

## SOME APPLICATIONS OF ATOMIC ENERGY TO DIAGNOSIS AND THERAPY

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Applications of atomic energy, used here synonymously with nuclear energy, for therapy began when radium was first used for treatment, since the rays emitted by radium and its disintegration products are manifestations of nuclear atomic energy. In 1932 Professor Ernest Lawrence invented the cyclotron and since then radioactive species of almost all of the elements have been generated in it. Many of the artificial radioactive species of those elements which make up our bodies disintegrate too rapidly to be useful to us in medicine. But some of them produced by bombardment in a cyclotron, and recently by fission of certain heavy atomic nuclei, last sufficiently long that they can be utilized by physicians. A few of the applications to diagnosis and therapy thus far explored are briefly summarized in the following discussion.

The extreme sensitiveness of appropriate detecting devices for the emitted rays makes it possible to measure accurately the concentrations of the elements in dilutions often as great as a billion or more times beyond former methods, and studies are thus possible with elements normally present in the body in minute amounts without disturbing existing physiological equilibria.

*Radio-Iron.*—During the war radioactive red blood cells were obtained (1) in which the hemoglobin molecules had become "tagged" with radioactive iron injected into volunteer donors. Determinations by physical methods of the time that the radioactive cells remained in the circulating blood of volunteer recipients after treating the donor blood with various adjuncts made it easy to determine the best preservative for addition to the whole blood collected on the coasts of the United States and flown to the battle fronts.

Last year a British worker (2) used such "tagged" erythrocytes to circumvent the difficulties formerly encountered in determining blood volume, and found the value to be 73.5 cc. per kilogram of body weight in normal subjects. Compensated heart cases had blood volumes in close agreement with normal, but in a case of heart failure, there was a considerable increase in both the amount of blood corpuscles and the circulating blood volume. In another case of heart failure treatment resulting in compensation was associated with a 28 per cent decrease in blood volume and an 18 per cent decrease in red blood cells.

Other investigators (3) have shown that anemic dogs absorb "tagged" iron rapidly from the gastro-intestinal tract whereas absorption is slow when the iron level is adequate. Only 0.3 per cent was absorbed in 23 hours after the last feeding in non-anemic dogs, but 59 per cent of the radioactive iron was absorbed by anemic dogs in the same time. Four per cent of the absorbed labelled iron was contained in the erythrocytes in the first case as compared with 78 per cent in the anemic dogs.

*Radio-Iodine.*—The thyroid gland normally contains about one part of iodine in a thousand whereas the blood averages less than one part in ten million. Because of this marked localization and because radio-iodine emits gamma-rays, it is easy to carry on many diagnostic and metabolic studies *in situ* merely by placing a sensitive detecting device over the gland. Hamilton and co-workers (4) found that, when 0.1 microgram of sodium iodide, the iodine of which was labelled with radio-iodine, was administered to patients with thyroid disease, the following percentages of the dose had localized in the thyroid at the end of one day:

<i>Diseases</i>	<i>Per Cent Uptake</i>
Hypothyroidism without goiter . . . . .	2.0
Normal controls . . . . .	18.5
Non-toxic goiter . . . . .	25.0
Toxic goiter . . . . .	61.5

Certain cancers of the thyroid show accumulation of radioactive iodine not only in these structures but also in metastases to the bones (5). In such cases it is a hope, when sufficient radio-iodine becomes available as a by-product of fission of uranium-235 or of plutonium, that cures may result from the radiation emitted by large doses. Similarly, large doses of radioactive iodine have been reported to be effective in treating toxic goiters by such internal radiation. The dangers of radiation of surrounding vital structures incidental with roentgen-therapy are largely avoided by this method.

*Radio-Sodium.*—Radioactive sodium produced in a cyclotron has recently been used as an aid in the diagnosis of peripheral vascular diseases (6). It was injected in such a small amount as to be of no harm, as isotonic sodium chloride, into an antecubital vein and a foot was then placed close to a tube sensitive to the gamma-rays emitted. Dependent upon the arm-to-foot circulation time, the tube was activated in twenty to fifty-five seconds in normal subjects as the radioactive sodium was carried into the foot. The radioactivity of the foot continued to increase until the concentration became more or less uniform throughout most of the body. A plot of increased radioactivity of the foot against time after injection reached a plateau in about forty minutes normally as equilibrium was reached. When the circulation to the foot was impaired, the plateau was not so high nor reached so quickly as normally.

In a patient with peripheral vascular spasm the plateau was only about one-third as high as normally. After bilateral thoracolumbar sympathectomy was performed, the plateau was far above normal. Other conditions in which the plots were of diagnostic value were arteriosclerosis; thrombo-angiitis obliterans; various vascular obstructive lesions; scleroderma; and Raynaud's disease. In some cases the new technique may furnish information concerning vascular supply which is valuable in determining the level at which amputation is necessary.

*Radio-Phosphorus.*—Because phosphorus is present in all cells and it can readily be made radioactive in a cyclotron, it has been employed far more commonly than any other artificial radio-element in biological tracer studies as well as in therapy. Usually it is converted to disodium hydrogen phosphate for administration.

Numerous investigators have sought to treat tumors with radio-phosphorus by differential localization in them, since cells in rapid mitosis utilize much phosphorus for the formation of nucleoproteins and it might therefore be expected that these cells would localize more or less selectivity much of an intravenous dose of radioactive sodium phosphate and thereby be destroyed. The fundamental principle involved here is that the destructive ionizing radiation emitted by the radioactive phosphorus will penetrate only for limited distances so that it will affect adversely only the tissues in which it is localized. Radio-phosphorus has been explored extensively in leukemias, lymphosarcoma, multiple myeloma, etc., but early hopes for effectiveness in soft tissue tumors have not been wholly realized. This is so largely because the phosphate salts in bone are relatively so insoluble that too much destruction of bone marrow results from the high localization in bone when sufficient amounts to affect such tumors adversely are administered. The extensive studies of Dean Doan and Professor Wiseman of the College of Medicine with radioactive phosphorus generated in the cyclotron of the Physics Department of The Ohio State University during the last six years have shown, as well as the work of others, that radio-phosphorus is highly efficacious in the treatment of polycythemia rubra vera and promises to supplant all former therapeutic measures in this disease. They have used it successfully in the treatment of chronic leukemias, especially myelogenous leukemia.

## REFERENCES

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