

CICATRIZATION OF WOUNDS.

VIII. STERILIZATION OF WOUNDS WITH CHLORAMINE-T.

BY ALEXIS CARREL, M.D., AND ALICE HARTMANN, M.D.

(From the Laboratories of The Rockefeller Institute for Medical Research, New York, and Hospital 21, Compiègne, France.)

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In a previous article¹ it was shown that the presence of bacteria at the surface of a wound retards the normal process of cicatrization. According to the nature and size of the infection, the curve representing cicatrization deviated from the calculated curve.² In order to investigate the substances which are capable of influencing tissue repair, it is, therefore, imperative that the wound should be kept in an aseptic condition. No specific influence on the progress of healing could be attributed to the substance experimented with unless the possible action of infection was entirely eliminated.

Sterilization of a wound is easily effected by the application of Dakin's hypochlorite solution at the surface of the tissues under appropriate conditions of concentration and duration.³ In the experiments to be described, it was attempted to simplify the method by substituting for the instillations of Dakin's hypochlorite solution a paste designed gradually to yield up to the tissues one of Dakin's chloramines contained therein. Investigations were undertaken to ascertain whether this paste would be able to keep a sterile wound in an aseptic condition, as well as to sterilize an infected wound, and whether it would retard tissue repair.

Chloramine Paste.

Some unpublished experiments of Dakin had shown the necessity of avoiding fatty substances in the composition of paste intended for the sterilization of wounds.

¹ Carrel, A., and Hartmann, A., *J. Exp. Med.*, 1916, xxiv, 429.

² du Noüy, P. L., *J. Exp. Med.*, 1916, xxiv, 451.

³ Carrel, A., and Dehelly, G., *Le traitement des plaies infectées*, Paris, 1916.

Dakin mixed with vaseline or lanoline certain antiseptic substances which are insoluble in water. Once these substances were applied to the wounds, their bactericidal power became almost negligible. Carrel also experimented with aqueous solutions of antiseptic substances mixed with lanoline, but they failed to have an influence on the infected wounds. It appeared that the active substance remained in the lanoline and exerted no effect upon the bacteria. Carrel next combined certain antiseptic substances in agar, but found that the consistency of the agar rendered it unsuitable for practical use. The cakes yielded to the tissues the liquid they contained, but they were too brittle and easily destroyed.

It was concluded from these experiments that, in order to be efficient, the bactericidal substance would have to be combined with a fat-free substance capable of being moulded exactly to the surface of the wound. At this point Daufresne⁴ succeeded in preparing a paste composed of sodium stearate and of toluene sodium *p*-sulfochloramide, the bactericidal properties of which had been discovered by Dakin and which is named chloramine-T for convenience. This paste is sufficiently firm not to flow away when applied to a wound, and yet fluid enough to be moulded to the anfractuositities of a granulating surface or of a fractured bone. The paste contains 8 per cent of sodium stearate and 4 to 15 parts per 1,000 of chloramine-T.

The paste is placed in sterile glass receptacles from which it is withdrawn at the time of dressing by means of wooden spatulas which have been sterilized in the autoclave. It is also preserved in tin tubes, to the ends of which is attached a rubber tube ending in a tapering glass tube. By means of the tube the paste can be injected into deep wounds or fistulas.

Technique for the Application of the Chloramine Paste.

The chloramine paste is designed to maintain in an aseptic condition wounds which have already been disinfected, or to sterilize slightly infected wounds. It should only be applied to wounds which yield small quantities of secretion, have little or no necrotic tissue, and little or no infection.

Neutral sodium oleate is poured on to the wound and the surrounding skin from a flask with a small opening. The granulations, the epithelial edges, and the skin are gently swabbed with a piece of absorbent cotton attached to a forceps. By this means an excellent

⁴ Daufresne, M., *J. Exp. Med.*, 1917, xxvi, 91.

cleansing process is effected. The patient should feel no pain; any suffering indicates either that the sodium oleate is incorrectly prepared or that the cleansing is imperfectly carried out. The sodium oleate is next removed with a plug of cotton soaked in water, and the surface of the skin is dried by carefully applying a compress of absorbent gauze.

A sufficient quantity of chloramine paste is withdrawn from the receptacle by means of a sterilized wooden spatula and applied to the surface of the wound to the thickness of at least 1 cm. It should cover not only the granulations, but also the epithelial edges and part of the surrounding skin. If the wound is deep and anfractuous the tube containing the chloramine paste is introduced into the opening, and sufficient chloramine paste is expressed to fill the cavity. But no pressure should be applied during the process.

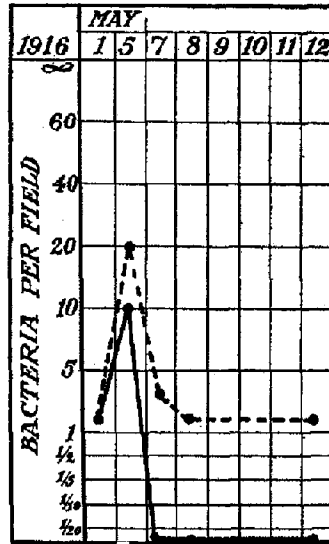
A compress of dry gauze, which should be much larger than the wound itself, is next placed over the chloramine paste. The compress is applied to the surface of the skin and attached to it by means of two or three strips of adhesive plaster. It is important that the gauze should be placed exactly over the wound, for if the bandage is shifted the gauze will introduce bacteria from the surrounding skin on to the surface of the granulations and reinfection will ensue. Above the gauze is placed a piece of absorbent cotton enveloped in gauze. The dressing must not be compressed by bandages and should be renewed every 24 hours. The wound is washed out with sodium oleate every day or two, depending on the condition of the skin. The application of chloramine should be painless; any sensation of pain signifies a technical error on the part of the surgeon.

The bacteriological condition of the wound is examined every day in film preparations of secretions taken from various parts of the wound.

Effect of a Paste Containing 4 Parts per 1,000 of Chloramine-T upon the Bacteriological Condition of an Aseptic or Slightly Infected Wound.

The influence of sodium stearate containing 4 parts per 1,000 of chloramine-T was first tested on surface wounds which had been rendered almost aseptic by instillations of Dakin's hypochlorite solution.

In the first experiment a comparison was made of the effect on the bacteriological condition of a slightly infected wound of sodium stearate alone, and of sodium stearate containing 4 parts per 1,000 of chloramine-T.



TEXT-FIG. 1. Experiment 1. Case 366. Comparative action of sodium stearate and of sodium stearate containing 4 parts per 1,000 of chloramine-T. Wound in back of thigh. The upper part of the wound is dressed with sodium stearate containing 4 parts per 1,000 of chloramine-T. The lower part is dressed with sodium stearate. The upper half of the wound is sterile, while the lower half remains unchanged. The solid line indicates the upper part of the wound; the broken line, the lower part.

Experiment 1. Case 366. Comparison of the Action of Chloramine-T and of Sodium Stearate.—Elongated wound at the back of the thigh.

May 4, 1916. The area of the wound is 23 sq. cm., and the surface averages 1 bacterium per field (Text-fig. 1). The upper half of the wound is dressed with sodium stearate containing 4 parts per 1,000 of chloramine-T, and the lower half is dressed with sodium stearate.

May 5. The upper half of the wound contains 10 bacteria per field, and the lower half 20 per field. Same dressing.

May 6. Same dressing.

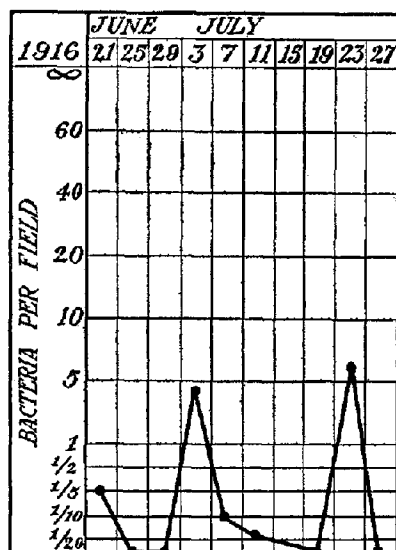
May 7. The upper half of the wound is aseptic; the lower part contains 3 bacteria per field. Same dressing.

May 8. The upper part of the wound is aseptic; the lower half contains 1 bacterium per field. Same dressing.

May 12. The upper half has no bacteria, and the lower half 1 per field.

This observation shows, on the one hand, that sodium stearate has no effect on a slightly infected wound, and, on the other hand, that sodium stearate containing 4 parts per 1,000 of chloramine-T produces surgical asepsis. The bacteria disappeared completely from the films taken from the portions of the wound treated with chloramine-T, whereas they were present in all the films from the part not so treated.

In the following experiments it was attempted to maintain in an aseptic condition wounds which had been rendered surgically sterile at the beginning of treatment.



TEXT-FIG. 2. Experiment 2. Case 488. Preservation of asepsis in a wound by treatment with chloramine-T paste, 4 parts per 1,000. Wound at back of right leg. Two slight reinfections.

Experiment 2. Case 488. Slight Reinfection of a Wound Treated with Chloramine-T, 4 Parts per 1,000.—Wound at back of right leg. Treated with sodium hypochlorite solution.

June 17, 1916. The wound contains but 1 bacterium in 5 fields. Dressing with chloramine-T, 4 parts per 1,000.

June 21. 1 bacterium in 5 fields (Text-fig. 2).

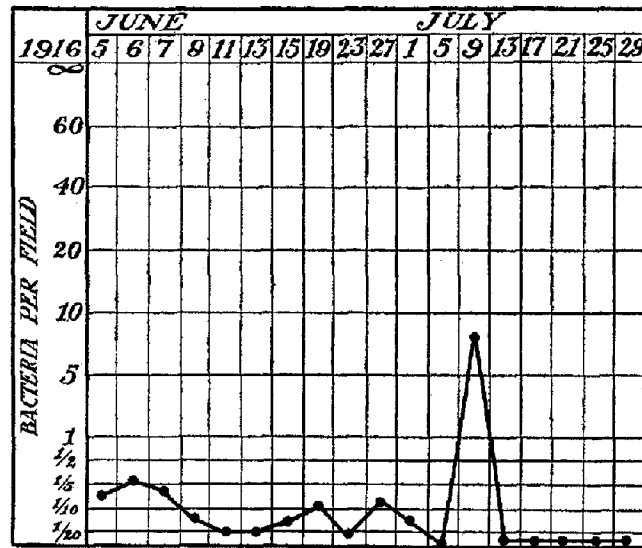
June 25-29. No bacteria.

July 3. Reinfection; 4 bacteria per field.

July 7-19. 1 bacterium in 20 fields; sometimes none.

July 23. Slight reinfection; 6 bacteria per field.

July 27. No bacteria; complete healing.



TEXT-FIG. 3. Experiment 3. Case 491. Effect of chloramine-T, 4 parts per 1,000, upon the asepsis of a wound.

Experiment 3. Case 491. Wound Kept Aseptic with Chloramine-T, 4 Parts per 1,000. Slight Reinfection.—Wound on inner side of right thigh.

Apr. 13, 1916. Wound is covered with necrotic tissue. Moderate infection. Sterilization with sodium hypochlorite.

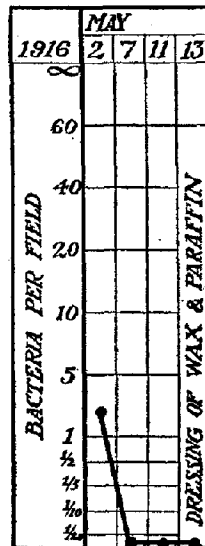
June 3. The wound is surgically sterile.

June 4. Wound is granulating and still shows small sections of necrotic aponeurosis. In these parts alone about 3 bacteria per field are found. The major portion of the wound is covered with surgically sterile granulations. Washing with neutral sodium oleate; dressing with 4 parts per 1,000 of chloramine-T.

June 5-15. The wound is dressed in the same manner and remains surgically sterile (Text-fig. 3).

July 9. Reinfection of wound; 8 to 10 bacteria per field. Dressing with chloramine-T, 10 parts per 1,000.

July 13. Wound is sterile.
 July 14. Chloramine dressing, 4 parts per 1,000.
 July 13-29. Wound has remained sterile.



TEXT-FIG. 4. Experiment 4. Case 450. Effect of chloramine-T, 4 parts per 1,000, upon the asepsis of a wound.

Experiment 4. Case 450. Sterilization of a Slightly Infected Wound and Preservation of Asepsis with Chloramine-T, 4 Parts per 1,000.—Wound on outer surface of right leg; sterilized with sodium hypochlorite.

May 2, 1916. The secretions contain 2 bacteria per field (Text-fig. 4).

May 3. Wound is washed with neutral sodium oleate; dressing with chloramine-T, 4 parts per 1,000.

May 7. All the bacteria have disappeared.

May 13. Grafts of skin are applied to the granulations and the wound is dressed with wax and paraffin.

Experiment 5. Case 327. Reinfection of a Sterile Wound Treated with Chloramine-T, 4 Parts per 1,000.—Wound in the antero-external region of the left thigh; sterilized with sodium hypochlorite and chloramine-T solution.

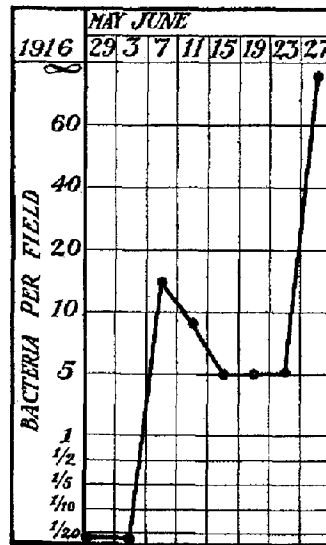
May 25, 1916. The wound, which is 25 sq. cm. in area, is surgically sterile. Dressing with chloramine-T, 4 parts per 1,000.

May 29. Wound sterile (Text-fig. 5); same dressing.

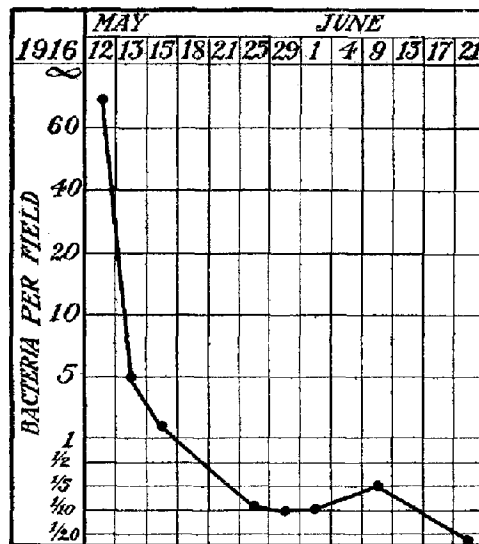
June 3. Wound sterile; same dressing.

June 7. Reinfection; same dressing.

June 27. Large number of bacteria.



TEXT-FIG. 5. Experiment 5. Case 327. Reinfection of an aseptic wound in spite of treatment with chloramine-T, 4 parts per 1,000.



TEXT-FIG. 6. Experiment 6. Case 445. Infection of cutaneous origin of a smooth and granulous wound in the foot. Sterilization with chloramine-T, 4 parts per 1,000.

Experiment 6. Case 445. Sterilization with Chloramine-T, 4 Parts per 1,000, of a Small, Slightly Infected Surface Wound.—Wound in the dorsal region of the foot.

May 12, 1916. Wound shows grayish granulations and the secretions contain approximately 100 bacteria per field (Text-fig. 6). Dressing of chloramine-T, 4 parts per 1,000.

May 29. Wound is surgically sterile and remains sterile through June 21, at which date complete healing is effected.

It has thus been shown that wounds in the fleshy regions could be maintained in a condition of surgical asepsis with sodium stearate containing 4 parts per 1,000 of chloramine-T. It was also possible to sterilize wounds presenting a slight infection of cutaneous origin. But in other cases the 4 parts per 1,000 of chloramine-T failed to maintain the asepsis. In Experiment 5 cutaneous reinfection developed in spite of the daily application of chloramine-T. The same occurred in Experiments 2 and 3, in which bacteria reappeared. It is probable, therefore, that the concentration of chloramine-T was too weak.

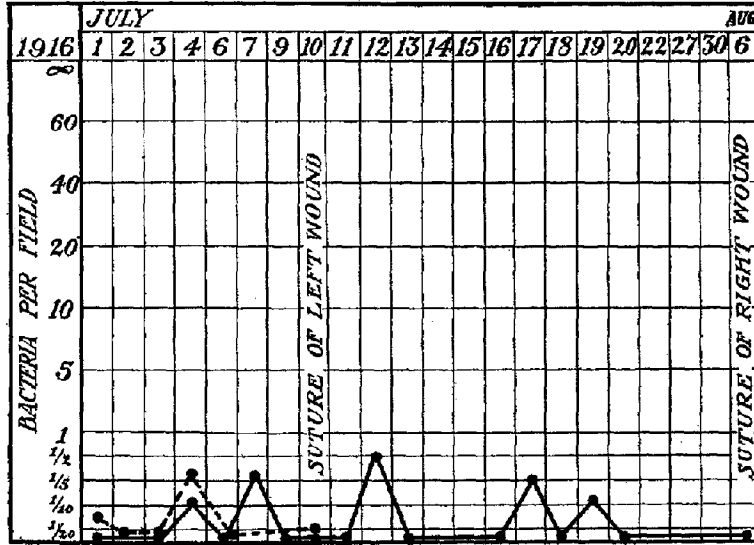
Effect of a Paste Containing 10 Parts per 1,000 of Chloramine-T upon the Bacteriological Condition of an Aseptic or Slightly Infected Wound.

Wounds, in some cases accompanied by fracture, were sterilized with Dakin's solution, and then dressed with chloramine-T, 10 parts per 1,000.

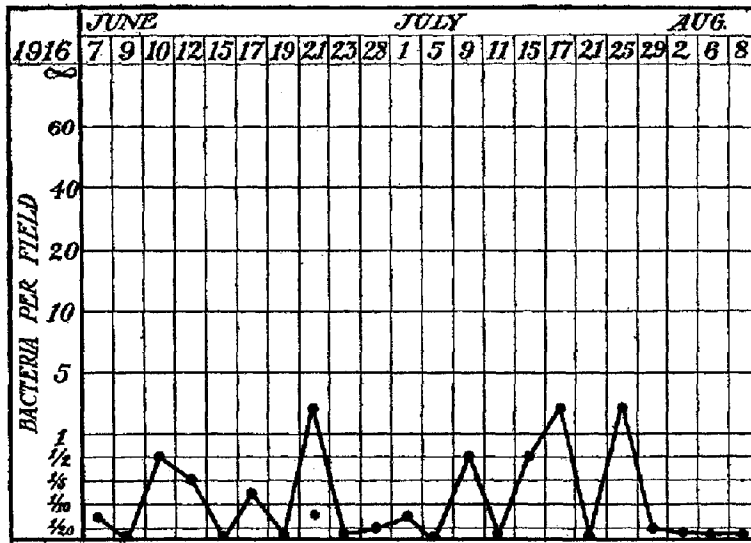
Experiment 7. Case 548. Preservation of Asepsis with Chloramine-T, 10 Parts per 1,000, of Two Penetrating Wounds in the Region of the Buttocks, Accompanied by Extensive Tissue Detachment.—Deep wounds in both buttocks caused by a projectile which entered the right thigh, came out between the buttocks in the anal region, and penetrated the left buttock, where it produced extensive muscular detachment. The large wounds and the intramuscular channels were sterilized with Dakin's hypochlorite solution.

July 1, 1916. The right wound has a surface area of 4 sq. cm., and the left of 10 sq. cm. These wounds communicate by means of deep anfractuous passages with the wounds located in the vicinity of the anus. Chloramine-T, 10 parts per 1,000, is carefully injected into the channels. This dressing is repeated daily.

July 6. The lower portion of the left wound has closed (Text-fig. 7). The deep channels healed spontaneously; the cavity separating the right wound from the anal region was kept in an aseptic condition by means of chloramine-T, and its sides grew together without the need of counter-incision.



TEXT-FIG. 7. Experiment 7. Case 548. Preservation of asepsis of two deep wounds in the region of the buttocks by the use of chloramine-T, 10 parts per 1,000. The solid line indicates the right wound; the broken line, the left wound.



TEXT-FIG. 8. Experiment 8. Case 516. Preservation of asepsis in an open fracture by means of chloramine paste, 7 and 10 parts per 1,000.

July 10. Closing of the left wound.

Aug. 6. The right wound is sutured. The curve indicated that the wounds remained aseptic during the treatment.

Experiment 8. Case 516. Maintenance of an Osseous Cavity in an Aseptic Condition with Chloramine-T, 7 and 10 Parts per 1,000.—May 17, 1916. Fracture of the upper part of the left tibia. Local sterilization with sodium hypochlorite.

June 4. At the level of the fracture there is a cavity the size of a small egg, containing grayish secretions. The opening of the cavity is at the base of a wound situated on the inner surface of the leg. The wound and cavity are surgically sterile. They are filled with chloramine-T paste, 5 parts per 1,000.

June 6. The paste has not been absorbed. Between the paste and the surface of the cavity is a fluid, transparent substance. Slight reinfection; 4 bacteria per field. Chloramine dressing, 7 parts per 1,000.

June 7. Wound is sterile (Text-fig. 8).

June 13. Wound is sterile. After the osseous cavity has been filled with chloramine paste a portion of the wound is sutured, but the loss of cutaneous substance effected at the time the wound occurred prevents its complete closure. The open part of the wound is covered with chloramine paste, 7 parts per 1,000. The wound remains aseptic.

July 10. Chloramine paste is removed from the osseous cavity. The walls of the cavity are seen to be covered with granulations. Without removing the paste which remains in the cavity, the latter is filled with chloramine paste, 10 parts per 1,000. The osseous cavity has remained completely aseptic. The slight reinfections shown by the curve exist only at the edges of the wound.

Aug. 22. The cavity has almost filled and is covered with epithelium.

Experiment 9. Case 625. Preservation of Asepsis in Five Flesh Wounds with Chloramine-T, 10 Parts per 1,000.—Numerous wounds in the left leg produced by bursting shells.

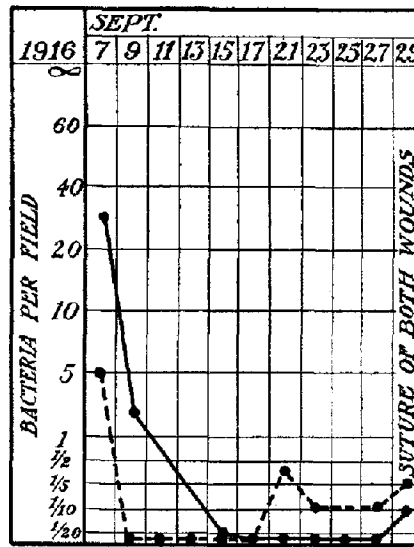
Sept. 5, 1916. Patient admitted to the hospital. The wounds are covered with pus and are treated with sodium hypochlorite.

Sept. 11. The pus has disappeared and the wounds are sterile (Text-fig. 9). Chloramine dressing, 10 parts per 1,000.

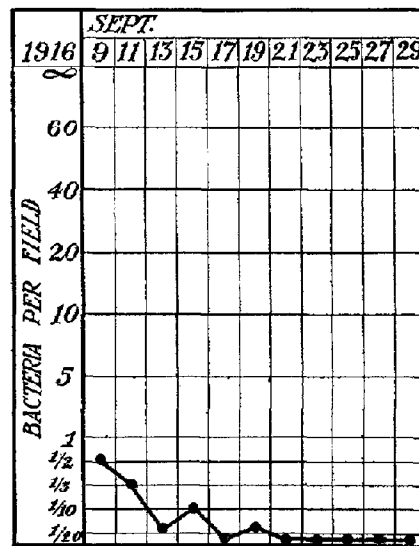
Sept. 13. Suture of three of the wounds; the other two are dressed with chloramine-T. They remain sterile through Sept. 29, when they are sutured.

Experiment 10. Case 590. Preservation of Asepsis in a Flesh Wound with Chloramine-T, 10 Parts per 1,000.—Wounds in the right thigh, accompanied by femoral fracture, produced by bursting shells. Treated with sodium hypochlorite.

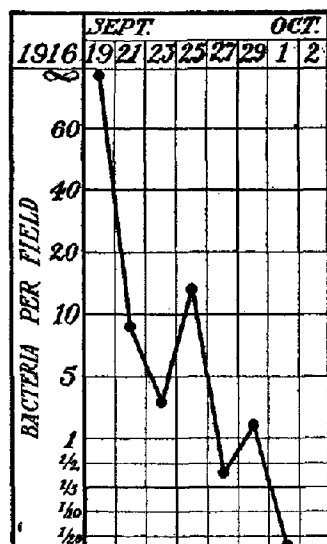
Sept. 11, 1916. The anterior wound is surgically aseptic (Text-fig. 10). Chloramine dressing. The wound is separate from the site of the fracture and remains sterile through Sept. 29 under chloramine dressing.



TEXT-FIG. 9. Experiment 9. Case 625. Preservation of asepsis of flesh wounds with chloramine-T, 10 parts per 1,000. The solid line indicates the posterior wound; the broken line, the anterior wound.



TEXT-FIG. 10. Experiment 10. Case 590. Preservation of sterility in a wound accompanied by femoral fracture with chloramine-T, 10 parts per 1,000.



TEXT-FIG. 11. Experiment 11. Case 620. Sterilization of a slightly infected wound with chloramine-T, 10 parts per 1,000.

Experiment 11. Case 620. Sterilization of a Slightly Infected Flesh Wound with Chloramine-T, 10 Parts per 1,000.—Numerous shell wounds. A large wound in the left buttock is treated with sodium hypochlorite. It is gradually cleansed.

Sept. 25, 1916. Wound contains 10 to 20 bacteria per field (Text-fig. 11). There are practically no secretions. Chloramine dressing, 10 parts per 1,000.

Sept. 27. Wound is surgically aseptic; same dressing.

Oct. 1. The bacteria have completely disappeared.

Experiment 12. Case 634. Reinfection Followed by Sterilization of Two Flesh Wounds with Chloramine-T, 10 Parts per 1,000.—Numerous shell wounds on the forehead, shoulder, and elbow. Disinfection of wounds with Dakin's hypochlorite solution.

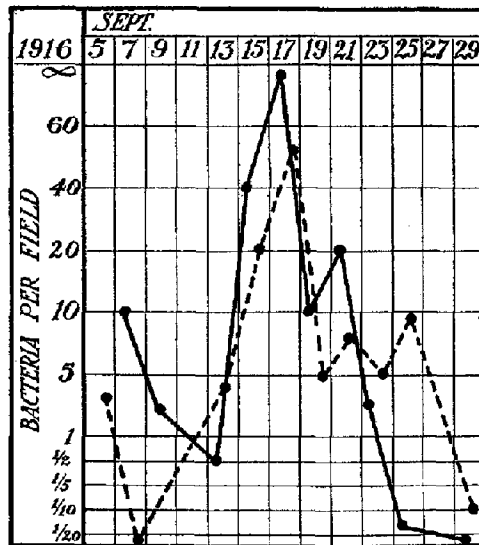
Sept. 11, 1916. The wounds on the forehead and left shoulder are almost sterile (Text-fig. 12). Application of chloramine paste and gauze dressing. The patient, who has also a severe fracture of the elbow and several other wounds, is very restless and the surface dressings become displaced.

Sept. 15 and 17. Reinfection from the skin. Considerable increase in the number of bacteria.

Sept. 17. Washing with neutral sodium oleate. The chloramine dressing is firmly fixed in place.

Sept. 19 and 21. Rapid diminution in the number of bacteria. Same dressing.

Sept. 29. Both wounds are sterile.



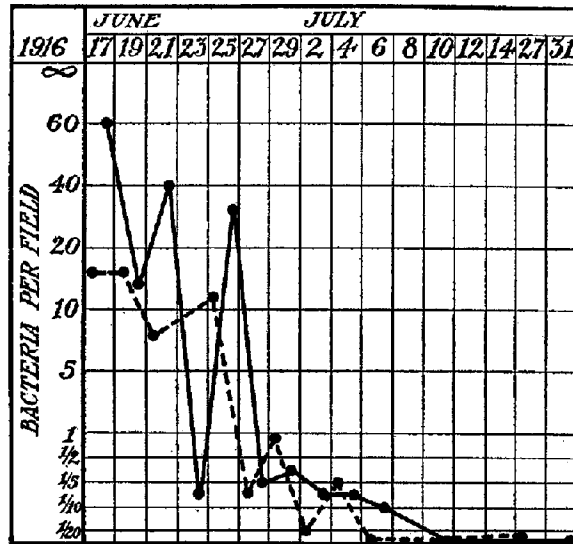
TEXT-FIG. 12. Experiment 12. Case 634. Reinfection of cutaneous origin, caused by shifting of dressing, and subsequent sterilization with 10 parts per 1,000 of chloramine-T. The solid line indicates the wound on the forehead; the broken line, the wound in the left shoulder.

The six experiments given above were selected from a series of sterile or slightly infected wounds treated with chloramine-T paste, 10 parts per 1,000. In every case the chloramine-T either maintained or produced the sterility of wounds infected from the skin. Nevertheless, this result can only be obtained if the dressings are made according to the technique described above. In Experiment 12, the dressings had not been firmly fixed at the surface of the wounds. The gauze shifted slightly and a cutaneous reinfection occurred. But sterilization was reestablished as soon as the appropriate technique was applied.

Sterilization of a Wound with Chloramine-T, 10 Parts per 1,000.

The above experiments and many others having shown that chloramine-T, 10 parts per 1,000, preserves a wound in an aseptic condition for several days and weeks, we next endeavored to ascertain whether it would also effect the sterilization of an infected wound.

The first of these experiments was made with surface wounds showing no necrotic tissue and slight infection. Later they were applied to wounds accompanied by a fracture.



TEXT-FIG. 13. Experiment 13. Case 519. Sterilization of two surface wounds of the left thigh with chloramine-T, 10 parts per 1,000. The solid line indicates the inside wound; the broken line, the posterior wound.

Experiment 13. Case 519. Sterilization of Two Flesh Wounds with Chloramine-T, 10 Parts per 1,000.—Two wounds of the thigh sterilized with sodium hypochlorite; subsequent reinfection. The wound on the inner side measures 24 sq. cm.; that towards the back, 19 sq. cm.

June 25, 1916. Both wounds are covered with smooth red granulations. No necrotic tissue; small amount of secretion; slight infection. Cocci, diplococci, and bacilli appear on the inside wound in the proportion of 30 per field, and 12 per field in the posterior wound (Text-fig. 13). Application of chloramine paste, 7 parts per 1,000.

June 26. Inside wound shows cocci, diplococci, and streptococci averaging 10 to 15 per field. In the posterior wound there are masses of cocci—6 to 8 per field. Washing with neutral sodium oleate; dressing with chloramine paste, 7 parts per 1,000.

June 27. Inside wound contains 1 coccus in 5 fields; posterior wound contains 1 coccus in every 7 fields.

June 30. Chloramine dressing, 10 parts per 1,000.

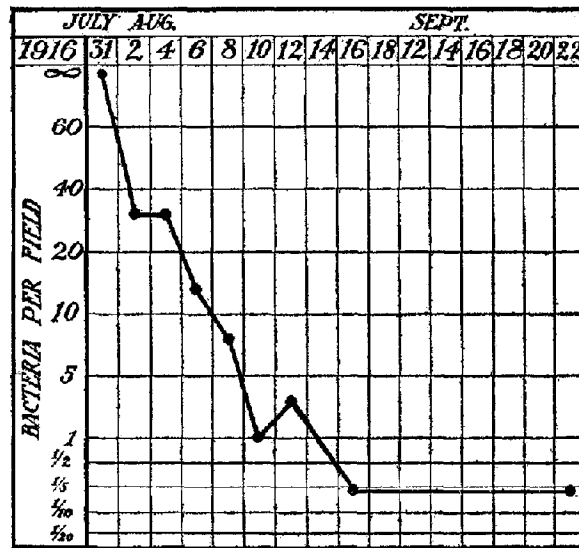
July 1. Inner wound shows 1 coccus in 8 fields; posterior wound shows 1 coccus in 8 fields. Same dressing.

July 4. Few bacteria. From this time on the wounds remain sterile.

July 27. The posterior wound has healed.

July 31. The inside wound has healed.

This experiment shows that a wound covered with smooth granulations, devoid of necrotic tissue, with a slight quantity of secretion, and a varied but sparse bacterial flora, may be completely sterilized with chloramine-T paste. The experiment was repeated with a large number of wounds and always produced identical results. Thereafter the same treatment was applied to more heavily infected wounds which still contained some necrotic tissue.



TEXT-FIG. 14. Experiment 14. Case 591. Sterilization of a seton wound in the sole of the foot with chloramine-T, 10 parts per 1,000.

Experiment 14. Case 591. Sterilization of a Seton Wound in the Sole of the Foot with Chloramine-T, 10 Parts per 1,000.—Seton wound in the sole of the foot produced by a fragment of a torpedo on July 24.

July 31, 1916. The wound is very much inflamed and infected. Large number of bacteria (Text-fig. 14). Treatment with Dakin's hypochlorite solution.

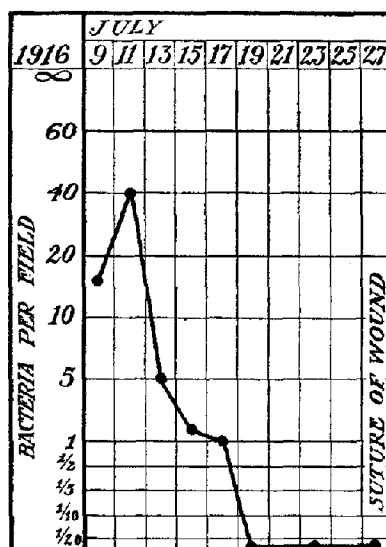
Aug. 3. Sole of the foot still infected. At the surface a small amount of necrotic tissue remains. Radiological examination of the wall of the wound shows the presence of nine minute fragments which cannot be removed owing to their small size. Injection of chloramine paste into the channel and chloramine dressing, 10 parts per 1,000.

Aug. 4. The wound still contains 30 bacteria per field.

Aug. 6 and 8. The wound is becoming sterile.

Aug. 10. The wound now contains only 1 bacterium per field.

Aug. 16. The wound has become surgically sterile. It remains in this condition through Sept. 22, when complete sterilization is effected.



TEXT-FIG. 15. Experiment 15. Case 562. Sterilization with chloramine-T, 10 parts per 1,000, of a slightly infected wound in the right buttock, accompanied by fracture of the ilium.

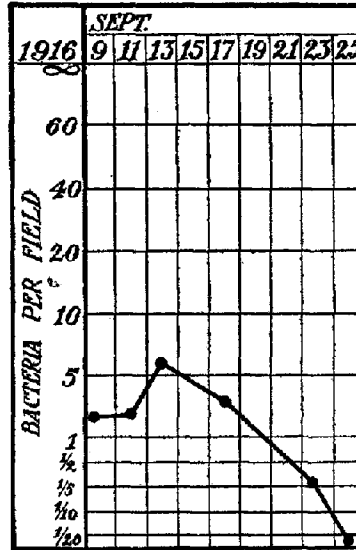
Experiment 15. Case 562. Sterilization of a Wound Accompanied by Fracture with Chloramine-T, 10 Parts per 1,000.—July 4, 1916. Large shell wound in the upper part of the right buttock and fracture of the ilium. Wound is first treated with Dakin's hypochlorite solution.

July 9. The surface of the wound is cleansed. The secretions average 15 bacteria per field (Text-fig. 15). Dressing with chloramine paste, 10 parts per 1,000.

July 10. Wound is covered throughout with red granulations; only at isolated points is it still grayish in color. Chloramine dressing, 10 parts per 1,000.

July 13. 5 bacteria per field.

- July 17. The grayish spots have disappeared. About 1 bacterium per field.
 July 20. Wound is sterile.
 July 27. Wound is sutured.



TEXT-FIG. 16. Experiment 16. Case 646. Sterilization with 10 parts per 1,000 of chloramine-T of a deep, slightly infected wound.

Experiment 16. Case 646. Sterilization of a Slightly Infected Flesh Wound with Chloramine-T, 10 Parts per 1,000.—Sept. 8, 1916. Numerous suppurating and severely infected wounds on the left leg. Two of the wounds are treated for 48 hours with Dakin's hypochlorite solution.

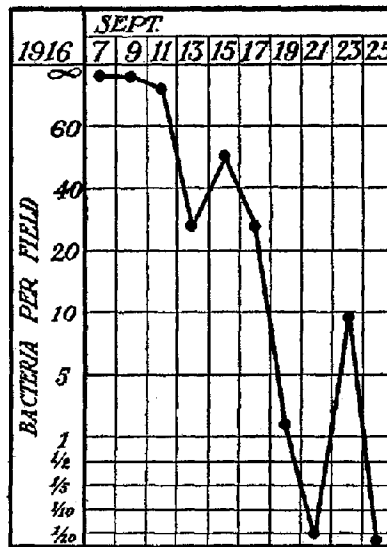
Sept. 11. The inside wound is still infected (Text-fig. 16). It is deep, and the calf is still inflamed. Chloramine dressing, 10 parts per 1,000.

Sept. 23. Wound is surgically sterile.

Experiment 17. Case 441. Sterilization of a Small, Severely Infected Wound with Chloramine-T, 10 Parts per 1,000.—Sept. 4, 1916. Removal by a bursting shell of the fourth and fifth fingers of the left hand, and of the greater part of the fifth metacarpal.

Sept. 6. Suppurating wound, severely infected and painful, containing necrotic tissue and large numbers of bacteria. Treatment for 5 days with Dakin's hypochlorite solution.

Sept. 11. The wound still contains large numbers of bacteria in the necrotic parts (Text-fig. 17). Red granulations have appeared. Dressing with chloramine paste, 10 parts per 1,000.



TEXT-FIG. 17. Experiment 17. Case 441. Sterilization of a severely infected wound containing a small quantity of necrotic tissue with chloramine-T, 10 parts per 1,000.

Sept. 13. The wound contains 30 bacteria per field. Same dressing.

Sept. 19. Wound is almost sterile; contains 1 bacterium per field.

Sept. 21. A few bacteria are found on a small fragment of necrotic aponeurosis.

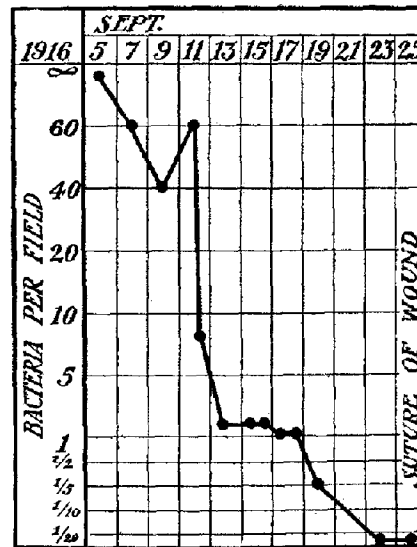
Sept. 25. Wound is sterile.

Experiment 18. Case 626. Sterilization with Chloramine-T, 10 and 15 Parts per 1,000, of a Large, Severely Infected Wound, Accompanied by Fracture.—Extensive wound, more than half the thickness of the forearm in depth, with fracture of the radius and cubitus.

Sept. 5, 1916. The wound, which is 9 days old, appears grayish in color. The muscular and osseous surfaces have been evened, but they are still covered with necrotic tissue and blue pus. The limb is swollen and painful. Chloramine dressing, 10 parts per 1,000.

Sept. 7. The blue pus has almost completely disappeared. At the surface and bottom of the wound some necrotic tissue remains. Application of chloramine paste, 15 parts per 1,000, at the level of the osseous extremities. The rest of the wound is covered with chloramine-T, 10 parts per 1,000.

Sept. 13. The wound now contains 1 bacterium per field (Text-fig. 18). The granulations of the section of the wound treated with chloramine paste, 15 parts per 1,000, have assumed a deep red color. The necrotic tissue has completely disappeared.



TEXT-FIG. 18. Experiment 18. Case 626. Sterilization with 10 and 15 parts per 1,000 of chloramine-T of a wide, severely infected wound of the forearm, accompanied by fracture of the upper part of both bones, and with pyocyanic infection and necrotic tissue.

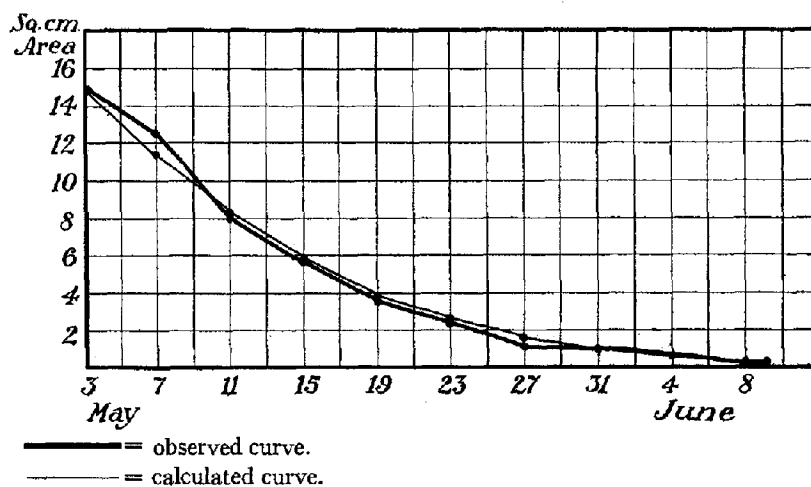
- Sept. 19. Wound is surgically sterile.
 Sept. 23. The bacteria have disappeared from the films.
 Sept. 25. Wound is sutured.

The wounds in the above experiments were in different stages of infection. Some were simple flesh wounds unaccompanied by necrotic tissue and with but slight suppuration. Others showed necrotic tissue and greater suppuration, while in a third group cases of severe local infection were accompanied by fracture. The wound in Experiment 18 was complicated by fracture of the radius and ulna and showed abundant suppuration. Moreover, it contained a large number of *pyocyanus* bacilli. All these wounds were easily sterilized with chloramine-T paste, 10 or 15 parts per 1,000. In 48 hours the blue pus had almost completely disappeared from Wound 18. But sterilization took place more slowly than would have been the case if instillations of sodium hypochlorite had been used. These results were obtained with a paste containing 10 to 15 parts per 1,000 of

chloramine-T. The 15 parts per 1,000 of chloramine-T caused slight irritation to the skin and congested the granulations. Apparently the concentration of chloramine-T must not exceed 10 parts per 1,000.

Effect of Chloramine Paste on the Rate of Cicatrization.

In the following experiments an attempt was made to determine whether chloramine-T, when used in a concentration of 4 and of 10 parts per 1,000, has any effect upon the process of cicatrization. The chloramine paste was applied to wounds whose surface was measured every 4 days, and whose healing curve had been calculated according to the formula of du Nôuy. By comparing the curves as calculated and observed we were able to determine whether the action of the chloramine paste retarded the process of cicatrization. Experiments were made with surface wounds treated with chloramine-T in a concentration of 4 and 10 parts per 1,000. The results were approximately identical in all cases. Only two typical experiments will be described.



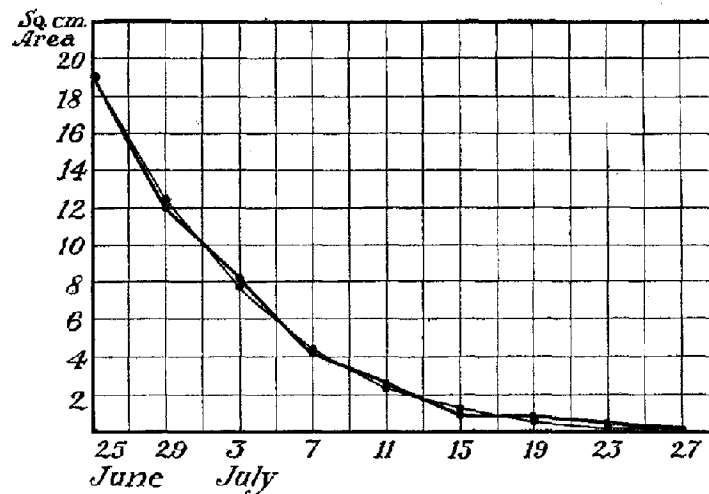
TEXT-FIG. 19. Experiment 19. Case 450. Effect of 4 parts per 1,000 of chloramine upon the rate of cicatrization of a wound. Application of chloramine paste on May 3 to 13.

Experiment 19. Case 450. Effect of Chloramine-T, 4 Parts per 1,000, on the Cicatrization of an Aseptic Wound.—Granulous wound.

May 3, 1916. Wound almost sterile and contains only a few bacteria. The surface measures 15 sq. cm. The cicatrization curve, calculated according to the formula of du Noüy, shows that the healing process should be accomplished on June 8. Chloramine dressing, 4 parts per 1,000.

May 7. The wound is sterile; same dressing. From this time on the cicatrization curve descended and caught up with the calculated curve (Text-fig. 19).

From May 11 to 13, at which time wax was substituted for the chloramine-T, the curve followed the calculated curve.



TEXT-FIG. 20. Experiment 20. Case 519. Effect of chloramine-T, 7 and 10 parts per 1,000, upon the rate of cicatrization of a wound. The wound was dressed from June 27 to 30 with chloramine-T, 7 parts per 1,000, and from June 30 to July 27 with chloramine-T, 10 parts per 1,000.

Experiment 20. Case 519. Effect of Chloramine-T, 7 and 10 Parts per 1,000, upon the Cicatrization of an Aseptic Wound.—Granulating wound at the back of the thigh.

June 25, 1916. Superficial measurement, 19 sq. cm. The secretions contain 10 bacteria per field. The course of cicatrization is calculated according to the formula of du Noüy.

June 27. The wound is surgically aseptic. Chloramine dressing, 7 parts per 1,000, is used until June 30.

June 30 to July 27. Chloramine dressing, 10 parts per 1,000. The curve coincided almost exactly with the calculated curve; nevertheless, after July 19 slight retardation of the healing process apparently occurred (Text-fig. 20).

The above experiments, as well as others that are analogous, show that sodium stearate containing from 4 to 10 parts per 1,000 of chloramine-T does not retard the process of cicatrization to an appreciable extent. In Experiment 20 during the first 25 days the observed curve coincided with the calculated curve, after which the rate of healing became slightly reduced.

SUMMARY.

Sodium stearate has no effect upon the bacteriological condition of a wound, but the addition of 4 parts per 1,000 of chloramine-T renders it antiseptic. Experiment 1 enabled us to compare the action of sodium stearate alone with that of sodium stearate containing 4 parts per 1,000 of chloramine-T. Wounds which had been previously sterilized could be maintained in an aseptic condition by 4 parts per 1,000 of chloramine-T, although in some cases reinfection occurred (Experiments 2, 3, and 5). For this reason the concentration of chloramine-T was increased.

Surface wounds, deep-seated wounds, and osseous cavities, which had previously been either completely or almost completely sterilized, could be maintained for days and even weeks in a condition of surgical asepsis by the use of a paste containing 7 and 10 parts per 1,000 of chloramine-T. Experiments 7, 8, 9, 10, and 12 are examples of this. Slightly infected wounds (Experiments 9, 11, and 12) were sterilized in the same manner.

Next, it was attempted to sterilize wounds which were suppurating and more or less infected, and in some cases accompanied by fracture. This attempt was probably successful because the wounds used for the experiments showed but slight quantities of secretions and only a shallow layer of necrotic tissue. It is useless to attempt to sterilize severely infected wounds with a paste, for the volume of chloramine-T that can be applied is too limited. A large volume of an active substance is required to sterilize a wound which secretes great quantities of pus, for owing, on the one hand, to the dilution of this substance with the secretions, and, on the other, to its combination with the proteins contained in the pus, the concentration of the antiseptic is rapidly diminished. For these reasons it is essential that the antiseptic solu-

tion should be constantly renewed, so that the concentration may be sufficiently strong to effect the destruction of the bacteria. Therefore, the chloramine-T paste cannot sterilize a severely infected wound.

The concentration of the active substance contained in a paste must at the same time be sufficiently weak to be innocuous to the tissues. We have seen that it should not exceed 15 parts per 1,000. Thus, it is evident that if the secretions from the wounds are abundant, the substance could exert its action upon the microorganisms for the space of only a few hours. For this reason the chloramine paste should only be applied under the conditions specified in our experiments; that is, in connection with moderately infected wounds which have been carefully washed with sodium oleate, and possess but slight quantities of secretion. Under these conditions, the chloramine paste effects the complete disappearance of the bacteria and maintains the sterility thus secured for as long a time as may be wished. If the technique followed in the dressing is not exactly as above described, reinfection will occur. If applied in this manner the chloramine paste is not injurious to the tissues, for the cicatrization curves of the wounds thus treated show but slight modification from the calculated curves.

Chloramine paste makes it possible, therefore, to keep wounds sufficiently free from microorganisms so that the effect of substances which are believed to influence cicatrization can be studied.

CONCLUSIONS.

1. Under the conditions of our experiments chloramine paste maintains the asepsis of a wound already sterile, and sterilizes an infected wound.
2. Under the same conditions chloramine paste causes no apparent modification of the cicatrization curve of an aseptic wound.