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THE TREATMENT OF ACID AND ALKALI BURNS

AN EXPERIMENTAL STUDY

BY EDWARD C. DAVIDSON, M.D.

OF DETROIT, MICH.

FROM THE SURGICAL RESEARCH LABORATORY OF THE HENRY FORD HOSPITAL

ALTHOUGH acid and alkali burns of the skin are of frequent occurrence, the treatment of such lesions has not received the critical attention which it merits. A few special types of chemical burns of the eyes have been investigated, but in this situation the caustic is acting under quite different conditions than upon skin. Unlike the eye, skin is protected by a resistant horny layer of cells whose vulnerability is further lessened by its normal oily secretion. A chemical burn may occur only after this protective mechanism has been penetrated either by a strong caustic or by prolonged contact with a less concentrated one.

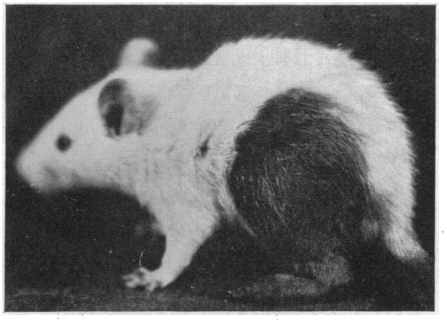

FIG. 1.—Showing rat 24 hours after exposure for 15 seconds to 70–71 per cent. nitric acid which was treated by washing with water. The control animals and the rats treated by neutralization succumbed in less than 14 hours.

Acids and alkalies produce changes in the tissues which are similar to those caused by heat, but the problem of management is an entirely different one. Heat burns are more or less self-limited in depth because tissue is a poor conductor of heat and any hot material which may splash on skin soon chills. Such a lesion is then in condition to proceed with the normal reparative processes. In acid and alkali burns the destructive action of the caustic may be progressive because any considerable excess of either H or OH ions is incompatible with cell life.[1] The problem of management of such lesions is then primarily one of disposing of the irritant which is still present so that the process of healing may begin.

The principle of neutralization has been the basis of treatment of such burns. Acetic acid has generally been the agent used in alkali burns and sodium bicarbonate in acid burns. Smith[2] and Holland,[3] however, have advocated the use of water as a first-aid treatment and secondary neutralization. This difference of opinion from generally accepted practice was not supported by any observations of burns treated by the two methods under controlled conditions. Because of the fundamental importance of the disposition of the acid or alkali, it seemed desirable to determine the efficacy

of neutralization in contradistinction to simple dilution in experimentally produced burns of this origin.

Classification.—The degrees of cutaneous irritation seen in acid and alkali burns are identical to the changes produced by heat burns of increasing severity. A first degree burn is shown by an arterial and capillary hyperæmia. The dilatation at first involves the superficial vessels, but later progressively involves the deeper subcutaneous tissue partly directly and partly by reflexes. This congestion is accompanied by itching, burning and pain. When the irritant sets up such a vigorous inflammatory reaction that exudate is formed more rapidly than it can be carried away by the lymphatics, vesicles or blebs form, which characterize a second degree burn. Sollman [4] states that this accumulation of fluid takes place between the upper and lower layers of the rete Malpighii. The remaining layers of the rete Malpighii have but little resistance to infection and in this way there may be actual loss of tissue substance. If the corrosive agent continues its action beyond this stage actual cauterization of the tissue or a third degree burn results. This type of lesion is caused by strong acids and alkalies. Such burns show three fairly well-defined areas; first, there is inflammation and hyperæmia at the depth and periphery of the lesion, next a layer of necrotic tissue, and finally a layer in which solution of the individual cells has taken place.

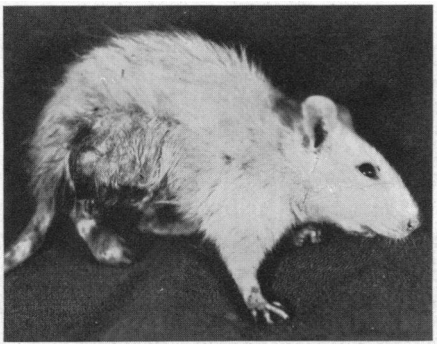

FIG. 2.—Showing rat 24 hours after exposure for 15 seconds to 96 per cent. sulphuric acid, which was treated by neutralization with sodium bicarbonate. (Compare with Fig. 3.)

FIG. 3.—Showing rat 24 hours after exposure for 15 seconds to 96 per cent. sulphuric acid, which was treated by vigorous washing with water. (Compare with Fig. 2.)

Method.—Rats were used in all experiments which were done in triplicate. The animals were anæsthetized with ether and a hind leg was immersed for a given period in the test solution, which was at room temperature. Three groups of animals were kept under observation for each concentration of acid or alkali tested. In one group the excess of the caustic was carefully wiped away with cotton and these were considered the controls. The irritant was neutralized in the rats of the second group with five per cent. sodium bicarbonate for the acid burns and one per cent. acetic acid for the alkali burns. The rats in the third group were treated by vigorous washing with water. This was accomplished either by holding the affected part under a running tap or by

placing the animal in a large tank of water. The animals were then placed in separate cages and nothing further was done to alter the course of the tissue reaction to the caustic. If death did not occur promptly in those rats which showed extensive sloughing the animal was sacrificed.

The latent period of sensory stimulation of various concentrations of the same acids and alkalies were determined in three individuals by applying a drop of the caustic upon the inner surface of the forearm. All observations were done in duplicate and the reaction time was measured with a stop watch.

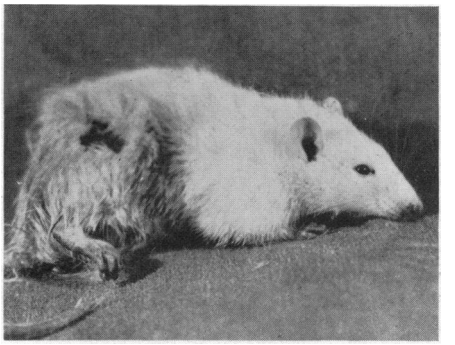

FIG. 4.—Showing rat 24 hours after a six minute contact with 37 per cent. hydrochloric acid. Control animal in which the excess was carefully wiped away. (Compare with Figs. 5 and 6.)

Acid Burns.—The action of concentrated acids [4] consists of withdrawal of water in the formation of acid albumins, in softening of the connective tissues and epithelium and in special situations in solution of calcareous material. The acid albumins are insoluble in moderately strong, but soluble in concentrated or weak acids. The affinity for water is so strong in the case of concentrated sulphuric acid that not only is water withdrawn from the tissues, but the elements hydrogen and oxygen are split off from their chemical combination with carbon leading to charring.

RESULTS

Mineral Acids, Nitric Acid.—When nitric acid comes in contact with skin or hair it gives the characteristic yellow xanthoproteic reaction. The caustic action of a thirty second exposure to 70 or 71 per cent. nitric acid was observed in three rats. Death occurred promptly and autopsy revealed involvement of skin, subcutaneous tissue and muscle to such a degree that it appeared impossible to arrive at a conclusion about what might be accomplished by treatment.

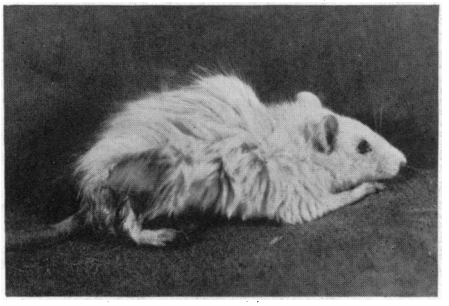

FIG. 5.—Showing rat 24 hours after a six minute contact with 37 per cent. hydrochloric acid which was treated by neutralization with sodium bicarbonate. (Compare with Figs. 4 and 6.)

Three groups of rats were then exposed to acid of this same concentration for a fifteen second interval. There was practically no latent period before activity began. This was evidenced by xanthoproteic reaction of the hair and skin, prompt œdema and complete disability of the extremity. Death occurred in the control animals in three to six hours and autopsy revealed that the depth of the burn extended down to and involved the underlying muscle.

The second group of rats which were treated by prompt neutralization with sodium bicarbonate differed but little from the control animals. The leg became œdematous promptly, and was held rigid in extension. The hair separated readily from the skin. Such animals succumbed in five to fourteen hours and again autopsy revealed involvement of the underlying muscle in the burn.

The animals in the third group which were vigorously washed in water, showed the characteristic xanthoproteic reaction of the hair and skin, but the hair did not pull out readily. (See Fig. 1.) There was marked œdema of the extremity at the end of twenty-four hours, but unlike the previous animals, the treated extremity was useful. All of these rats survived and although some late sloughing occurred, healing took place without any disability.

A series of experiments were performed using 50 per cent. nitric acid for intervals varying from fifteen to sixty seconds. A group of six rats were used to test the effect of the acid for each time interval, in three rats the acid was neutralized and in the others thorough washing was employed. The rats which were exposed to the acid for fifteen and thirty seconds whether treated by neutralization or water, did not reveal a true burn, but there was the usual xanthoproteic reaction. The ones which were immersed for forty-five seconds showed œdema of the extremity and this was equally marked in both groups. The rats which were immersed for sixty seconds and neutralized acted entirely differently, however, from those which were washed. In the former the extremity was curled up, shrunken, dark colored and useless, and death occurred in about eighteen hours. In the latter the only evidence of contact with the caustic was œdema of the foot and characteristic coloration of the hair. None of the animals revealed any evidence of disability and all recovered.

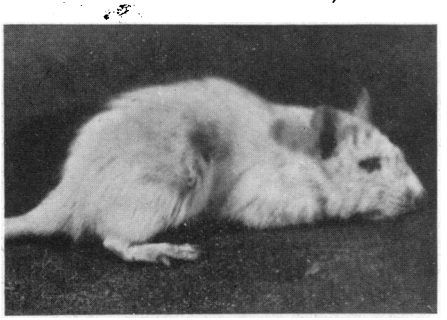

FIG. 6.—Showing rat 24 hours after a six minute contact with 37 per cent. hydrochloric acid which was treated by washing with water. (Compare with Figs. 4 and 5.)

Sulphuric Acid.—Similar experiments were performed with 96 per cent. sulphuric acid. The period of immersion was fifteen seconds. The action upon the skin was so vigorous in the control animals during the next few minutes after the excess had been carefully wiped away that it was deemed advisable to wash after this interval to prevent prompt death. There was immediate œdema, redness, and complete loss of function of the extremity. Death occurred in less than ten hours and in each instance autopsy revealed involvement of muscle in the burn. A group of rats with similarly produced lesions were treated by prompt neutralization with a 5 per cent. solution of sodium carbonate. This procedure caused a tremendous sensory stimulation in those animals in which the anæsthesia was gradually wearing off and a definite increase in temperature of the solution was noted. Death generally occurred in animals so treated in ten hours and invariably in less than twenty-four hours. A third group were treated by neutralization with 5 per cent. sodium bicarbonate and again similar sensory stimulation was seen during the process, but not as great heat evolution was observed. Œdema and redness developed promptly and there was complete disability of the extremity which was drawn up under the animal. (See Fig. 2.) Eighteen hours later extensive sloughing of the skin over the thigh began and death occurred in twenty-four to forty-eight hours. A fourth group was treated by vigorous washing with water. The sensory stimulation which was seen during

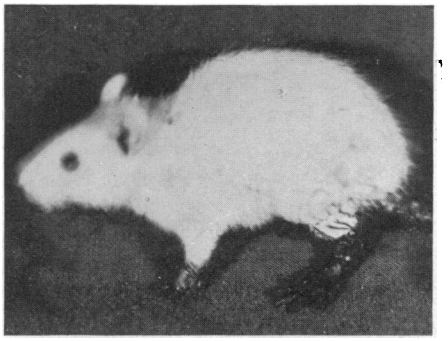

FIG. 7.—Showing rat 18 hours after a six minute contact with 50 per cent. sodium hydroxide. Control animal in which the excess was carefully sponged away with cotton. Gangrene of hind leg is evident. (Compare with Figs. 8 and 9.)

the process of neutralization was not observed. There was prompt redness and œdema of the extremity, but this subsided in about twenty-four hours. The leg remained useful and at no time was there any disability caused by the irritant. (See Fig. 3.) In no instance did any late sloughing occur and all animals recovered.

Observations were then made using 50 per cent. sulphuric acid for an interval of thirty seconds. In the control animals a burn occurred which extended down to muscle and the skin of the thigh formed one large slough. No charring occurred. These animals succumbed in about eight hours. Neither the rats which were treated by washing nor those treated by neutralization showed any evidence of a burn.

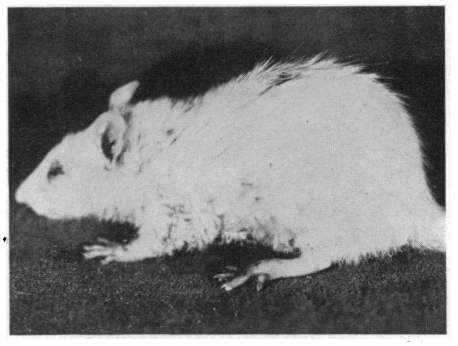

FIG. 8.—Showing rat 24 hours after a six minute contact with 50 per cent. sodium hydroxide which was treated by neutralization with acetic acid. (Compare with Figs. 7 and 8.)

The effect of immersion for one minute in a 25 per cent. solution was next determined. The controls which were sponged revealed only a slight redness of the extremity but no actual burn. The treated animals revealed no signs of the effect of the irritant. Immersion for one and one-half minutes in a 10 per cent. solution did not produce any lesion even in the control animals.

Hydrochloric Acid.—The caustic action of hydrochloric acid was much less vigorous than that of the acids just described. It was necessary to immerse the extremity in 37 per cent. acid for one minute and allow further contact for five minutes before proceeding with treatment to produce analogous lesions to those previously described. The control animals showed a gradually developing œdema and the leg slowly went into a position of contracture. (See Fig. 4.) The toes became gangrenous and after eighteen hours sloughing of the skin of the thigh developed. Death occurred in about twenty-four hours. The rats which were treated by neutralization showed sloughing of the skin of the thigh at the end of twenty-four hours the leg was useless and death generally occurred in about thirty-six hours. (See Fig. 5.) The animals which were treated by vigorous washing showed some œdema of the extremity and redness of the feet. (See Fig. 6.) At the end of forty-eight hours the hair began to separate, but no sloughing of the skin occurred and all rats so treated survived. An effort was made to produce burns with less concentrated acid, but this was ineffectual because of difficulty experienced with the anæsthetic and protecting the lungs from the fuming acid.

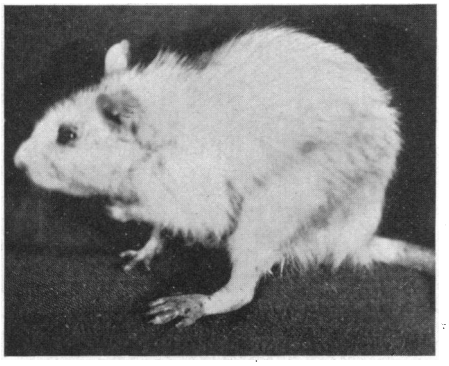

FIG. 9.—Showing rat 24 hours after a six minute contact with 50 per cent. sodium hydroxide which was treated by washing vigorously with water. (Compare with Figs. 7 and 8.)

Organic Acids, Acetic Acid.—It was deemed advisable to determine whether organic acids acted similarly to the mineral acids. The animals were immersed in 99 per cent. acetic acid for thirty seconds. In the control animals the extremity invariably turned an intense red color, but the hair did not show any alteration. All of the rats succumbed in less than two hours and examination revealed that the skin which appeared intact upon inspection was completely destroyed and readily separated from the muscle. Little difference was noted between the animals which were treated by neutralization from those

which were washed. In each instance there was œdema and redness but no actual sloughing of the skin. Exposure to the same concentration for one minute merely increased the severity of the local reaction but no real difference was noted between the rats treated by the two methods. When rats were immersed for one minute and an interval of five minutes was allowed before proceeding with treatment all died regardless of what was done. However, when the interval was lessened to two minutes before proceeding with the treatment, all of the animals from which the acid was removed by washing survived, while two out of three which were treated by neutralization succumbed in less than eighteen hours.

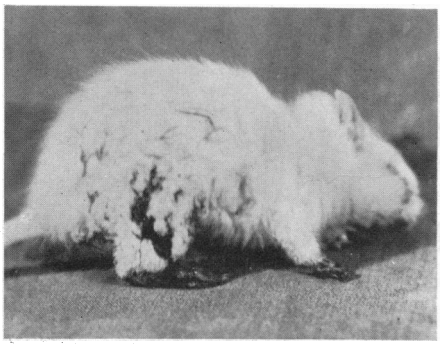

FIG. 10.—Showing rat 18 hours after a six minute contact with 50 per cent. potassium hydroxide. Control animal in which the excess was carefully sponged away with cotton. Gangrene of hind leg present. (Compare with Figs. 11 and 12.)

Trichloracetic Acid.—The caustic action of a saturated solution of trichloracetic acid was observed in three groups of rats. The period of immersion was one minute. The exposed extremity in the control animals immediately became rigid and was held in extension. The skin became milky white within a few minutes, the hair showed no change. Death occurred in such animals in about one and one-half hours. The animals which were treated by neutralization and by washing showed essentially the same picture. The extremity was useless, it was held rigidly in extension and the skin was white in color. The entire leg in all these rats appeared devitalized. Death occurred in the treated animals in ten to twelve hours. Experiments were then done using a half saturated solution and exposing the animals for thirty seconds. The control animals again showed complete disability of the exposed extremity. The rats appeared quite toxic within half an hour after contact with the acid and succumbed in four to five hours. The rats whose lesions were treated by neutralization showed the same characteristic white skin. The leg was pulled up under the body but was used occasionally. At the end of eighteen hours there was moderate œdema and the rats died in twenty-four to thirty-six hours, but at autopsy there was little gross evidence of a burn. The rats which were treated by washing showed œdema of the foot at the end of eighteen hours, but no disability resulted from the lesion and the general activity of the animals did not appear decreased. One rat died fifty hours after exposure to the acid. Another showed the late development of a slough on the lower leg, but the toes remained intact and revealed no deformity.

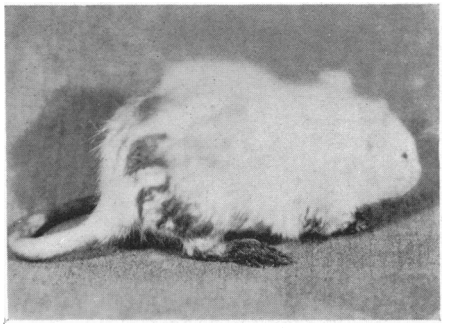

FIG. 11.—Showing rat 24 hours after a six minute contact with 50 per cent. potassium hydroxide, which was treated by neutralization with acetic acid. (Compare with Figs. 10 and 12.)

Alkali Burns.—According to Holland [3] the effect of alkalies is local and limited to the part with which they come in contact. Ammonia, however, may be an exception in view of the three lethal cases reported by Fairbrother,[5] in which death occurred from respiratory and cardiac failure within five hours of the accident. The corrosive action of alkalies are thought to be due to the free alkali combining with the tissue elements forming alkaline albuminates

or with fats to form soaps. Their hygroscopic action of withdrawing water from the cells also contributes to the necrosis. The sloughs which they form are very soluble and consequently alkali penetrates deeply into tissues. It is stated that the total effect upon tissue depends upon the total quantity of OH ions which can be split off under the conditions of the body. The "actual or immediate effective alkalinity of a solution depends upon the dissociated OH ions; but as these combine with the tissues, further OH ions are split off (potential) alkalinity which continue the action.[4]

RESULTS

Sodium Hydroxide.—A long latent period for 50 per cent. sodium hydroxide was observed. It was necessary to immerse the extremity for one minute and allow the contact with the caustic to continue for five additional minutes before proceeding with treatment, in order to obtain a satisfactory lesion. The skin and hair of the control animals varied but little from normal appearance at the end of this six minute interval. Gradually œdema and maceration of the skin with the formation of thick œdematous sloughs developed. (See Fig. 7.) The maceration of the tissue was entirely unlike the destruction seen in acid burns and appeared characteristic of alkali burns. The action of the sodium hydroxide after once begun was rapidly progressive and all of the control animals were sacrificed in eighteen hours. The rats whose lesions were treated by neutralization showed œdema and redness of the foot at the end of twenty-four hours and gradually the skin of the thigh and flank sloughed, however, recovery occurred. (See Fig. 8.) The hair of the rats which were treated by washing remained intact. No sloughing of the skin occurred. (See Fig. 9.) The only evidence of a burn was moderate œdema of the toes and excoriation of the skin of the foot, however, healing took place promptly and without deformity.

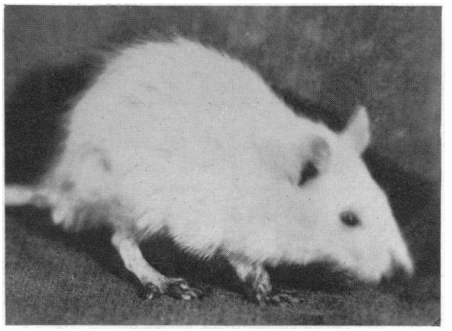

FIG. 12.—Showing rat 24 hours after a six minute contact with 50 per cent. potassium hydroxide, which was treated by vigorous washing with water. (Compare with Figs. 10 and 11.)

Potassium Hydroxide.—Here again on account of the long latent period, the same duration of exposure to 50 per cent. potassium hydroxide was necessary as in the experiments with sodium hydroxide. A progressive lesion was again noted in the control animals. (See Fig. 10.) At the end of eighteen hours the foot was swollen and purple in color. The skin was exceedingly moist and mascerated. The toes were shrivelled and gangrenous. The skin was broken in numerous places exposing the muscles of the thigh. The controls were sacrificed at this time. The lesions of the rats treated by neutralization were quite similar. (See Fig. 11.) The extremity was useful but there was great disability. The skin was œdematous and red, and over the thigh sloughing occurred. The toes were dark colored and presented the picture of a dry gangrene. The rats treated by washing, unlike the control and neutralized rats, showed only slight redness of the foot. (See Fig. 12.) There was no œdema and the extremity functioned normally. The hair was everywhere intact and it was difficult to actually demonstrate a burn.

Lime.—An effort was made to produce experimental burns with lime but there are other factors involved than its purely alkaline nature. Calcium oxide may be placed on dry skin and no reaction takes place, the skin likewise tolerates calcium hydroxide, which is not a very active alkali. During the process of slaking, the factor of heat is of tremendous importance. The heat of solution of a single gram of calcium oxide is 18,330

calories. To test the duration of this thermal factor water was added to about 5 grams of calcium oxide. The temperature immediately rose to 98° centigrade. When activity of calcium oxide has once begun on skin there is an addition to this heat factor the avidity of the lime for water which causes further tissue necrosis. Because of this complicated action lime does not lend itself readily for investigation of tissue changes caused by alkalinity.

Sensory Threshold of Skin.—In view of the tremendous difference in the time factor observed in acids and alkalies before tissue injury occurred, it

TABLE I.

Showing Latent Period of Sensory Stimulation of Various Caustics.

Caustic	C. W. M. Latent period	E. C. D. Latent period	W. C. E. Latent period
Acetic Acid			
99 per cent.	14″	11.8″	17″
50 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
25 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
Trichloracetic Acid			
Saturated Solution	5″	14″	13″
Half Saturated Sol.	17″	15″	16″
Potassium Hydroxide			
50 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
25 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
Sodium Hydroxide			
50 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
25 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
Ammonium Hydroxide			
28 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
Nitric Acid			
70 per cent.	4″	2″	8″
50 per cent.	37″	22.6″	45″
25 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
10 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
Sulphuric Acid			
96 per cent.	3.5″	4.6″	4″
50 per cent.	50″	45″	48″
25 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
10 per cent.	3′ No stimulation	3′ No stimulation	3′ No stimulation.
Hydrochloric Acid			
37 per cent.	15″	17″	
25 per cent.	3′ No stimulation	3′ No stimulation	

seemed desirable to determine the latent period upon human skin before a sensory response took place. These observations are summarized in Table I. It is interesting to note that in the highly concentrated mineral and organic acids stimulation occurred in 3.5 to 8 seconds and relatively slight changes in the concentration cause a marked prolongation of the latent period. When a 25 per cent. concentration was reached none of the acids gave a sensory response in three minutes. It is of further interest to note that 50 per cent.

sodium and potassium hydroxide and 28 per cent. ammonium hydroxide gave no stimulation in three minutes.

Discussion.—The results of the experiments with acids and alkalies were quite uniform. In every instance the rats which were washed thoroughly survived longer than those which were treated by neutralization, and the local lesion at any given period after exposure to the caustic revealed less evidence of irritation than those which were treated by neutralization. The striking difference in the results of treatment by the two methods may be due to the additional trauma of heat of neutralization superimposed upon the already existing caustic burn. Heat of dilution must be considered in the rats which were treated by washing, but because of the method used, this heat was promptly carried away, and the sum total of the burn was that due to the caustic agent alone.

The question may be raised whether the results might not be further improved by neutralization of any of the alkali or acid which may still be present after vigorous washing. No experiments to determine this point have been made. It has been noted, however, that dilute acids and alkalies are not very active upon the skin. It is problematic whether the caustic in the slight dilution which is present after energetic washing can cause further tissue injury. It might be added that after such thorough reduction of the concentration that little damage might be anticipated from neutralization of the residual caustic.

CONCLUSIONS

1. Concentrated mineral and organic acids react with skin promptly. As the dilution of the acid increases there is a striking prolongation of the latent period. Concentrated hydrochloric acid is a much less vigorous caustic than either concentrated nitric or sulphuric acids. There is some evidence to suggest that trichloracetic acid is absorbed like phenol and acts as a general protoplasmic poison.

2. Sodium and potassium hydroxide react with skin only after a prolonged latent period.

3. The results obtained in the treatment of experimentally produced alkali and acid burns were decidedly better when the caustic agent was removed by dilution with water than when rendered inert by neutralization.

4. When treatment by neutralization is employed, it should only be used after the maximal amount of the caustic has been removed by thorough washing.

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