



THE EFFECTS OF SURGICAL EXCLUSION OF AIR
FROM PNEUMATISED BONE

with

a preliminary study of the general and intra-
osseous vasculature of the wing of the domestic
fowl.

by

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SUMMARY.

During the past 40 years, the surgery of the pneumatic system of the human temporal bone has undergone a considerable change. Although cavitation surgery still has an important place, numerous obliterative procedures have been developed which employ muscle, fat, bone, cartilage or even foreign substances such as methyl methacrylate in order to fill the operation cavity. The local changes which these materials undergo have been widely studied, but no systematic investigation has been undertaken to determine what happens to normal developing and fully developed air cells of the mastoid type when they have been isolated from the atmosphere as a result of the performance of such obliterative procedures.

In order to investigate this problem, the pneumatised humerus of the domestic fowl, *Gallus domesticus*, was chosen for the experimental investigation. The events occurring during the pneumatisation process in this bone, and the histological features of the air space lining, are identical with those seen in the human temporal bone. In addition, because of the large size of its pneumatic system and the relatively complex trabecular arrangement, the bone was found to be more satisfactory for the purpose of the experiment than the *Bulla mastoidea* of animals such as the cat and guinea pig. Only cockerels were used. Hens were excluded from the investigation because of the peculiar physiological medullary new bone formation which occurs in laying birds. It was considered that this phenomenon, although easily recognisable histologically, might unnecessarily complicate the interpretation of the results.

A preliminary study of the arterial supply of the wing of the domestic fowl was first carried out, not only to determine the vascular anatomy in the region of the upper end of the humerus, but also to establish the origin and course of the vessels supplying the humerus with blood. The intrasosseous vascular pattern of the pneumatizing and fully pneumatized humerus was then examined and compared with that of the ulna in order to establish the modification of the vascular pattern in association with pneumatization, and to assess whether the proposed operative procedures would seriously interfere with the blood supply of the bone.

The birds were next arranged in two series on the basis of a radiological assessment of the stage of pneumatization. The first series of 24 birds showed full pneumatization, the second series of 20 birds showed partial pneumatization. In one subgroup of each series the foramen pneumaticum was blocked with a pedicled muscle graft. In the other subgroup of each series the foramen pneumaticum was blocked with methyl methacrylate. The operations were performed on the left humerus, the right being used as a control. Serial sacrifice was carried out weekly over 4 weeks, and monthly over a period varying from 5-8 months. All bones were first inspected macroscopically and then examined histologically. In addition, perfusion studies were carried out on several of the post-operative humeri in order to determine the vascular changes within the pneumatic system following surgical exclusion of air, and to confirm that the operative procedures did not seriously

interfere with the blood supply of the bones.

As a result of the operative procedures and the consequent exclusion of air from the pneumatic system of the humerus, changes were seen not only in the epithelium lining the air space, but also in the sub-epithelial tissues, the bone substance itself, and the contents and size of the pneumatic system. These changes occurred in a definite time sequence.

Pneumatisation ceased, and congestion and dilatation occurred in relation to the vessels of the subepithelial tissues. In association with this alteration in vascular dynamics, the subepithelial tissues became oedematous, and the air space became filled with a fluid transudate. The previously flat lining cells became markedly round in appearance, and underwent a foamy cytoplasmic change. They were found to be heavily laden with fat, and many of them floated off into the fluid-filled air space.

The subepithelial mesenchymal tissue then began to proliferate out into the air space, being rapidly followed by a vascular outgrowth which provided a blood vessel core for the developing tissue. In some islands within this tissue, numbers of stellate mesenchymal cells became round in appearance and underwent a foamy change due to the intracellular deposition of lipid material. In other areas, a transformation into true fat cells was seen taking place in relation to the ramifying blood vessels. Myeloid cells appeared in increasing numbers in association with this change, but the haemopoietic activity was short-lived. The

free myeloid elements soon decreased as the fatty tissue matured, and as the vascularity became reduced. The overall change appeared to represent the process of reconversion of the bone to a marrow-containing one.

Two or three months after operation, masses of cholesterol granuloma tissue were found scattered throughout the pneumatic system. The connective tissue of the granulomata contained numerous multinucleate giant cells and foam cells heavily laden with fat. No haemosiderin granules were seen, and surprisingly little collagen was present. In many sections it could be seen that the granulomata were formed as a reaction to crystals deposited in the tissues themselves following focal areas of degeneration in the mesenchyme. In other sections, there was no doubt that many of the granulomata were formed by the proliferation of strands of connective tissue ~~cut~~ into pneumatic spaces filled with cholesterol crystals and fat embedded in a protein gel.

Four types of new bone formation were also observed:-

- a. new bone was deposited on the existing trabeculae, so thickening and strengthening them,
- b. bony trabeculae and plates were laid down in an orderly fashion just beneath the lining epithelium,
- c. isolated islands of new bone appeared in the midst of the masses of vascular mesenchyme. These enlarged and fused with adjacent islands giving rise to a bizarre reticular pattern,
- d. a deposition of new bone was observed in the cholesterol

granulomata.

These progressive space-filling and obliterative changes reduced the original air space to a scattered collection of small fluid-filled spaces enclosed in a mass of newly formed tissue. The changes were correlated with the development of a negative pressure, with a rising protein level in the fluid transudate, with the accumulation of cholesterol crystals in the fluid filling the obstructed pneumatic system, and with local alterations in the intraosseous vasculature. The development of the changes was also correlated with the degree of pneumatisation at the time of operation, and with the nature of the operative method of obstruction of the pathway of ventilation of the bone.

The relevant historical and scientific background of the problem has been reviewed.

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The present work does not contain any material which has been submitted or accepted for the award of any other degree in any University.