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# RADIOACTIVE YTTRIUM 90

## A review of its properties, biological behavior, and clinical uses

by

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Yttrium, element 39 in the periodic chart, stands between strontium and zirconium, and just above the rare earths. The element is named after Ytterby, a village in Sweden. Like the rare earths, yttrium forms only compounds in which its valence number is three. Its chemistry has been reviewed in a monograph by VICKERY (1960). Yttrium 90 has a half life of 64.2 hours. It decays to stable zirconium 90 by the emission of beta particles only, whose maximum energy is 2.25 million electron volts (MeV). This beta particle energy is somewhat greater than that of radioactive phosphorus ($^{32}P$) (1.72 MeV), but the radiological effects of $^{90}Y$ should not differ greatly from those of $^{32}P$, and the shorter half life of $^{90}Y$ is a clinical advantage.

Yttrium 90 is produced either by the neutron irradiation of stable yttrium, or by chemical separation from its parent isotope, strontium 90. Production from stable yttrium is rather expensive, and the specific activity of the product is necessarily limited, but this isotope may be produced carrier-free for therapeutic use by separation from $^{90}Sr$ (half life 28 years), providing essentially all the $^{90}Sr$ is removed from the $^{90}Y$.

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The separation of $^{90}Y$ from $^{90}Sr$ by repeated precipitation of yttrium hydroxide is laborious, and the handling of the $^{90}Sr$ entails serious safety problems. For these reasons $^{90}Y$ has not been widely used for therapy, even though it has certain advantages over gold 198 colloids and chromic phosphate $^{32}P$ suspensions.

Yttrium 90 in unlimited quantity can now be produced cheaply, quickly, and essentially free from strontium 90 by means of ion exchange resin columns, popularly called 'cows' (TUCKER 1960), and a rapid and simple method for the detection of minute quantities of $^{90}Sr$ contamination in $^{90}Y$ solutions is now available (DOERING, TUCKER & STANG 1960). Using these methods for the production and analysis of $^{90}Y$, the author of this paper produced large quantities of $^{90}Y$ for clinical use during the years 1959—1961.

Analyses by independent methods, of the $^{90}Sr$ content of every lot of $^{90}Y$ produced during that time, showed that the rapid analytical method for $^{90}Sr$ contamination is invariably as accurate and as sensitive as these authors report, and that an yttrium-strontium 'cow' of suitable size can be operated for several years without any hazardous rise in $^{90}Sr$ contamination of the $^{90}Y$.

The analytical method is sufficiently accurate for the detection of 0.02 microcuries of $^{90}Sr$ in the presence of 100 millicuries of $^{90}Y$, which corresponds to a ratio of one microcurie of $^{90}Sr$ in five million microcuries of $^{90}Y$.

Operation of the cow is extremely easy. The entire process of production and assay of the yttrium 90 and the analysis for strontium 90 can be carried out by a properly trained laboratory assistant in a few hours. For each 100 millicuries (mC) $^{90}Sr$ on the resin bed, almost 100 mC carrier-free $^{90}Y$ citrate can be eluted off. The $^{90}Y$ on the resin bed then grows back at an exponential rate, so that it reaches 50 mC $^{90}Y$ in about 2.7 days (64.2 hrs), 75 mC in 5.4 days, and 87.5 mC in 8.1 days (3 times the half life of yttrium 90). Since the $^{90}Sr$ parent lasts so long, the cow furnishes seemingly unending quantities of $^{90}Y$.

Although the $^{90}Y$ is eluted from the ion column in the form of carrier-free yttrium citrate, simple methods for conversion to other chemical forms can usually be developed if needed.

The availability of yttrium 90 in various chemical forms suitable for use on humans has awakened new interest in its clinical applications. The absence of gamma radiation makes for ease and safety in handling $^{90}Y$. A variety of stable solutions, chelates, or colloids of $^{90}Y$ can be produced at moderate cost, and methods for modifying the distribution of $^{90}Y$ in the body have opened up new possibilities of clinical use.

## Biological behavior of yttrium

Early interest in yttrium 90, and in some of the radioactive rare earths, centered about the use of colloids of these elements to achieve selective irradiation of bone marrow, liver, spleen and lymph nodes. GOFMAN (1949) developed methods for the preparation of these colloids, whose localization

in various organs of the mouse, rat and rabbit was studied (DOBSON, GOFMAN, JONES, KELLEY & WALKER 1949) (WALKER 1950).

Because of the difficulty of separation of $^{90}Y$ and of preparation of some of the colloids, further investigation of these was rare during the first years after the original investigations.

Nevertheless, interest in the biological behavior of many yttrium compounds continued. RAMSDEN (1961) wrote an excellent review on the tissue distribution, the mechanism of deposition in bone, and the state in the blood, of $^{90}Y$ in its various chemical forms, and a compilation of knowledge of the uptake of yttrium colloids by the reticulo-endothelial system has appeared (HALPERN, BENACERRAF & DELAFRESNAYE 1957).

The investigations of the biological behavior of yttrium have led to some useful clinical applications. In general, the clinical usefulness of yttrium 90 depends upon finding forms of yttrium which will either remain in situ if injected into a tumor or body cavity, or which will concentrate in certain organs or tissues when injected intravenously. A variety of $^{90}Y$ compounds have been found to remain in situ when injected, and considerable success has been achieved in the matter of specific tissue and organ localization.

KAWIN (1953) found in the rat that intravenously injected yttrium ion was partly excreted in the urine, combined with amino acids or proteins. An in vitro study of the interaction of yttrium compounds with serum constituents (ROSOFF, LEWIN, HART et coll. 1958) showed that yttrium chloride was bound to the albumin fraction of the serum. KYKER (1954) found that the yttrium ion at low concentrations behaved as a colloid, and that the $^{90}Y$ chloride with carrier remained almost entirely in situ when injected intrapleurally or intraperitoneally in dogs or rats.

LEWIN, HART, GREENBERG et coll. (1954) found that carrier yttrium chloride enhanced the cavitary localization of intraperitoneally injected $^{90}Y$ in mice and in humans, that 100 milligrams carrier yttrium caused essentially all the yttrium to remain in situ, and that yttrium 90 was deposited on the surface of the cavity. These results are in agreement with numerous subsequent findings by others.

Many yttrium compounds have been injected into man and into experimental animals, and their distribution within the body has been determined.

SCHEER (1956) studied the distribution in the rat of colloidal yttrium hydroxide stabilized with dextran and proposed clinical use of $^{90}Y$ in that form.

MAYER & MORTON (1956) described methods for the production of yttrium fluoride suspensions and determined their distribution in mice, rats and in the human.

SPEER, HILL & DENTON (1961) published simple methods for the preparation of stable colloids of yttrium hydroxide and yttrium phosphate, and studied the distribution of these compounds upon injection into mice and into leukemic patients.

COOK, MILES, NEAL & THOMSON (1958) compared the tissue distribution of $^{198}Au$ colloid and of various yttrium 90 compounds after intraperitoneal injection into mice. The distributions in the mouse corresponded well with that subsequently found in man. Yttrium chloride, colloidal yttrium silicate, and colloidal yttrium hydroxide stabilized with dextran were used, and they described the preparation of the silicate and hydroxide. Liver damage was reported histologically in mice when yttrium chloride was injected in amounts corresponding to as little as 0.3 milligrams yttrium. Because of the possibility of toxic effects of the yttrium ion in the human subject, they believe that yttrium colloids or other non-ionic forms of yttrium would be preferable to soluble ionic compounds, such as yttrium chloride, as carrier for $^{90}Y$ used in therapy.

Since it has been repeatedly shown that $^{90}Y$ with yttrium chloride carrier remains in the peritoneal or pleural cavity after injection, yttrium chloride may be a suitable medium for carrier. The possibility of chronic toxic effects of the yttrium ion has been one reason why many colloids or insoluble forms of yttrium have been used as carriers. Lack of toxicity and ease of preparation are two of the most important factors in the selection of a suitable yttrium carrier.

Certainly the possibility of any long term toxic effects must be considered if yttrium is used prophylactically, since the patients may survive for many years after the treatment. Judgment of the importance of the toxic effects of yttrium must be based on two general sources of information on this subject: (1) published data on the animal toxicity of various yttrium compounds, and (2) observations on the toxic effects of yttrium in the human published by persons who have been using yttrium in clinical therapy.

Although observations on the toxicity of yttrium date back to 1929 (STEIDLE & DING), quantitative data did not appear in the literature until 1956. The LD-50 found by DUBOIS (1956) for intraperitoneal yttrium chloride, nitrate, and oxide in the rat, indicate a lower toxicity for the very insoluble yttrium oxide than for the much more soluble yttrium chloride and nitrate. His results are given below:

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|---|---|
| LD-50 (yttrium chloride) ..... | 450 mg per kg = 132 mg Y/kg |
| LD-50 (yttrium nitrate) ..... | 350 mg per kg = 117 mg Y/kg |
| LD-50 (yttrium oxide) ..... | 500 mg per kg = 395 mg Y/kg |

KYKER & CRESS (1957) found, for intraperitoneal yttrium chloride, a LD-50 of 45 mg yttrium per kg in the rat, and of 88 mg per kg in the mouse. This toxicity for the rat is considerably greater than that found by DUBOIS. The LD-50 at 30 days was not significantly different from that at 10 days.

MACDONALD, NUSBAUM, ALEXANDER et coll. (1952), studying the skeletal deposition of yttrium, reported that rats injected intraperitoneally with yttrium chloride every second day with single doses of 60 mg yttrium ion per kilo body

weight, to total doses as high as 936 mg yttrium, showed no signs of either chronic or acute toxicity. Although a total of forty rats were injected, and some injections were continued for over five months, no fatalities occurred. This would indicate a very low toxicity for intraperitoneally injected yttrium chloride in the rat. The authors believed that most of the yttrium chloride was absorbed from the peritoneal cavity, but this is in disagreement with the finding that yttrium chloride in such amounts remains in the cavity where it is injected. The complete lack of reports on toxic effects of yttrium chloride appears in wide disagreement with the studies of DUBOIS, and of KYKER & CRESS, and therefore must be regarded with scepticism. SPENCER (1963) states that in approximately fifty patients who were given 100 mg intrapleural injections of yttrium chloride, she observed no toxic reactions at all.

Although opinions vary as to the advisability of using the ionic forms of yttrium in man, a number of investigators have used ionic yttrium as carrier for $^{90}Y$ in therapy, and have looked for toxic reactions in the patients. Those observations which include appreciable numbers of patients, in which the search for side reactions was especially thorough, and in which the period of observation was long, are especially valuable for evaluating the acute or chronic toxicity of yttrium in the human subject. Most of the published clinical observations on the chronic toxicity of yttrium in man are quite limited in scope, and unless the toxic effect is sudden or dramatic, it may be overlooked. This must be born in mind in evaluating published reports on the toxicity of yttrium in the human. The clinical use of yttrium compounds as carriers for $^{90}Y$ is a calculated risk, as is the use of any other new drug. The observations on toxicity reported here should be useful, but they are necessarily limited. If other clinical groups begin long term studies on the applications of yttrium in its various chemical forms, it will be most helpful if they include a careful search for chronic toxic effects.

### Modification of distribution of yttrium by chelating agents

Modification of the distribution of intravenously injected yttrium has been accomplished by chelating the yttrium with a variety of chelates. By choice of a suitable chelate and a proper ratio of yttrium to chelate concentration, high urinary excretion, or specific localization of $^{90}Y$ in bone or in stomach wall occurs. Since the chelates are non-toxic, this has opened up new therapeutic applications for yttrium 90.

Yttrium chloride $^{90}Y$ injected intravenously in man shows low urinary excretion and a high liver uptake, probably due to the fact that $^{90}Y$ combines with proteins to form high molecular weight compounds. However, if $^{90}Y$ chelated with ethylenediamine tetra-acetic acid (EDTA) is injected, it is rapidly excreted in the urine. If $^{90}Y$ nitrilotriacetic acid (NTA) chelate is injected, little $^{90}Y$ is excreted in the urine, but it is taken up by bone, liver, spleen, and kidneys (LEWIN, HART, GREENBERG et coll. 1954).

DUDLEY (1955) studied the distribution in rats and in rabbits of a number of intravenously injected $^{90}Y$ chelates, among them citrate, EDTA, NTA, N'hydroxyethylenediamine triacetic acid (ED-ol), and NN'dihydroxyethylglycine (EG-diol). DUDLEY found that when chelates of $^{90}Y$ containing excess EDTA, EG-diol or ED-ol were injected into rabbits, the $^{90}Y$ was preferentially deposited in bone. ED-ol chelate was found to give the most specific deposition in bone. When ED-ol chelate containing a minimum ratio of ED-ol to yttrium was injected, the $^{90}Y$ was markedly concentrated in the wall of the stomach. He suggested use of $^{90}Y$ chelates to irradiate bone or stomach selectively. The study of $^{90}Y$ ED-ol was extended to include distribution in dogs (DUDLEY & GREENBERG 1956), and some species difference between rabbits and dogs was reported in the specificity of deposition in the stomach wall. However, the excretion and distribution pattern of $^{90}Y$ chelates in the human has been found to be in general agreement with that reported by DUDLEY for rabbits (HART, GREENBERG, LEWIN et coll. 1955), so that $^{90}Y$ may be used for specific organ localization or for more or less uniform distribution throughout the entire body.

The extent of urinary excretion of yttrium chelates in man has been shown to be directly related to the stability constant of the chelate (KROLL, KORMAN, SIEGEL et coll. 1957). This principle led to investigation of chelates which can be used to remove yttrium and fission products from the body (ROSOFF, RITTER, SULLIVAN et coll. 1961).

## Clinical applications of yttrium 90

1. *Palliation of malignant effusions.* SIEGEL, HART, BROTHERS et coll. (1956) used $^{90}Y$ with yttrium chloride carrier for the palliation of malignant effusions.

Therapeutic effectiveness was investigated in 16 patients. The results compared favorably with those usually obtained by other methods of treatment. Of the 16 patients, favorable results were obtained in eight cases. Thirteen patients received $^{90}Y$ intrapleurally, and 3 intraperitoneally. No acute side reactions attributable to stable yttrium were observed in any of these patients, although fibrosis of the lining of the serous cavity was found at autopsy, and in several cases transient chest pain occurred after the injection of yttrium. Autopsy was performed on five patients. In four of these, thickening of the pleura in varying degree was present, and fibrous adhesions and loculation of fluid occurred in one patient. No radiation damage to the lungs, to adjacent organs, or to the bone marrow was observed. Repeated complete blood cell counts, platelet counts, and bone marrow aspirations were performed. No symptoms of radiation sickness were observed, nor did depression of the hematopoietic system occur in any of the patients. Good retention of the yttrium within the injected cavity was found in all cases. Quantitative data on the localization of the $^{90}Y$ is included in this study. The intrapleural dose varied

from 10 to 30 millicuries $^{90}Y$, and the three intraperitoneal doses were 10, 30, and 40 mC. One to two hundred milligrams yttrium chloride carrier was injected into the pleural or peritoneal cavity of each patient. In addition to these 16 patients, in whom the therapeutic value of $^{90}Y$ was investigated, 24 other patients were injected with 100 to 200 milligrams yttrium chloride containing only traces of $^{90}Y$ to study the distribution of the yttrium in the body. Although a total of 40 patients were injected with 100 to 200 mg yttrium chloride, one of the more toxic forms of yttrium, no acute toxic symptoms occurred.

WALTER, JONES & FISHER (1961) used colloidal yttrium silicate ($^{90}Y$) for the treatment of malignant effusions. Fifteen patients were treated with 30 to 40 millicuries $^{90}Y$ intrapleurally, or 50 to 75 mC intraperitoneally. Six patients died within one month but nine patients were studied for periods of from 5 to 14 months. Six of these had good palliation, good localization of the yttrium silicate was found, and no nausea or vomiting occurred. The authors believe that some form of yttrium 90 should be suitable for all intracavitary uses for which gold 198 colloids have been used.

ANDREWS, KNISLEY, PALMER & KRETCHMAR (1956), in a report on the comparative therapeutic value of the radioactive colloids of gold 198, chromic phosphate $^{32}P$, $^{90}Y$ yttrium chloride, and lutecium 177, list some helpful criteria for the selection of tumor patients in whom treatment with intraperitoneal radioactive colloids is most likely to be successful. For single intracavitary injections of yttrium 90 they used 5 to 20 millicuries $^{90}Y$ containing 50 to 250 mg yttrium chloride. They observed that the deposition of yttrium 90 on the surfaces of the injected cavities was similar to that of gold 198 colloids, that radioisotopic colloids given after laparotomy as a prophylactic measure did not interfere with normal healing, and that $^{90}Y$ with carrier yttrium chloride could be employed for intraprostatic injection in the treatment of prostatic carcinoma. They speculated from observation of a small number of cases that damage to the gastrointestinal mucosa from intraperitoneally injected $^{90}Y$ may be more prominent because of the high energy beta particles of $^{90}Y$ than that produced by the less energetic beta particles of $^{32}P$. No acute toxic effects due to yttrium were observed. Some cavitary fibrosis but no extensive adhesions attributable to the treatment were found.

2. *Prophylactic use of* $^{90}Y$. The use of intraperitoneal radioactive isotopes as a prophylactic measure to prevent the re-occurrence of peritoneal tumors following surgical removal of a tumor was suggested by WOODWARD & HARPER (1953). Cell suspensions of Walker-256-sarcoma were injected intraperitoneally into rats, which were then injected with radioactive gold ($^{198}Au$) colloid. At suitable dose levels of the $^{198}Au$, there was a very marked decrease in the number of rats in which tumor ascites developed, a possibly significant prevention of tumor implantation, and a prolongation of survival of the animals. This

concept was later extended (GOLDIE, DISHER, SMITH & DAVIS 1959) to include radioactive yttrium. Yttrium phosphate $^{90}Y$, injected into the peritoneum of mice prior to injection with Krebs-2 ascites tumor cells, caused an increased resistance of the peritoneum to invasion by the tumor cells, accumulation of ascitic fluid was decreased, and the incidence of growth of tumor implants was reduced by the $^{90}Y$.

Up to this time, no extensive clinical studies on the effectiveness of $^{90}Y$ as a prophylactic agent have been reported, although ARIEL (1962) used combinations of $^{90}Y$ and $^{32}P$ chromic phosphate for this purpose, and several reports on the prophylactic use of gold 198 colloids have appeared (MÜLLER 1959, ROSE 1961, BELLION, ROBECCHI & CAVAGNINO 1960). ROSE's investigation is a detailed 8-year-follow-up of 114 patients given $^{198}Au$ following surgical removal of ovarian carcinoma. Twenty-four patients were treated for prophylaxis of ruptured cystadenocarcinoma and twelve patients for multiple peritoneal tumor seedlings.

Results to date indicate that routine intraperitoneal use of $^{198}Au$ colloids following surgical removal of ovarian carcinoma does prolong the life of certain classes of patients, and that peritoneal tumor seedlings can be effectively destroyed by this treatment.

Yttrium 90 appears to be worthy of extensive trial for prophylactic use. It has the advantage of safety in handling, and lower cost, and the effect should be much the same as that of $^{32}P$ or $^{198}Au$.

*$^{90}Y$ pellets and threads.* Yttrium 90 in the form of tissue-soluble filaments, and in the form of yttrium pellets has found application for the irradiation of sharply circumscribed tissue areas. GREENBERG & DUDLEY (1957) described the preparation and use of methyl cellulose tissue-soluble filaments of yttrium. in rabbits, dogs and man. The filaments were implanted into various tissues or tumors. Little or no foreign body reaction occurred from the yttrium oxide remaining at the site. Radiation effects were predictable and sharply localized, no translocation of the $^{90}Y$ occurred, and tissue repair at the radiation site was always complete. Use of such filaments to treat a variety of circumscribed lesions was suggested.

NOTTER (1959) described a technique for destruction of the hypophysis by means of yttrium 90 microspheres. MOSELEY & HARPER (1961) used $^{90}Y$ yttrium oxide pellets to achieve hypophysectomy. Over 100 patients with metastatic hypophyseal neoplasms were treated. In twenty cases which came to autopsy, an average of 90 % destruction of the gland was found, and control of the tumor was considered successful in 20 % of the patients treated.

*Liver scanning and liver circulation studies.* There is considerable interest in the use of various beta or gamma emitting colloids for liver scanning and for liver circulation studies. Isotopes such as $^{32}P$ and $^{90}Y$, which emit only energetic

beta radiation, can be detected externally because of secondary gamma radiation (bremsstrahlung) produced by the beta particles.

Gold 198 colloids are used for liver scanning, and suspensions of chromic phosphate $^{32}P$ have been used for liver circulation studies (DOBSON, WARNER, FINNEY & JOHNSTON 1953), but the chromic phosphate $^{32}P$ required for this is extremely difficult and expensive to prepare. A colloid or suspension of yttrium 90 may be suitable for these applications and would have advantages over chromic phosphate suspensions although gold 198 colloids may be the best substance.

*Determination of extracellular fluid space and renal clearance.* Yttrium 90 diethylenetriamine penta-acetic acid (Y-DTPA) was used (GREENWALD, HART, ROSOFF et coll. 1960) to estimate extracellular fluid space and renal clearance in man. Seven patients were tested, and it was concluded that Y-DTPA may be used as a reproducible and simple method for estimating extracellular fluid space. The renal clearance of Y-DTPA was comparable to that of inulin.

*Papillomatosis of the urinary bladder.* EINHORN, LARSSON & RAGNHULT (1955) used $^{90}Y$ EDTA for the treatment of papillomatosis of the urinary bladder. They found that the EDTA kept the yttrium in solution, and that only negligible absorption through the normal urinary bladder occurred.

*Therapy of multiple myeloma, leukemia and polycythemia vera.* Yttrium 90 with small amounts of carrier chelated with an excess of ED-ol has now been used for the therapy of multiple myeloma (GREENBERG, SAWITSKY, WEISFUSE et coll. 1962), polycythemia vera (GREENBERG, SAWITSKY, DUDLEY et coll. 1962), and leukemia (GREENBERG, DUDLEY & SAWITSKY 1958). Of eleven multiple myeloma patients treated with intravenous doses of 0.06 to 0.3 millicuries $^{90}Y$ ED-ol per kilogram bodyweight, good initial clinical response was reported in six patients. All patients who showed complete relief of symptoms eventually relapsed. Toxic side effects were limited to a transient pancytopenia.

Nine polycythemia patients were treated. One who died of congestive heart failure ten days after therapy was not included in the study. The other eight patients were studied from 5 to 17 months after therapy. The dose of $^{90}Y$ chelate ranged from 0.10 to 0.25 mC $^{90}Y$ per kilogram bodyweight, and an excellent response, both clinical and hematological, was obtained in all cases. Side effects were limited to transient petechiosis and epistaxis.

The preliminary clinical results of the treatment of chronic leukemia by the use of $^{90}Y$ chelates appear favorable. Intravenous injections of 0.25 millicuries $^{90}Y$ per kilogram resulted in a satisfactory stabilization of the white cell count at about 5 000 per cubic millimeter within a two week period. The erythrocyte counts were not significantly lowered, and the platelet counts showed slight declines but returned to normal. No toxic reactions were observed in the patients.

## Conclusions

Radioactive yttrium 90 has a half life and a beta particle energy which make it highly desirable for therapeutic use. The history, the methods for production, and some studies of the physiology, toxicology, and clinical applications of $^{90}Y$ have been reviewed. This isotope in several chemical forms can now be produced cheaply, and in forms suitable for clinical use. A number of successful therapeutic and some diagnostic applications have been reported, but yttrium has found its widest use for the palliation of malignant pleural or peritoneal effusions. The clinical results appear to be as good as those obtained by other methods of treatment. Since $^{90}Y$ emits only beta radiation, its handling is safer and easier than that of gold 198 colloids, which have been widely used for this purpose. Very little use has been made of $^{90}Y$ solutions for the postoperative prophylactic treatment of ovarian carcinoma and of peritoneal tumor seedlings, although $^{198}Au$ colloids appear to be of definite value for this, and routine injection of intraperitoneal radioactive solutions for the postoperative prophylaxis of certain classes of cases has been advocated. Much more extensive trial of $^{90}Y$ for prophylaxis is needed, and yttrium may find its most valuable clinical use as a routine prophylactic drug.

Modification of the distribution of injected yttrium by means of chelating agents has opened up new and interesting therapeutic uses for $^{90}Y$, especially for the irradiation of the bone marrow in polycythemia, leukemia, and multiple myeloma. Although clinical trials of $^{90}Y$ for these diseases have not been extensive, the results so far appear favorable and justify more widespread application.

Yttrium has a relatively low toxicity in man, although more careful searches for possible chronic toxic effects should be included with future therapeutic trials.

## SUMMARY

The clinical uses of yttrium 90, especially therapeutic applications, are reviewed and discussed. This isotope offers certain advantages over gold 198 colloids and chromic phosphate $^{32}P$. The distribution of $^{90}Y$ within the body can be modified by means of chelating agents, a technique which has widened its potential clinical applications. The use of $^{90}Y$ as a routine prophylactic measure after surgical removal of some intraperitoneal tumors appears promising and is especially worthy of more extensive clinical trial.

## ZUSAMMENFASSUNG

Untersucht und besprochen werden die klinischen Anwendungen von Yttrium 90 und seine therapeutische Applikation. Dieses Isotop bietet gewisse Vorteile gegenüber Gold 198 Kolloiden und Chromphosphat $^{32}P$. Die Verteilung von $^{90}Y$ im Körper kann mit Hilfe von Chelaten-bildenden Stoffen modifiziert werden, und durch diese Technik haben sich seine klinischen Anwendungsmöglichkeiten erweitert. Die Verwendung von $^{90}Y$ als routinemässigem Prophylaktikum nach chirurgischer Entfernung von intraperitonealen Tumoren scheint vielversprechend und dürfte eingehender klinischer Versuche wert sein.

## RÉSUMÉ

L'auteur passe en revue les utilisations cliniques de l'yttrium 90, et en particulier ses applications thérapeutiques. Cet isotope présente certains avantages sur l'or 198 colloïdal et sur le phosphate $^{32}P$ de chrome. La distribution de $^{90}Y$ dans le corps peut être modifiée par des agents chélateurs, technique qui a élargi ses applications cliniques possibles. L'utilisation de $^{90}Y$ comme méthode prophylactique courante après exérèse chirurgicale de certaines tumeurs intrapéritonéales semble prometteuse et mérite une expérimentation clinique plus étendue.

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