AN EXPERIMENTAL STUDY OF MUMMIFICATION PERTINENT TO THE ANTIQUITY OF CANCER

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The relatively recent description in scientific literature of many types of cancer suggests their infrequency until the relatively recent past, a view supported by the paucity of diagnoses of malignancies in ancient remains. While overall life span was short in antiquity, many individuals did live to the "cancer age," as there is ample evidence of a variety of degenerative disorders. It has been suggested that tumors are not well enough preserved for diagnosis, and tumors experimentally mummified and rehydrated were evaluated as to their preservation. It was found that cancers were actually better preserved than normal tissues. The absence of tumors in ancient tissues must be considered a reflection of a markedly lower incidence than in the modern population of the United States, in which cancer accounts for approximately 17% of all deaths. It is suggested that this increase in cancer is due to factors in the modern industrialized environment.


There are few references in the literature to the antiquity of cancer. Tumors mentioned in Egyptian medical papyri have been interpreted as neoplasms by one author, but simply as swellings or possibly varicose veins by others. The crab-like nature of malignant tumors was noted by the ancient Greeks c. 200 A.D., but the first reports in scientific literature of certain cancers have only been in the relatively recent past. These include Hodgkin's disease in 1832, multiple myeloma in 1840, cancer of the nasal passages in snuff users in 1761, and a variety of occupational tumors in the 18th, 19th, and 20th centuries. Most of these tumors have distinctive clinical and/or pathologic features, and their late description suggests infrequency of occurrence until the relatively recent past.

More evidence on this question can be obtained by direct study of ancient pathologic material. There are only a handful of reports of tumors in ancient remains. These are almost all gross diagnoses on skeletal material, as summarized by Brothwell. Only three microscopic diagnoses of tumors in mummified tissue have been reported. In Egyptian mummies, Sandison noted a small squamous papilloma of the hand, and Zimmerman diagnosed a dermatofibroma of the heel. The only malignancy reported was possible melanoma in several Peruvian mummies, although the authors did not feel that their sections were absolutely diagnostic.

Several explanations have been offered for this scarcity of tumors. As noted above, cancer may be a relatively recent disease. Another explanation offered is the early death of individuals in ancient populations. While this is correct in the overall statistical sense, there is evidence that many individuals did live to an advanced age in antiquity. Specimens have been described showing such diseases of the aged as atherosclerosis, Paget's disease of bone, and degenerative joint disease. In addition, it must be remembered that, at least in modern populations, processes such as leukemia and osteosarcoma are primarily diseases of the young.

Another explanation has been that tumors are not well enough preserved to allow diagnosis. Certainly the inherent problems of diagnosis are immensely magnified in examining ancient material. Skeletal pathology is usually reduced to nonspecific masses or defects in the bone. As most tumors do not affect bone, mummified material holds much greater promise for paleopathologic examination. However, artefacts of decomposition produce difficulties even in the recognition of normal tissues, and the diag-
nosis of malignancies is on another level of difficulty.

Artefacts due to rehydration are also a consideration. Rehydration of mummified tissues is based on the use of Ruffer's solution (water, alcohol, and sodium carbonate). While the rehydrated tissue is processed in the same fashion as fresh tissue, the artefacts of rehydration are compounded upon those of decomposition and desiccation.

As an approach to these problems, I undertook an experimental study of the effects of mummification on the histology of malignant tumors. Specimens from tumors were selected from cadavers undergoing autopsy, experimentally mummified, rehydrated, and compared with control sections prepared from adjacent fresh tumor tissue. The intention of the study was to assess the changes introduced by mummification and the ability of the modern pathologist to make the diagnosis of cancer in mummified material.

MATERIALS AND METHODS

The tumors examined were obtained from adult human cadavers undergoing postmortem examination at the Hospital of the University of Pennsylvania, all within 24 hours after death. One cubic centimeter specimens were taken from areas grossly identifiable as tumor. Primary tumors studied included large and small cell undifferentiated carcinoma of the lung, carcinoma of the breast and prostate, a carcinoid tumor of the ileum, and chronic lymphocytic leukemia involving lymph node and liver. Metastatic tumors included an ovarian carcinoma metastatic to the diaphragm, colonic adenocarcinoma metastatic to the lung, liver, and bone, carcinoid metastatic to the liver, and lung cancer metastatic to the skin, diaphragm, and bone.

The specimens were bisected and one half fixed in formalin and processed immediately. The other halves were desiccated in an Elconap oven at 40°C (104°F) for 7 to 14 days, simulating the conditions of mummification by heat used in ancient Egypt. The specimens, reduced by this process to dry, dark brown chips of tissue approximately 10% of their original weight, were rehydrated in Ruffer's solution, consisting of 50 parts water, 30 parts absolute alcohol and 20 parts 5% sodium carbonate solution. Overnight immersion provided full rehydration, and the specimens were then fixed in absolute alcohol for 24 hours and processed in the same fashion as fresh tissue. The slides were numerically coded and, to limit observer bias, were not examined until several weeks to months had elapsed. The slides of the mummified tissue were examined first and then compared with the control fresh tissue slides.

RESULTS

The lung is generally well-preserved under these conditions of mummification, and the primary lung tumors studied shared this preservation. The small hyperchromatic nuclei of the small cell carcinoma remained clearly visible (Fig. 1). The nuclei of the large cell carcinoma remained large and recognizable, but areas of the tumor were destroyed by bacterial and fungal contamination. After mummification, carcinoma of the breast and prostate both lost their glandular patterns, appearing as sheets of cells with hyperchromatic nuclei. The prostatic lesion was mucin-producing, and retained its affinity for the mucicarmine stain when mummified. A few large mitotic figures remained recognizable as well.

A carcinoid tumor metastatic to the liver was much better preserved than both the primary tumor described above and the adjacent liver. An argentaffin stain remained positive. Breast cancer metastatic to bone showed replacement of the marrow by nests of hyperchromatic cells, distinguishable from preserved areas...
of marrow by the presence in the marrow of admixed adipose tissue and by the smaller size of the marrow cells.

A number of undifferentiated tumors were preserved to variable degrees.

**Discussion**

This experimental approach produces changes similar to those observed by the author and others in the tissues of actual human mummies. Because of slower or more erratic desiccation, with more severe bacterial and fungal contamination, actual mummies are usually not as well preserved histologically, particularly in cytologic detail. However, the results presented in this paper do permit some extrapolations to actual mummies and the drawing of inferences as to the antiquity of cancer.

Malignant tumors were found to be much better preserved after mummification than normal tissues. The pattern of replacement of normal structures remains recognizable, and the cytologic features of malignancy are also preserved at times. The enlarged hyperchromatic nuclei of malignant cells are favorable to preservation by mummification, remaining visibly larger and more basophilic than adjacent normal nuclei. In a case of carcinoma of the prostate, large atypical mitotic figures were preserved as well.

Metastatic tumors were also well preserved, indeed better than the adjacent normal tissues. Tumor products such as mucin and argentaffin

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**Fig. 1.A)** Small cell undifferentiated carcinoma of lung, fresh tissue. The lung is replaced by cells with small hyperchromatic pleomorphic nuclei (H & E, ×325).

**Fig. 1.B)** Small cell undifferentiated carcinoma of lung, mummified tissue. The pattern of replacement of the lung by cells with small hyperchromatic pleomorphic nuclei is well preserved (H & E, ×325).
 pervasive. Among these papers, the one by Ruffer demonstrates the feasibility of diagnosing cancer in such ancient tissues.

In summary, while the rapid autolysis seen in the gastrointestinal tract makes it unlikely that tumors of that organ system will be diagnosed directly in mummies, the identification of metastatic tumor in liver or lung will probably supply the only inferences as to the occurrence of gastrointestinal cancer in ancient remains.

The results of this experimental study would indicate that the absence of reports of cancer in mummies is not due to any technical difficulty. Such lesions in ancient tissues should be if anything better preserved than normal tissues.

In an ancient population, lacking recourse to surgical intervention, evidence of malignancy should be present at death in essentially all
cases. Recent statistics indicate that approximately 17% of deaths recorded in the United States are attributed to cancer, and suggest that the chance of developing cancer over a lifetime is on the order of 25%.22 The virtual absence of malignancies in ancient tissues can only be interpreted as indicating their rarity or possible absence in antiquity. It has been estimated, on epidemiologic considerations, that up to 75% of human cancers are related to environmental factors.13 This study suggests that such factors are limited to modern industrialized society.

REFERENCES