapolate modern rates to past populations (Arriaza et al. 1995). Our confrontation of past and modern data suggests the opposite, at least as far as Pott's disease is concerned. The skeletal / soft tissue involvement ratio disagreement, as pointed out by Arriaza et al. should be better explained by the limitations of the paleopathological record itself.

Continuity

It seems reasonable to consider that tuberculosis has been present continuously, at least, at that area since pre-Columbian times. In fact, the well-known conditions linked to modern TB epidemiology – *urban life, crowding and low standard of life* – most probably have been there continuously too. The archaeological record supports this panorama, since coastal valleys have been well populated from the Early Intermediate period onward, associated to the first permanent settlements and the practice of agriculture and camelid herding. Indeed, the concentration of Pott's disease cases around 900 AD might represent a pandemic triggered by those changes.

Different osteological collections have provided similar information, with the important addition of probable prevalence oscillations along time (Arriaza et al. 1995; Buikstra and Williams 1991), a behavior characteristic of this opportunistic disease (Jones and Bassendine 1995). The gender-biased prevalence found at the Estuquiña series could be associated to particular settlement patterns of warrior societies (i.e., *men's house*).

Hypothesis

A relatively recent and very interesting historical review of tuberculosis as a *global epidemic* by Bates and Stead traced its origin to the early 17th century European *great white plague* (Bates and Stead 1993). From our point of view, a probable pre-contact American (or Andean, as restricted as our record provides information) pandemic should be considered as historical precedent, and possible source.

It is clear that tuberculosis existed in both the New and the Old World before the 1492 contact; nevertheless, little has been advanced regarding the time when TB first arrived in the Americas (Aufderheide and Rodríguez-Martín 1998; Buikstra and Williams 1991).

Our proposition does not disagree totally with the Neolithic *Mycobacterium bovis* mutation hypothesis as the source of a better human-adapted strain: *M. tuberculosis* (Stead et al. 1995). Stead et al. accepted the presence of TB in the pre-Columbian Americas, but restricted to the bovine form, arguing that “these infections must have been uncommon.”

The acceptance of a pre-contact pandemic in the Americas would imply either that:

1. The adaptive *Mycobacterium* mutation from *M. bovis* co-occurred in the Americas, or
2. A strain of *M. tuberculosis* arrived from Asia during the population of the Americas during upper Paleolithic times.

We consider the second possibility is more likely. Adaptability and opportunistic nature are basic characteristics of TB. Currently, TB exists in the entire world, and presents different dynamics according to local conditions. Similar differences in local conditions among ancient human populations could explain the prevalence differences found or suspected among archaeological populations in the Americas.

Moreover, the existence of a different *M. tuberculosis* strain in urban sites of pre-Columbian South America could have played a role on the European epidemics – the *great white plague* – which increased its presence since 400 years ago and peaked during the Industrial Revolution (Bates and Stead, 1993; Stead et al. 1995). In this regard, we consider the possibility of a similar process to the one proposed for trepanomatoses: a *strain exchange* between the Old and the New World. As with that case, we think that the ‘American’ TB strain settled in Europe with a delay because of the population dynamics between the ‘Worlds’ at the time (not many *natives* moved to Europe). It appears evident that the high mortality rate due to tuberculosis in Europe during the 17th century resembled more the exposition to a *new* pathogen, than the sudden effect agriculture and urbanization, as it has been presented (Bates and Stead 1993). The difference in timing of these events supports an American source.

Many questions could be raised from these data, but as a general statement, the whole suggests that TB has been present in the Andean region since pre-Columbian times, with an important prevalence. Now, beyond the level of just accepting the presence of TB in the Americas prior to 1492, new questions should be addressed referring the strains involved, the microevolution of them up to now, their resistance factors (*plasmids*), and, in general, their remarkable mechanisms of endurance. The combined tools of medicine, physical anthropology, and molecular biology are summoned to solve them, both in human and animal mummies.

Meanwhile, if we see TB as a marker for ‘poverty’ – or the lifestyle features associated with the concept – we could infer that those features have been present in the coastal Andean region for centuries. This also raises the question about the true impact of modern medicine on this long-standing human companion.

Conclusions

1. Human TB has been present in the Americas since pre-Columbian times.
2. There is evidence that the Southern Peruvian coast had an important TB prevalence, at a pandemic level, around 900 AD.
3. The existence of a pandemic level TB in this region of the Americas preceded the European one, and should be regarded as a possible source of it.
4. The persistence today of a high TB incidence in the region supports the claim of continuity, in a *dynamic equilibrium* of human TB as a health problem since pre-Columbian times.
5. From a historical perspective, the problem of TB clearly shows that the impact of modern medicine alone has been insufficient to eradicate this disease.

Acknowledgments. We would like to express our deep thankfulness to the following persons and institutions that contributed during the development of our research: Dr. Hilda Vidal Vidal, at the Museo Nacional de Arqueología y Antropología, and Dr. Ladis Delpino Vda. De Soto, at Tacisa, in Lima; Drs. Arthur C. Aufderheide and Wilmar I. Salo at the Departments of Pathology and Laboratory Medicine, and Biochemistry and Molecular Biology, University of Minnesota School of Medicine, Duluth; Dr. Genaro Herrera, at the Department of Radiology, Hospital Naval, Callao; Dr. Michael Schultz, at the Department of Anatomy, George August University, Göttingen; Dr. Fernando U. García, then at the

Department of Pathology, Kansas Medical Center, Kansas (now at Hahnemann); and the staff of Patología S.R.L., at the Clínica Javier Prado in Lima.

References Cited

- Allison, M., D. Mendoza and A. Pezzia
1973 Documentation of a Case of Tuberculosis in Pre-Columbian America. *American Review of Respiratory Diseases* 107: 985-991.
- Allison, M., E., Gerszten, J. Munizaga, C. Santoro and D. Mendoza
1981 Tuberculosis in Pre-Columbian Andean Populations. In *Prehistoric Tuberculosis in the Americas*, edited by J. E. Buikstra, pp. 49-61. Northwestern University Archaeological Program, Evanston.
- Arritaza, B., W. Salo and A. Aufderheide
1995 Pre-Columbian Tuberculosis in Northern Chile: Molecular and Skeletal Evidence. *American Journal of Physical Anthropology* 98: 37-45.
- Aufderheide, A. and C. Rodríguez-Martin
1998 *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge University Press, Cambridge.
- Bates, J., and W. Stead
1993 The History of Tuberculosis as a Global Epidemic. *Medical Clinics of North America* 77(6): 1205-1217.
- Buikstra, J. (editor)
1981 *Prehistoric Tuberculosis in the Americas*. Northwestern University Archaeological Program, Evanston.
- Buikstra, J. and S. Williams
1991 Tuberculosis in the Americas: Current Perspectives. In *Human Paleopathology, Current Syntheses and Future Options*, edited by D. Ortner and A. Aufderheide. Smithsonian Institution Press, Washington, DC.
- Cockburn, Aidan and E. Cockburn
1980 *Mummies, Disease and Cultures*. Cambridge University Press, New York.
- García-Frías, J.
1940 La Tuberculosis en los Antiguos Peruanos. *Actualidad Médica Peruana* 5: 274-291.
- Jones, D., and M. Bassendine
1995 Infection, Evolution and Autoimmunity: a Hypothesis. *Quarterly Journal of Medicine* 88: 919-925.
- Lombardi, G.
1992 *Autopsia de una Momia de la Cultura Nasca: Estudio Paleopatológico*. Tesis para optar el título de médico-cirujano. Universidad Peruana Cayetano Heredia, Lima.
- Lombardi, G.
1994 *Detección de Mycobacterium Tuberculosis en una Momia Nasca con Mal de Pott*. Premio Anual de Medicina 1993, Universidad Peruana Cayetano Heredia, Lima.
- Ministerio de Salud
1997 *Tuberculosis en el Perú, Informe 1996*. Dirección del Programa de Control de Enfermedades Transmisibles. Ministerio de Salud, Lima.
- Morse, D.
1961 Prehistoric Tuberculosis in America. *American Review of Respiratory Diseases* 83: 489-504.
- Morse, D.
1967 Tuberculosis. In *Diseases in Antiquity*, edited by D. Brothwell, W. Dawson. Springfield.
- Salo, W., K.D. Eisenach, M.D. Cave, M.L. Beggs, G.L. Templeton, C.O. Thoen and J.H. Bates
1994 Identification of *Mycobacterium Tuberculosis* DNA in a Pre-Columbian Peruvian Mummy. *Proc. Natl. Acad. Sci.* 91: 2091-2094.
- Stead, W., A.C. Aufderheide, J. Buikstra and T.A. Holcomb
1995 When did *Mycobacterium Tuberculosis* Infection First Occur in the New World? *American Journal of Respiratory and Critical Care Medicine* 151: 1267-1268.