

in an aspartate-free fructose medium. Since no increased lag period was observed the results suggest that these biotin analogs are utilized directly and without prior conversion to the vitamin. It was also found that

γ -(3,4-ureylenecyclohexyl) butyric acid was not a blocking agent for this organism, but instead possessed biotin activity.

Received April 27, 1951. P.S.E.B.M., 1951, v77.

Radioactive Sodium Clearance as a Test of Circulatory Efficiency of Tubed Pedicles and Flaps.* (18775)

HERBERT CONWAY, BERNARD ROSWIT, RICHARD B. STARK, AND ROSALYN YALOW.
(Introduced by A. R. Dochez.)

From the Veterans Administration Hospital, Bronx, New York.

It has been the objective of earlier studies (1-6) on the development of circulation in tubed pedicles and flaps to achieve an accurate test of efficiency of circulation and to encourage its substitution for the current practice of clinical decision as to the interval of time between operative stages in the transplantation of soft tissues. It is apparent that an accurate and dependable test, by shortening the waiting periods between operative stages, would shorten the time of hospitalization and would prevent the complication of tissue necrosis in those cases in which there is uncertainty as to the viability of the pedicle. It is of interest that the clinical problem in cases of peripheral vascular disease is not unlike that presented in the management of tubed pedicles and flaps whose circulation has been artificially contrived. In the

former, the clinician seeks to determine the degree of circulatory impairment and to measure the efficiency of the collateral circulation; in the latter, the surgeon is concerned with determination of the earliest date upon which an artificially contrived soft tissue circulation achieves the normal physiological level. Recently, Kety(7,8) showed that the

* Reviewed in the Veterans Administration and published with approval of the Chief Medical Director. Statements and conclusions published by authors are result of their study, and do not necessarily reflect the opinion or policy of the Veterans Administration.

1. Douglas, B., and Bucholz, R. R., *Ann. Surg.*, 1943, v117, 692.
2. Dingwall, J. A., and Lord, J. W., *Bull. Johns Hopkins Hosp.*, 1943, v73, 129.
3. Douglas, B., and Millikan, G. A., *Plast. and Reconstr. Surg.*, 1947, v2, 348.
4. Hynes, W., *Brit. J. Plast. Surg.*, 1948, v1, 159.
5. Conway, H., Stark, R. B., and Docktor, J. P., *Plast. and Reconstr. Surg.*, 1949, v4, 133.
6. Conway, H., Stark, R. B., and Joslin, D., *Surg., Gynec. and Obst.* in press.

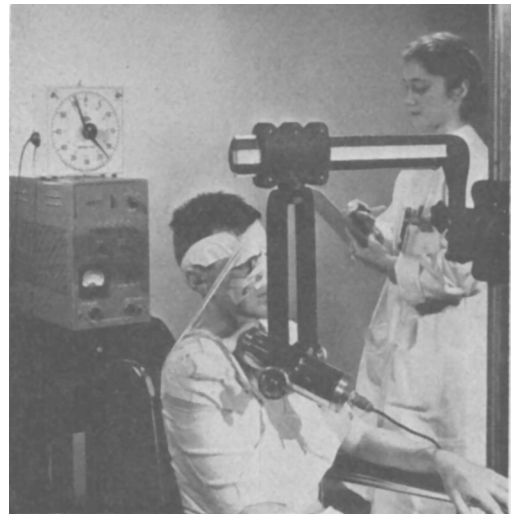


FIG. 1. Mica window of Geiger-Mueller counter placed over end of thoracoacromial pedicle to be transplanted for reconstruction of the nose, upper lip, and chin. Efficiency of circulation of tubed pedicle is determined by comparing clearance of radioactive sodium injected intradermally with that of control area. Relative clearance is determined by comparing half-life of radiosodium in the two areas. If clearance is as rapid from the end of pedicle to be transplanted as it is from the control area, the pedicle should withstand surgical transplantation successfully.

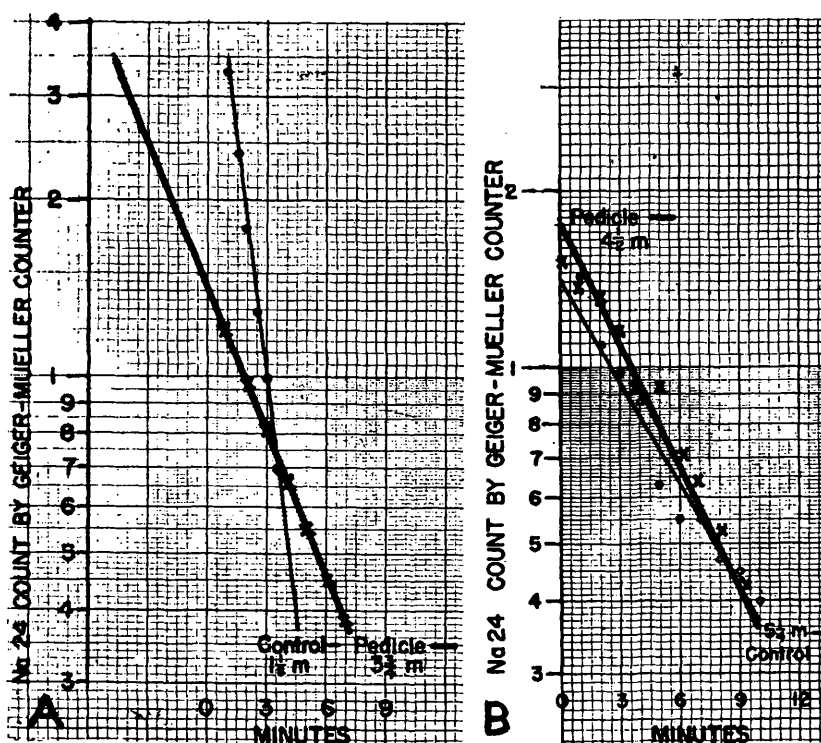


Fig. 2. Clearance of radiosodium from tissue of a pedicle is determined as the net counting rate after subtraction of background rate has been made. This is plotted as a function of time on semi-logarithmic paper. The half-life for resorption, or the time taken for net activity of radiosodium to be reduced to $\frac{1}{2}$ of its original value, is compared with that of control area. In (a) the clearance of radiosodium in control area is more rapid. Circulation in this control area of normal skin is assumed to be superior to that in the pedicle. However, in (b) the reverse is true, the clearance of radiosodium as determined by its half-life, being more rapid in the pedicle than in control. The pedicle was transplanted successfully one day following this test.

rate of disappearance of radioactive sodium (Na^{24}) from muscle tissue offers a superior type of assay of the status of the regional circulation in extremities. This observation was supported by the studies of Elkin, *et al.* (9) and of Stone and Miller (10) who showed that lymphatic drainage does not play a significant role in the intramuscular clearance of Na^{24} and that the radioactive material does not diffuse along intramuscular planes.

It occurred to us that a radiosodium clear-

ance technique might well be adapted to problems of circulation in pedicles of skin and subcutaneous tissues. It is the objective of this presentation to record observations on the clearance of radiosodium as a test of circulatory efficiency in tubed pedicles and flaps as they have been employed in plastic surgical reconstructions.

Technique. An injection of 0.05 cc of isotonic saline solution containing 0.1 to 0.5 microcuries of radioactive sodium (Na^{24}) is made intradermally at a point near the end of the pedicle which is to be transplanted. A similar injection is made as a control in the skin of the same region on the opposite side of the body. Patients are tested under approximately standard conditions of room temperature, test areas and time of day. Na^{24} has a physical half life of 14.7 hours decaying

7. Kety, S. S., *Am. Heart J.*, 1949, v38, 321.
8. Kety, S. S., *Am. J. Med. Sciences*, 1948, v215, 352.
9. Elkin, D. C., Cooper, F. W., Jr., Rohrer, R. H., Miller, W. B., Jr., Shea, P. C., Jr., and Dennis, E. W., *Surg., Gynec. and Obst.*, 1948, v87, 1.
10. Stone, P. W. and Miller, W. B., Jr., *Proc. Soc. Exp. Biol. and Med.*, 1949, v71, 529.

TABLE I. Radioactive Sodium Wheal.

Case	Type pedicle	Location	Defect	Length /width ratio	After con- struction, days	Min. required for half of initial dose of Na ²⁴ to be resorbed	Interpretation	Progress of case
1	Tubed P*	thoraco- acromial, right	symphysis mentis, chin	3:1	79	P control 7 3.75	2nd move made 5 days after ¾ severance	33 days after transplantation of tubed P to chin. 2 days following ¾ sever- ance of tubed P and 5 days before second end of tubed P transplanted to chin.
2	Open P	temporal, left	loss of eye, cheek, and half of nose	2:1	3	P control 3.5 1.5	test indicated directly P could not be moved	1 day later P elevated, cyanotic, re- turned to its bed.
3	Tubed P	thoraco- acromial, right	nose, palate	3:1	48	P control 1.75	correct prog- nosis by test	P successfully transplanted 1 day later.
4	Tubed P with open P pancake	thoraco- acromial, left	left nasal, malar, up- per lip	3:1	12	P control 4.5 4.75	P probably would have withstood transplantation at 9 days; cor- rect prognosis by test	tubed P completely detached success- fully.
5	Open P	temporal, right	right orbit, malar nasal	2:1	15	P control 2.25 1.5	test indicated base could be elevated	pancake doubly grafted with split- thickness skin graft, to under sur- face.
6	Open P	cross leg flap	FCC left tibia, fistula	1:1	19	P control 7 6	correct prog- nosis by test	transplanted successfully 3 days after test.
7	Open P	cross thigh, left	right distal leg	2:1	10	P control 6.5 6.5	correct prog- nosis by test	second end transplanted successfully 1 day later.
8	Tubed P	thoraco- acromial, right	right cheek	3:1	5	P control 5	transplanted successfully 9 days after test.	transplanted successfully 1 day after test.
								successfully transplanted 1 day after test.
								P transplanted successfully 2 days later.
								P transplanted successfully 1 day later.

* P = Pedicle.

by the emission of high energy gamma rays and beta particles, the maximum range of which in tissue is about 6 mm. A Geiger counter with thin mica window is placed in a fixed position over the site of intradermal injection. The counting rate is measured as a function of time. Since the injection is superficial, the counter will detect the radiation of beta particles and, with lesser efficiency, the gamma rays from the injected radioiodium, thus making it possible to use less than a tenth of the dose employed by Kety(7,8). Some of the radioiodium may be deposited accidentally on the skin and hence will not be cleared. This will give a background counting rate after the resorption of Na²⁴ is complete. The net counting rate is plotted as a function of time on semi-logarithmic paper. Within the limits of experimental error, the plotted points lie along a straight line. From the graph is determined the half-life for resorption, which is the time taken for the net activity to be reduced to one half its original value.

Results. It has been found from the study of nine pedicled flaps in eight patients that, if the rate of disappearance of radioiodium from the tubed pedicle is approximately equal to or more rapid than that of the control area, division and migration of the pedicle can be carried out successfully. In the study of one tubed pedicle, the time required for resorption of the dose of radioiodium to its half-life was more than twice that of the control area. In this case, in an attempt to establish the validity of the test, the pedicle was divided by incision. The degree of cyanosis which developed after division of the pedicle was such that its transplantation, a step which adds further burden to a feeble circulation, could not have been done with good surgical judgment at that time. The rotation and transplantation of a pedicle which shows gross signs of circulatory inadequacy is an invitation for the development of necrosis of the

flaps, a complication which defeats the purpose of the reconstructive operation. In this particular case, the cyanotic pedicle was returned to its former bed to await the development of sufficient collateral circulation. A refinement of those circulation tests which depend upon the measure of the rate of resorption of an injection is brought out by the employment of a tourniquet at that end of the pedicle which is to be transplanted. For tubed pedicles a rubber catheter serves as a tourniquet. For broad-based flaps, one or two rubber-shod gastric clamps may be used. In experiences with the saline wheal test, the fluorescein test, the atropine test and the histamine wheal test this technique has been found to provide more complete information since the resorption of the drug depends upon a contrived circulation the afferent and efferent pathways of which must travel the entire length of the pedicle. However, a tourniqueted pedicle clears radioiodium so slowly that the use of this modification of the test is not practical.

In comparing the radioiodium test for the evaluation of circulatory efficiency with other tests such as the saline wheal test, visualization by fluorescein dye and the histamine wheal test, the authors feel that the end point of the radioiodium clearance test is the most accurate of all. It is recorded accurately and by objective measures in a relatively short period of time.

Summary and conclusions. The rate of clearance of an intradermal wheal of radioactive sodium (Na²⁴) has been successfully employed in eight patients as a clinical test for the evaluation of the circulation in tubed pedicles and flaps. The experiences recorded indicate that the radioactive sodium clearance test, because of its simplicity and accuracy, has a wide field of application in the study of problems in the transplantation of soft tissues.

Received May 4, 1951. P.S.E.B.M., 1951, v77.