POSTOPERATIVE TEMPERATURE REACTIONS: REDUCTIONS OBTAINED BY STERILIZING THE AIR WITH BACTERICIDAL RADIANT ENERGY*

SEASONAL VARIATIONS

DERYL HART, M.D.

AND

S. E. UPCHURCH, M.D.

DURHAM, N. C.

FROM THE DEPARTMENT OF SURGERY, DUKE UNIVERSITY SCHOOL OF MEDICINE AND HOSPITAL, DURHAM, N. C.

WITH the introduction of sterilization of the air into our operating rooms, there was a striking improvement in postoperative results;[1, 2, 3] namely:

(1) Lower postoperative temperature elevations.
(2) Shorter duration of postoperative temperature elevations.
(3) Reduction in the percentage of infections.
(4) Improved wound healing.
(5) Less severe systemic reactions.

It was soon noted that during the warmer months this improvement in regard to the elevation of temperature and the duration of elevated temperature following operation was not so good as had been the case during the cooler months. An analysis of 132 individual stages of extrapleural thoracoplasty, performed in a field of sterile air,[4] showed that during the warmer months (May 15 to October 15) the number of patients running a postoperative temperature above 38° C. (100.4° F.) increased to 49 per cent as compared to 28 per cent for the cooler months (October 15 to May 15) while the number of patients running a temperature elevation (above 37.5° C. [99.5° F.] or the preoperative level) for more than four days after operation, increased to 43 per cent as compared to 13 per cent during the cooler months.[4]

Before beginning sterilization of the air, it had been our impression that the best postoperative reactions occurred during the warmer months, at which time we knew the bacterial contamination of the air was low. It has already been reported that, in our occupied operating rooms, the number of pathogenic or other bacteria floating in the air is greater during the cooler than during the warmer months[2, 5] (Charts 1 and 2). Therefore, large operative procedures of choice were postponed until such a time. Naturally, with sterilization of the air we obtained the greatest improvement in our results during those periods when the air contamination was highest. We were surprised, however, to find that under this new condition, even though our results were improved throughout the entire year, our greatest postoperative reactions now occurred during the summer, at which time we had formerly obtained our best results. It soon became evident that some factor other than air contamina-

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tion came into play during the warmer months and was the cause of the greater postoperative temperature reactions occurring then.

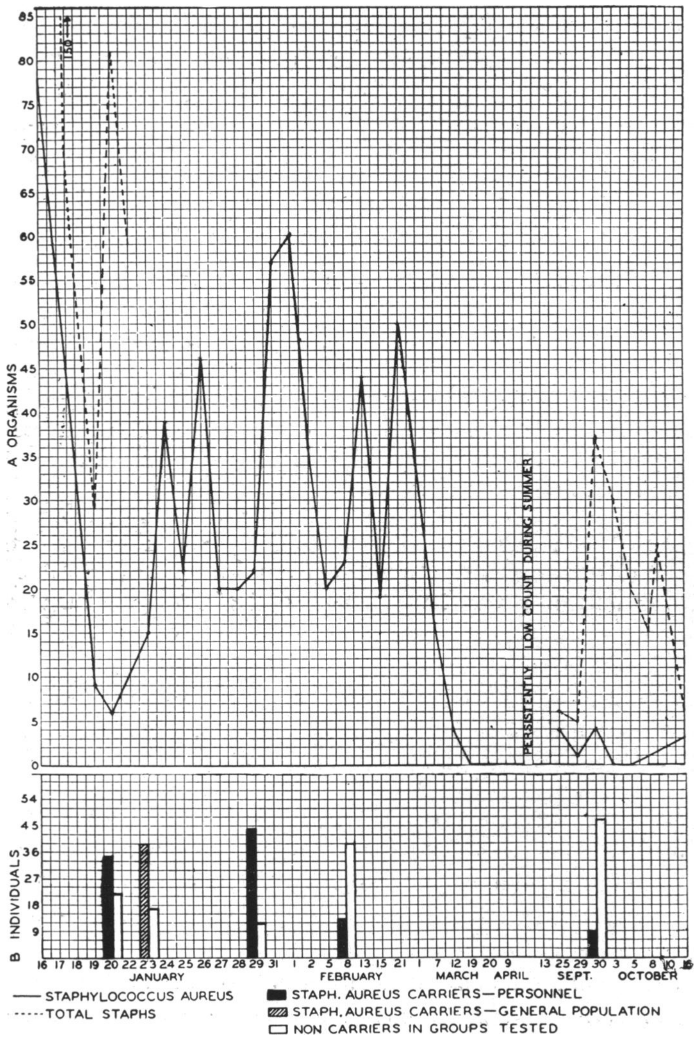

CHART I.—(A) Contamination of the air of the occupied operation room predominantly with Staphylococci. The graph shows the number of colonies settling on a petri dish of blood agar per hour of exposure.

(B) Shows the number of carriers of Staphylococci (in the nose and throat) among the operating room personnel and in the general population.

Some reduction in the number of organisms in the air may have been brought about by care in cleaning, isolating and ventilating the rooms and by masking all individuals who entered. The greatest drop came with the warmer months, at which time there was a sharp decrease in the number of carriers. (Arch. Surg., 34, No. 5, 874, May, 1937).

On attempting to explain this, we thought of the possibility that during the warmer months it was more difficult for the patient to dissipate his body heat and consequently his body temperature might be higher. This may play a part but its rôle must be limited since there is no increased elevation before operation or after the first few days following operation. It seems probable that perspiration may play an important rôle in washing organisms out of deeper, more protected parts of the skin, either by the normal flow or by massage and maceration of the wet skin, so that on a hot day the surface of the skin cannot be kept sterile for more than a few minutes (Fig. 1). This increases the likelihood of wound contamination from the skin of either the patient or some member of the operating team. The most severe and the only extensive infection that we have had in over 400 clean primary incisions performed in a field of sterile air occurred in the first stage of an extrapleural thoracoplasty and resulted from a tear in the operator's glove on a very hot

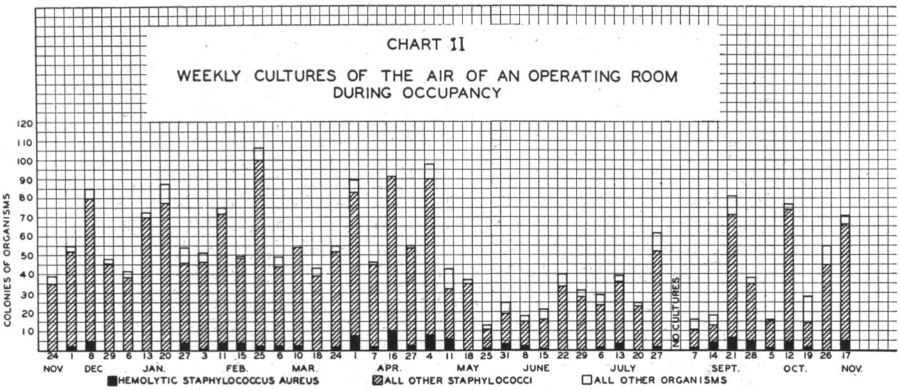

Chart 2.—Weekly cultures of the air of an operating room during occupancy. The cultures were made by exposing a petri dish of blood agar to sedimentation from the air for one hour. After incubating the plates for 48 hours, the colonies were identified and counted. Note the low total count and particularly the few hemolytic yellow Staphylococci during the warmer months. There was a close correlation between the intensity of the growth of these organisms in the noses and throats of the occupants of a room and the degree and type of bacterial contamination of the air in his room.

summer day. A large quantity of perspiration ran into the wound. Even though this was washed out immediately and as thoroughly as possible with sterile physiologic salt solution, the patient's temperature rose to 40° C. within 24 hours, and the wound became extensively infected. The patient recovered following adequate drainage.

In order to obtain a more accurate evaluation of the seasonal variations in the postoperative reaction of the patient as indicated by the temperature elevation and its duration, we analyzed three groups of patients. Some of each group had been operated upon with and some without radiation of the air. The temperature charts were taken as an index of the postoperative reaction since the clinical thermometer is a highly accurate instrument and the records were made by a large number of nurses who had no idea that they were to be used other than as an accurate record of the patient's course. Nothing was left to the interpretation of the doctor who might be prejudiced in favor of air sterilization.

Group I.—Extrapleural Thoracoplasties: These are taken since they are operations of great magnitude, with inevitable trauma; complete hemostasis is difficult to obtain; it may not be possible to obliterate the dead space; and in our cases continuous catgut has been used for the buried sutures. The disadvantage of this type of case is that the temperature reaction may come from a stirring up, or an extension of the tuberculous process. However, this will usually be equalized in a large number of operations.

Group II.—Inguinal Herniorrhaphies: These are ideal in that they are clean incisions in otherwise healthy individuals. They are, however, small

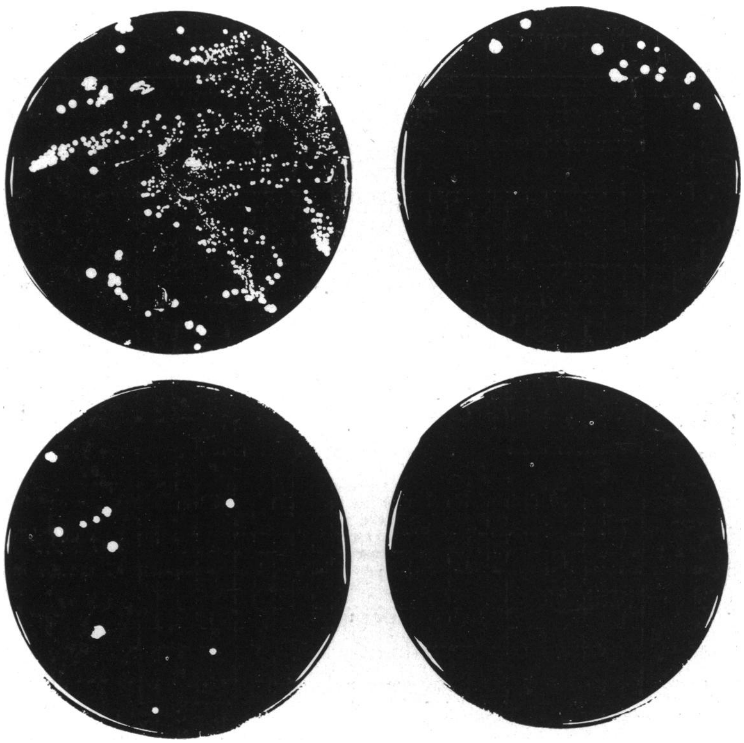

Fig. 1.—Photographs of one of many series of 48-hour cultures of perspiration made from the skin of the hands of four members of the operating team (or operative region). The organisms are predominantly white Staphylococci. Cultures of the hands made immediately following their preparation for the operation showed no growth.

operative procedures and should show little reaction or infection even without sterilization of the air (in our hospital 3.6 per cent, all mild[3]). In this group of cases, since this was not a planned experiment, but a review of operations already performed, most of the larger herniae in obese individuals are in the group with radiation. A higher percentage of the smaller herniae, in which infection is less likely to occur, are in the group without radiation. This should be kept in mind in interpreting the charts since one would expect the greater postoperative reaction following the larger operation. Also in this group with radiation two of the highest reactions occurred in two children of one and one-half and two years of age, who had their hernia repaired under ether anesthesia (Charts 4 A, 7 A, and 10 A—June and July). It is our impression that very young children operated upon under ether anesthesia frequently run a relatively high postoperative temperature.

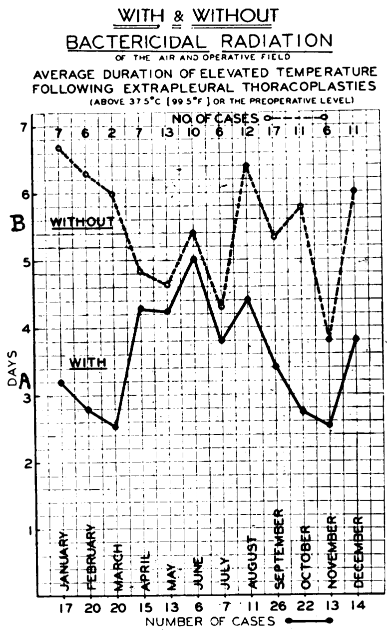

CHART 3.

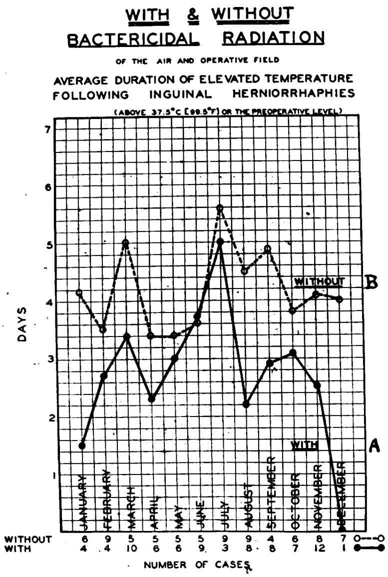

CHART 4.

CHART 3.—Average duration of elevated temperature following extrapleural thoracoplasties (recorded by month of operation). (A) With bactericidal radiation. (B) Without bactericidal radiation.

The following points should be noted in Charts 3, 4 and 5:

(1) With bactericidal radiation there was a reduction in the average duration of elevated temperature throughout the entire year.

(2) The reduction in the average duration of elevated temperature when the air was sterilized was greatest when the bacterial contamination was highest. (Compare A with B and correlate with Charts 1 and 2.)

(3) Without radiation the decrease in the average duration of postoperative temperature elevation during the warmer months was not as great as the drop in air contamination (Charts 1 and 2).

(4) With sterilization of the air the postoperative temperatures were of the longest average duration during the warmer months.

(5) Paragraphs three and four above, suggest that during the warmer months some condition other than air contamination enters the picture and causes the increased systemic temperature reaction. This condition may be the increase in the temperature and humidity of the surrounding air, but it seems more likely to be an increase in the wound contamination brought about by the bacteria in the perspiration resulting from this high temperature and humidity level.

CHART 4.—Average duration of elevated temperature following inguinal herniorrhaphies (recorded by month of operation). (A) With bactericidal radiation. (B) Without bactericidal radiation. See legend appended to Chart 3 for points of special interest.

Part of the higher average elevation and longer average duration of elevated temperature during June and July where radiation was used was caused by operations on two young children (one and a half years old for June and two years old for July), under ether anesthesia. Children of this age are more likely than adults to run a higher and longer temperature elevation following any operation under ether anesthesia. Part of the temperature reaction during February with radiation was caused by a postoperative parotitis.

GROUP III.—Radical Mastectomies: These form a very poor group for study since the operation leaves the skin flaps with a poor blood supply. As a result, the skin may slough and secondary surface infection may follow. In addition to this, three of the cases in which radiation was used showed ulceration before operation. These three cases had a mild infection in the incision following operation and these alone accounted for three of the higher temperature recordings noted in Charts 5 A, 8 A and 11 A (February, March and October). Such ulcerated cases were ruled out in statistical analyses for postoperative wound infections in clean primary operative incisions both in

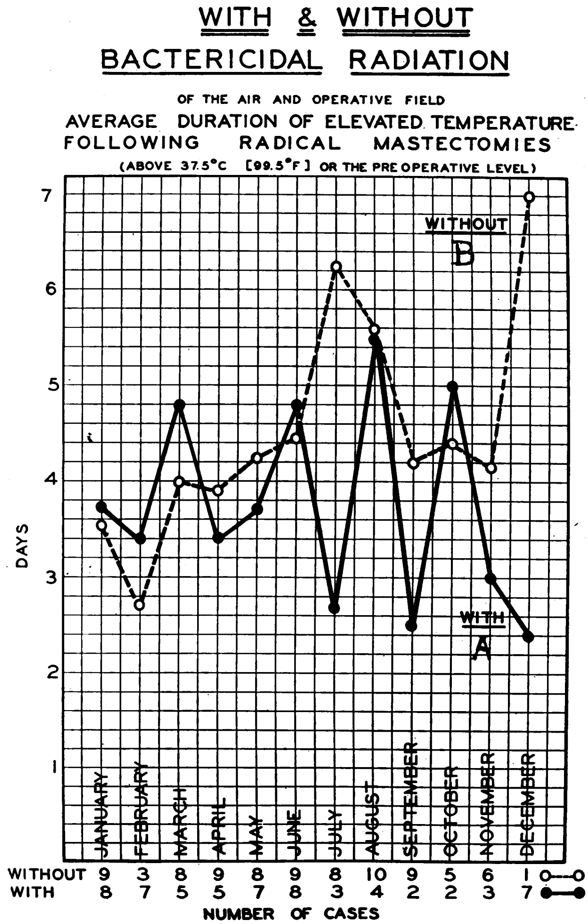

CHART 5.—Average duration of elevated temperature following radical mastectomies (recorded by month of operation). (A) With bactericidal radiation. (B) Without bactericidal radiation. Note that for three months, February, March and October, the average temperature duration each month was increased for the group with radiation by one mild wound infection resulting from an ulcerated, infected tumor present at the time of operation. In curve B (without radiation) there was a very short average duration of elevated postoperative temperature during January, February and March, so this graph does not follow the curve shown in Chart 3. Radical mastectomy wounds are a poor selection for this study since, in addition to the cases showing ulceration before operation, the impaired blood supply in the large skin flaps may result in sloughing with the possibility of secondary, localized, superficial infection which may cause a low grade temperature reaction until healing is complete. Compare with Charts 3 and 4 and see legend appended to Chart 3 for points for special consideration.

the radiated and nonradiated groups. These ulcerated cases were, therefore, not included in previous reported statistics on operating room infections.

Each of the three groups of operations were divided into two series, one including all operations performed in a field of sterile air and the other, all those performed without air sterilization.*

For both series of each group, every operation was recorded in the month during which it was performed. Three charts were made of each series, so arranged as to compare the results in series A, where bactericidal radiation was used, with the results in series B, where radiation was not used. For both series in each group, the charting by months shows at a glance the variations dependent on the time of year and a comparison of A with B in each group shows the relative improvement brought about by radiation of the air during each month of the year.

The average duration of elevated temperature following operation is shown by months for:

Group I	Extrapleural Thoracoplasties	A—with radiation B—without radiation	Chart 3
Group II	Inguinal Herniorrhaphies	A—with radiation B—without radiation	Chart 4
Group III	Radical Mastectomies	A—with radiation B—without radiation	Chart 5

The maximum temperature elevation for every case (highest point at, or above which there are more than two recordings) expressed in percentages of the total number of such operations performed under similar conditions during the month is shown by months for:

Group I	Extrapleural Thoracoplasties	A—with radiation B—without radiation	Chart 6 A, B
Group II	Inguinal Herniorrhaphies	A—with radiation B—without radiation	Chart 7 A, B
Group III	Radical Mastectomies	A—with radiation B—without radiation	Chart 8 A, B

In these charts each case is placed in the division (37°–37.5°, 37.6°–38°, 38.1°–38.5°, 38.6°–39° and 39°+ C.) in which it falls. The number of cases in each division is then expressed as a percentage of the total number of cases for the given month to give Charts 6, 7 and 8.

Every recorded temperature for eight days following operation (taken at four-hour intervals when the patient is running any elevation, otherwise every

* If there was any difference in the general operating room technic it was less rigid where air sterilization was used than where it was not used. This is particularly true of the thoracoplasty and mastectomy groups and applied especially to skin sterilization, masking, number of visitors allowed, time selected for operation, and the duration of occupancy of the room before operation. The question of difference in masking has been raised frequently. Two large gauze masks each eight thicknesses of butter gauze were worn over the nose and mouth during many of the thoracoplasties without radiation, while only one was worn, without other covering, for most of the thoracoplasties with radiation.

WITH BACTERICIDAL RADIATION

OF THE AIR AND OPERATIVE FIELD

TEMPERATURE ELEVATIONS FOLLOWING EXTRAPLEURAL THORACOPLASTIES
PERCENTAGES BASED ON THE HIGHEST TEMPERATURE FOR EACH OPERATION

EACH OPERATION IS PLACED IN THE MONTH DURING WHICH IT WAS PERFORMED AND IN THE HIGHEST TEMPERATURE GROUP IN OR ABOVE WHICH THERE ARE AS MANY AS THREE RECORDINGS DURING THE POSTOPERATIVE COURSE

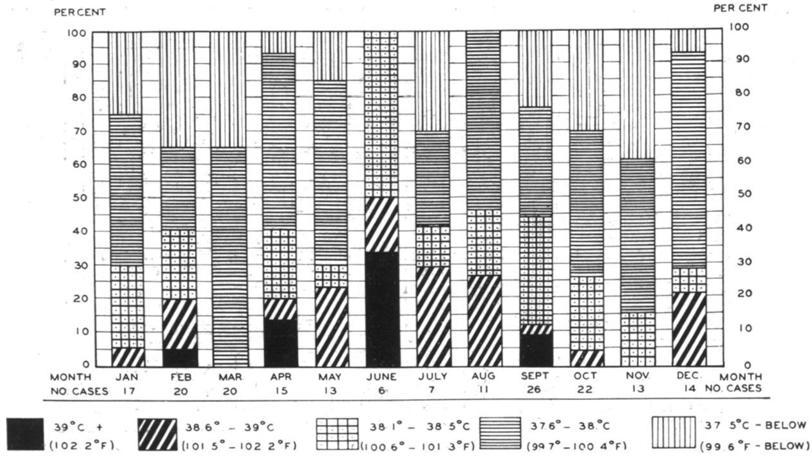

CHART 6A.

WITHOUT BACTERICIDAL RADIATION

OF THE AIR AND OPERATIVE FIELD

TEMPERATURE ELEVATIONS FOLLOWING EXTRAPLEURAL THORACOPLASTIES.
PERCENTAGES BASED ON THE HIGHEST TEMPERATURE FOR EACH OPERATION.

EACH OPERATION IS PLACED IN THE MONTH DURING WHICH IT WAS PERFORMED AND IN THE HIGHEST TEMPERATURE GROUP IN OR ABOVE WHICH THERE ARE AS MANY AS THREE RECORDINGS DURING THE POSTOPERATIVE COURSE

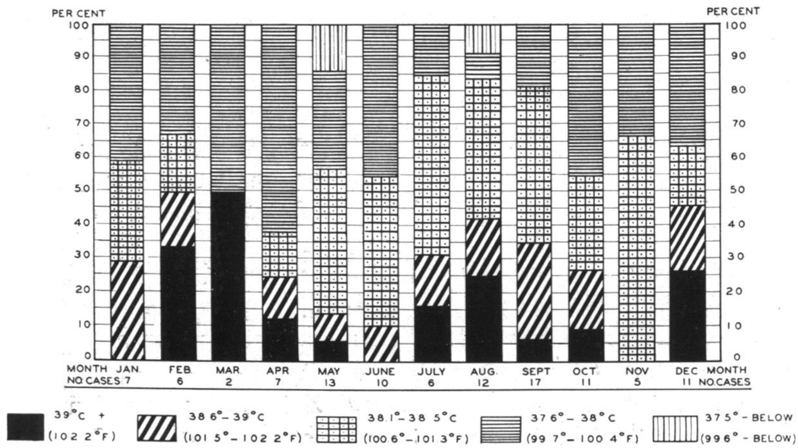

CHART 6B.

CHART 6.—Maximum temperature elevations following extrapleural thoracoplasties. (A) With bactericidal radiation. (B) Without bactericidal radiation.

Each operation is placed in the month during which it was performed and in the highest temperature group (37°–37.5°; 37.6°–38°; 38.1°–38.5°; 38.6°–39°; 39.1°+C.), in or above which there are as many as three recordings during the postoperative course. The number of cases in each temperature group is then expressed as a percentage of the total number of thoracoplasty operations performed during that month. This is done to facilitate comparisons, since the total for each month is 100 per cent regardless of the number of operations performed. The total number of cases on which the percentages are based is given beneath each month.

Special attention is called to the same five general points of interest in regard to the elevation of temperature in Charts 6, 7 and 8 as are given for the duration of temperature in the legend for Chart 3. (See legend for Chart 3, substituting average elevation for average duration of temperature).

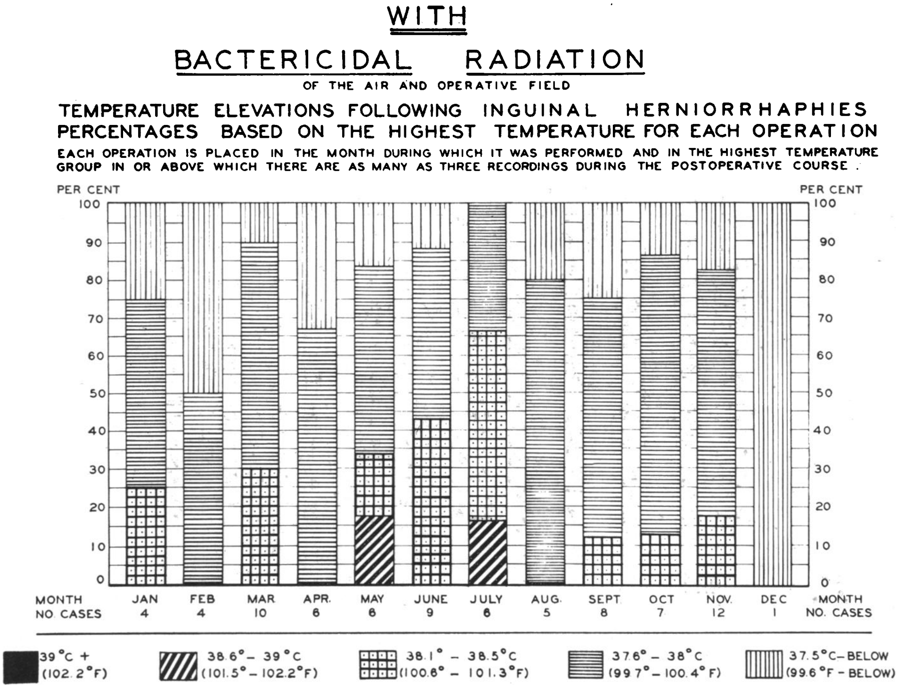

CHART 7A.

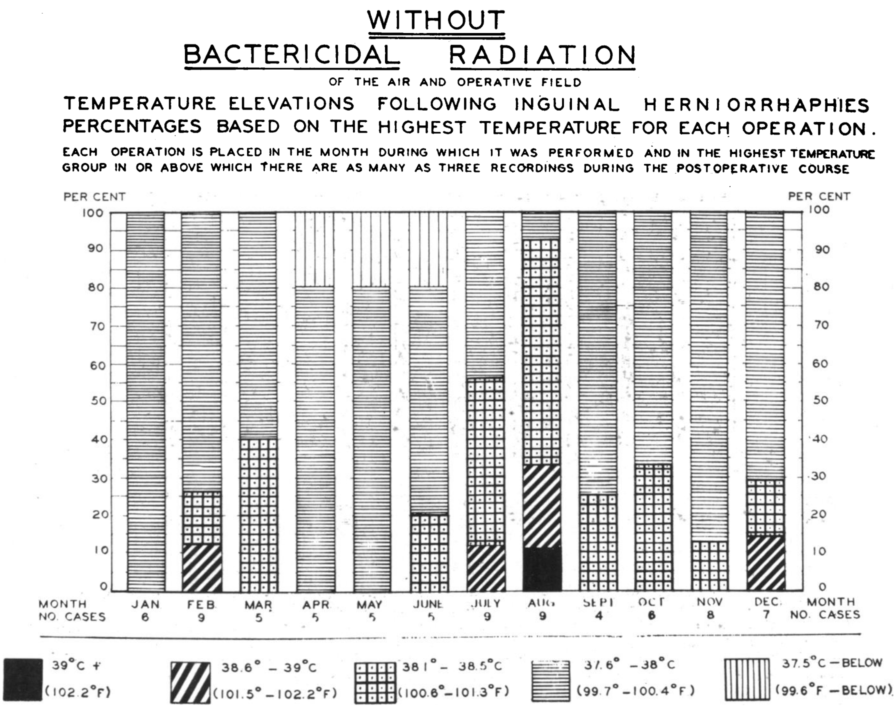

CHART 7B.

CHART 7.—Maximum temperature elevations following inguinal herniorrhaphies. (A) With bactericidal radiation. (B) Without bactericidal radiation.

The method used in making the chart and the reason therefor are given in the legend for Chart 6. The special points for consideration in regard to the elevation of temperature are similar to those given for the duration of temperature elevation in the legend to Chart 3. See legend to Chart 4 for note about higher temperatures on two small children operated upon during June and July, and one patient with postoperative parotitis operated upon in February.

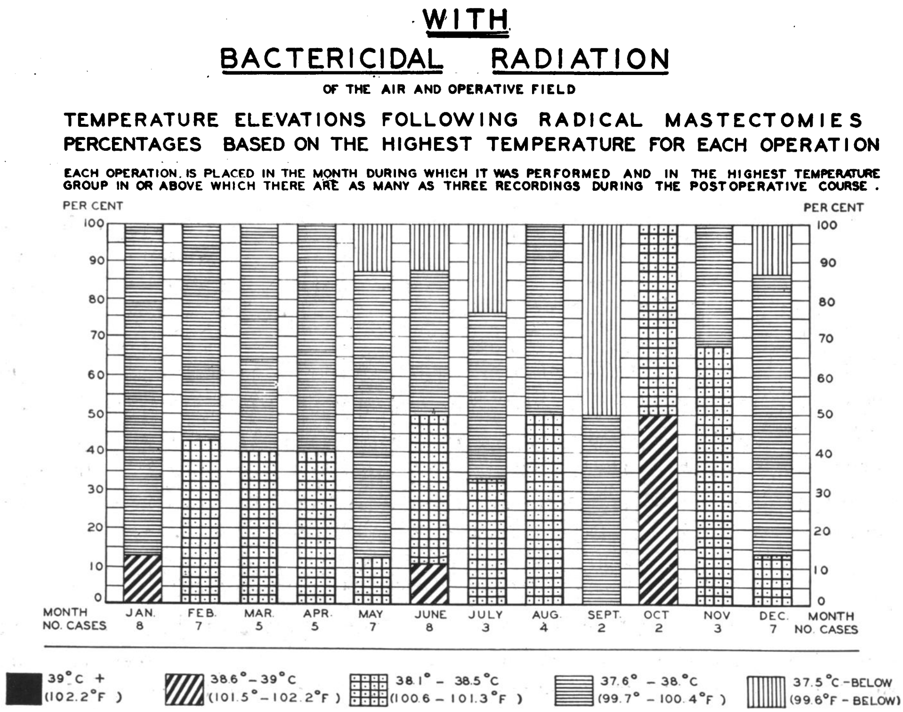

CHART 8A.

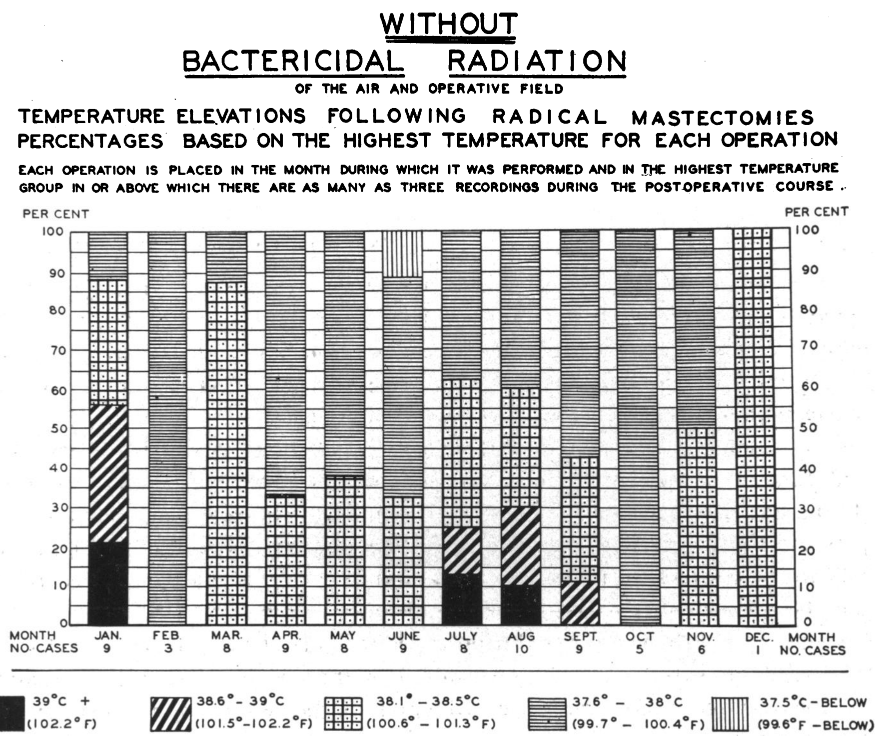

CHART 8B.

CHART 8.—Maximum temperature elevations following radical mastectomies. (A) With bactericidal radiation. (B) Without bactericidal radiation.

The method used in making the chart and the reason therefor are given in the legend for Chart 6. The points for special consideration in regard to the elevation of temperature are similar to those given for the duration of the temperature elevation in the legends to Charts 3 and 5.

four hours except at 12 midnight and 4 A.M. when the patient is sleeping) on every patient is shown by months for:

GROUP I	Extrapleural Thoracoplasties	A—with radiation B—without radiation	Chart 9 A, B
GROUP II	Inguinal Herniorrhaphies	A—with radiation B—without radiation	Chart 10 A, B
GROUP III	Radical Mastectomies	A—with radiation B—without radiation	Chart 11 A, B

In preparing Charts 9, 10 and 11, every recorded temperature for eight days following operation was placed in the appropriate division (37°–37.5°, 37.6°–38°, 38.1°–38.5°, 38.6°–39° and 39°+ C.) and the total number of recordings in each division was then expressed as a percentage of the total such recordings for the given month. The total number of operations for each month is shown at the bottom of the charts.

EFFECT OF BACTERICIDAL RADIATION OF THE AIR

Without sterilization of the air, the average duration of the postoperative temperature elevation was longest when the air contamination was high and shortest when the air contamination was low. With sterilization of the air, there was a reduction in the average duration of elevated postoperative temperature roughly proportional to the degree of air contamination (compare A with B in Charts 3, 4 and 5 and correlate with Charts 1 and 2). There was a similar reduction in the average highest elevation of postoperative temperature (compare A with B in Charts 6, 7 and 8 and correlate with Charts 1 and 2), and in the height of the total temperature recordings for eight days following operations (compare A with B in Charts 9, 10 and 11 and correlate with Charts 1 and 2).

SEASONAL VARIATIONS IN THE POSTOPERATIVE TEMPERATURE REACTION

When bactericidal radiation was not used, the average duration of elevated temperature was definitely shorter during the earlier of the warmer months in extrapleural thoracoplasties, April through July, (Chart 3 B) and in inguinal herniorrhaphies, April through June, (Chart 4 B). Radical mastectomies (Chart 5 B) did not show such a drop since the curve was very low for January, February and March but it was also low during April, May and June as compared to July, August, and December. The charts showing the highest postoperative temperature elevations for each case (Charts 6 B, 7 B and 8 B) and those showing every temperature recording for eight days following operation (Charts 9 B, 10 B, and 11 B) have similar low recordings for the earlier warm months, April through June. All the charts (3 B through 11 B) showed a rise during the latter part of the warmer months.

With the introduction of sterilization of the air by bactericidal radiation, as noted above, there was little reduction in the temperature elevation and little shortening of the duration of elevation during these warmer months when

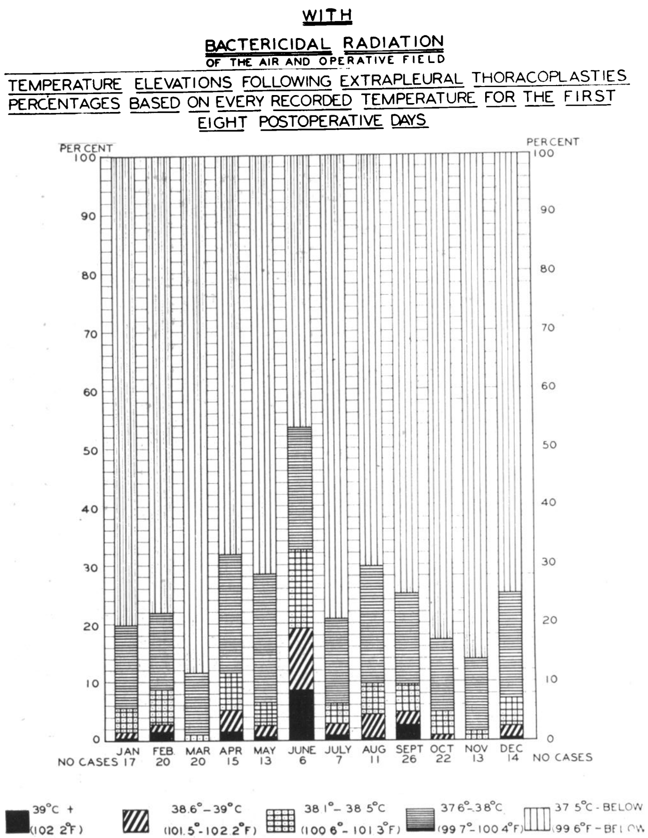

Chart 9A

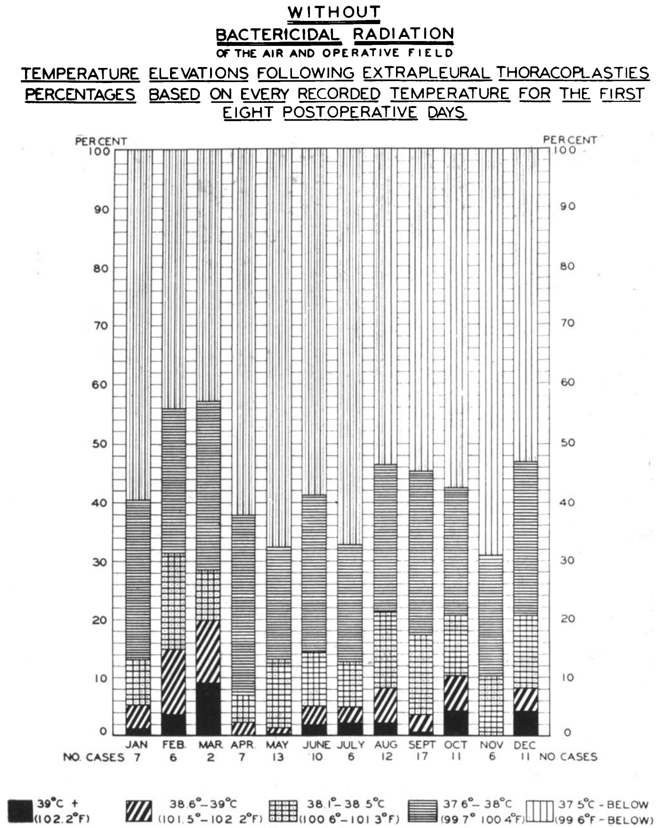

Chart 9B

CHART 9.—Every recorded temperature for eight days following extrapleural thoracoplasties. (A) With bactericidal radiation. (B) Without bactericidal radiation.

The percentages in this chart are based on every recorded temperature for eight days following operation (taken every four hours when the patient was running any elevation; otherwise, every four hours except at 12 midnight and 4 A.M., when sleeping). Every recorded temperature for eight days following operation was placed in the month during which the operation was performed and in the temperature group (37°–37.5°; 37.6°–38°; 38.1°–38.5°; 38.6°–39°; 39.1°+C.) in which it fell. The number of recordings in each temperature group was then expressed as a percentage of the total recordings in all the temperature groups for that particular month. Compare with Chart 6, where the percentages are based on the highest level reached during the postoperative course. This chart naturally shows a much higher percentage of normal temperatures than Chart 6. It does not cover more than eight days, since most temperatures are down to normal in less than that time. To cover a longer period would increase the percentage of the lower and diminish the percentage of the higher temperature groups. Attention is called to the same points of special interest as given in the legends for Charts 3 and 6.

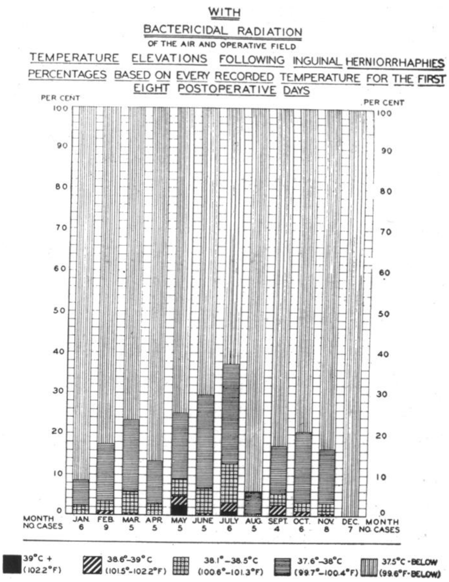

Chart 10A

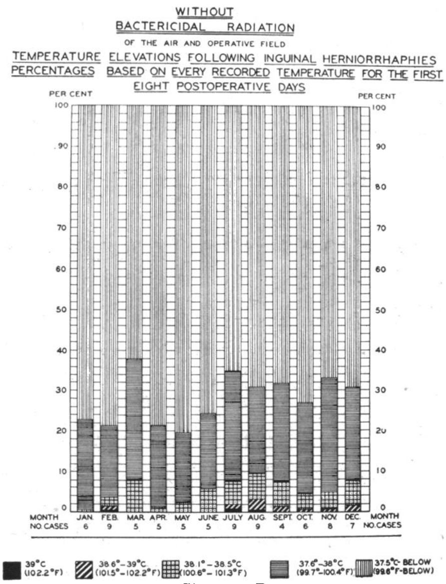

Chart 10B

CHART 10.—Every recorded temperature for eight days following inguinal herniorrhaphies. (A) With bactericidal radiation. (B) Without bactericidal radiation.

The percentages are based on every recorded temperature for eight days following operation. See legend to Chart 9 for note as to how the chart was prepared and the reason therefor. This chart has the same relationship to Charts 4 and 7 that Chart 9 has to Charts 3 and 6. See legends to Charts 4 and 7, and the legend to Chart 3 for five points for special consideration.

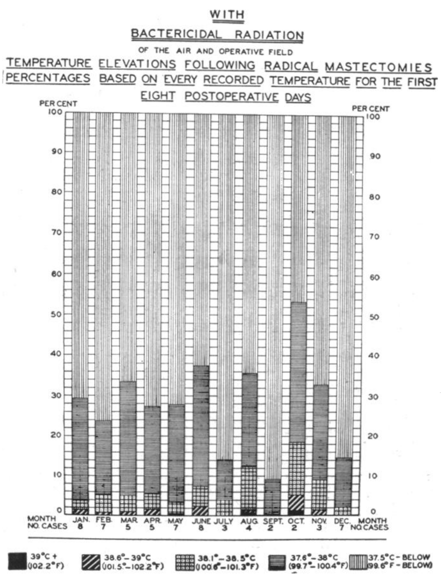

Chart 11A

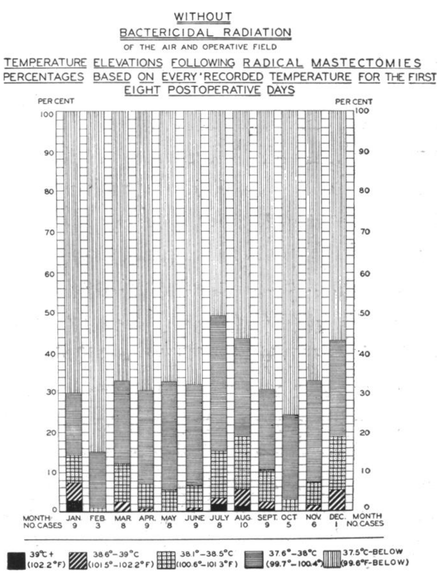

Chart 11B

CHART 11.—Every recorded temperature for eight days following radical mastectomies. (A) With bactericidal radiation. (B) Without bactericidal radiation.

The percentages are based on every recorded temperature for eight days following operation. See legend to Chart 9 for note as to how the chart was prepared and the reason therefor. This chart has the same relationship to Charts 5 and 8 that Chart 9 has to Charts 3 and 6. See legends to Charts 5 and 8 and the legend to Chart 3 for five points for special consideration.

the air contamination is lowest. When the air is sterilized we have the highest and most prolonged temperature reactions during the warmer months. It can also be noted that where radiation was not used (B in Charts 3 through 11) the drop in the average duration of elevated temperature and average height of elevation was not as great as the drop in the amount of air contamination (compare A and B Charts 3 through 11 and correlate with Charts 1 and 2).

COMMENT.—It seems to me that we have two conditions which vary with the time of year and that each has its effect on the postoperative temperature reaction. One of these is air contamination, which is quite variable with peaks and depressions throughout the year but in general is higher during the winter, may drop during April or May and begin to rise again from July to September or October (Charts 1 and 2). This contamination can, to a large extent, be overcome by sterilization of the air, and the results of this sterilization are seen by comparing A with B in the charts. The other condition is the temperature and humidity of the outside air, which may affect the patient directly by its influence on the dissipation of body heat or more indirectly by increasing perspiration, which facilitates the passage of bacteria out of the deeper layers of the skin, either directly by flow or indirectly by massage and maceration of the wet skin during the operative procedure. This contamination of the skin surface impairs our sterile technic and predisposes to wound contamination. In our section of the country, the general temperature and humidity of the air, with its resultant effect on the individual causing an increase in perspiration, reaches its peak during July and August, but may be of some significance from May through September. During April, May and June, the air contamination is usually low while the temperature and humidity are such that excessive perspiration is rare. Our best postoperative results without air sterilization occur during this period. During July and August, the air contamination is usually low but excessive perspiration is at its peak for the year. From April or May through July or August, we are less likely to obtain remarkable reductions in the postoperative temperature reactions by sterilization of the air, while during July and August, contaminated perspiration may cause an increase in the intensity of this reaction either with or without sterilization of the air. During September and October, with the cessation of excessive perspiration, there may be varying degrees of increase in the air contamination. In so far as this increasing air contamination causes an increase in the postoperative temperature reaction, we can obtain improvement by sterilization of the air. These general surgical principles, however, will in general be relatively stable with any operator working in the same operating room with a constant personnel. Local and general resistance of the patient may play an important part in the reaction in the wound and may vary widely with different individuals and with operations in different parts of the body. Particularly in the case of mastectomies, the local resistance may vary greatly as the result of variation in the amount of fat present and the blood supply available to all parts of the flaps. In certain cases without primary infection sloughs develop in the skin flaps. Secondary infection is then inevitable and may cause slight but prolonged elevation of temperature. Three of the patients in the group of mastectomies with radiation had ulcerated lesions before operation, and following operation their wounds became mildly infected. Even though the ulcerated area was entirely covered during the operation, these patients ran a definitely increased risk of infection as a result of cutting across the lymphatics which drained the ulcerated area. These three infections accounted for three of the peaks of temperature elevation and duration where radiation was used (Charts 5 A, 8 A and 11 A—February, March and October). Children having a general anesthetic are more likely than adults to run a relatively high postoperative temperature elevation. This accounted for two of the higher temperature levels in herniorrhaphies performed with radiation (Charts 4 A, 7 A and 10 A—June and July).

SUMMARY.—(1) In the well-run, modern operating room air contamination by pathogenic bacteria is the greatest source of danger of wound contamination as indicated not only by gross suppuration in the occasional case but by an increased local and systemic reaction in many patients whose wounds never show evidence of gross suppuration. Over 95 per cent of this danger of contamination from the air can be eliminated by sterilization of the air with bactericidal radiation.[1, 2, 3, 4]

(2) In the occupied operation room this air contamination is, in general, much lower during the warmer than during the cooler months.

(3) Without air sterilization the decrease in the postoperative reaction of the patient during the summer is not as great as the reduction in the air contamination with pathogenic bacteria.

(4) With the elimination of air contamination by sterilization, the postoperative reaction of the patient is greater during the warmer months than during the colder months.

(5) Three and four in the summary can be explained by the rôle which perspiration may play in producing wound contamination by washing bacteria out of the deeper layers of the skin during the operative procedure.

CONCLUSIONS

Before the introduction of antiseptic and aseptic surgery, contact contamination of operative wounds played by far the major rôle in operating room infections, so that despite the emphasis placed by Lister on the air as a source of danger it came to be ignored.

With the great reduction in contact contamination brought about by the development of aseptic surgery and the improved local resistance of the patient brought about by improved hemostasis and the development of relatively atraumatic surgery, operations of progressively increasing magnitude were performed. With the elimination of most of the contact transfers of large numbers of bacteria in operative procedures, the fewer bacteria floating in the air have assumed the place of major importance to-day. This same method of transfer probably plays an important rôle in the spread of certain infectious diseases, particularly those affecting the respiratory passages.[6, 7] In the small incisions made in individuals in vigorous health with minimal trauma, good hemostasis, nonirritating sutures and ligatures, and located in healthy tissue where dead space can be obliterated and the part kept at rest during the early stages of healing, the few mildly pathogenic organisms entering from the air will very rarely cause suppuration. As we diverge from these more or less ideal conditions and operate upon the patient who has less general resistance, carrying our larger procedures in which a greater amount of trauma is inevitable, in which complete hemostasis is difficult to obtain, at times in tissues of lowered resistance, possibly with dead space which cannot be obliterated or parts which cannot be immobilized or with the use of catgut which may at times be indicated, occasionally with the necessity of inserting drains, and during epidemics of respiratory infections when not only may the number of bacteria but the pathogenicity of the bacteria in the air be increased, the dangers of the wound's becoming infected with organisms dropping out of the air becomes progressively greater. Under any given conditions the local and systemic reaction of the patient is greater when more virulent organisms in larger numbers enter the wound.

With the elimination of the air as a source of wound contamination, perspiration assumes a position of major importance. By continuously washing bacteria out of the protected deeper layers of the skin it prevents the maintenance of sterility on the surface of the skin of the patient which may at times be exposed in the operative field, contaminates the sterile gowns of the team, and accumulates, in quantity, in the rubber gloves from which it may be expressed into the wound if an accidental puncture occurs. Perspiration may thus help account for the fact that in the summer months there is a greater postoperative temperature reaction than would be expected with the low air contamination. Likewise, the results obtained by sterilization of the air are not as striking during the warmer months as they are during the cooler part of the year when the air contamination is greater.

Air conditioning with the elimination of perspiration may bring us another step nearer that probably unattainable ideal of operating without the entrance of any bacteria into the wound.

REFERENCES

[1] Hart, Deryl: Sterilization of the Air in the Operating Room by Special Bactericidal Radiant Energy. Jour. Thorac. Surg., **6**, No. 1, 45, October, 1936.

[2] Hart, Deryl: Operation Room Infections; Control of Air-Borne Pathogenic Organisms, with Particular Reference to the Use of Special Bactericidal Radiant Energy; Preliminary Report. Arch. Surg., **34**, No. 5, 874, May, 1937.

[3] Hart, Deryl: Sterilization of the Air in the Operating Room by Bactericidal Radiant Energy: Results in Over 800 Operations. Arch. Surg. In press.

[4] Hart, Deryl: Sterilization of the Air in the Operating Room with Bactericidal Radiation. Jour. Thorac. Surg., **7**, No. 5, 525–535, June, 1938.

[5] Hart, Deryl, and Schiebel, H. M.: Rôle of the Respiratory Tract in Air Contamination: A Comparative Study of the Bacterial Flora of the Air of a Room with the Flora

in the Nasopharynx of Its Occupants: Correlation with Contamination of the Air in the Operating Room. Arch. Surg. In press.
[6] Wells, W. F., and Wells, M. W.: Air-Borne Infections. J.A.M.A., **107**, 1699, 1936.
[7] Wells, W. F., and Wells, M. W.: Air-Borne Infection. J.A.M.A., **107**, 1805, 1936.

DISCUSSION.—DR. REGINALD H. JACKSON (Madison, Wis.): History, I am sure, will record an ever increasing debt of gratitude to Hart and his colleagues for their pioneer work in calling attention to the hitherto generally overlooked fact that entirely aside from the long-recognized sources of clinical wound infection, such as imperfect sterilization of instruments, ligatures, gloves, *etc.*, there exists a most potent direct source of wound contamination and infection in the air of the operating room, one which strikes with a frequency and viciousness in direct relation to: First, the number of human beings in the room and; second, the time of the year, the peak of clinical wound infections synchronizing with the peak of upper respiratory infections of humans.

All surgeons, without exception, must be aroused to a renewed interest in this subject. Through the scientific investigations of Hart, Ives, and Hirschfield, J. Staige Davis and others, the following statements may be accepted as unequivocally true:

(1) That practically all operating rooms contain, in the air, on the floors, walls and ceilings, more Staphylococci and, at times, hemolytic Streptococci, than any other department in the hospital except the nose and throat department.

(2) The *Staphylococcus aureus* is the principal and general source of infection of clinical wounds.

(3) These infecting agents gain direct entrance to the wound by precipitation from the air overlying the wounds, and by droplet infection.

(4) Every wound made by the surgeon is contaminated and potentially infected in direct proportion to its size and the length of time of its exposure.

(5) There are nearly always in the room, carriers of *Staphylococcus aureus* or hemolytic Streptococcus.

(6) The surgeon himself may unwittingly be a carrier.

(7) A run of such cases always means that the air of the room contains (as proved by culture) a higher percentage of these organisms than normally.

(8) While the average incidence of such baleful clinical wound infections is from 4 to 6 per cent (heretofore recognized as an irreducible minimum), it at times rises to 18 to 20 per cent.

(9) A scientific bacteriologic check-up on every link in the so-called aseptic chain may achieve a 100 per cent credit, and yet the incidence of clinical wound infections continues at two to three times the average.

Certainly we all know that it is within the power of the surgeon to change a contaminated, potentially infected traumatic wound into a clean one which will generally heal per primam, through débridement and thorough cleansing with soap. Why—in view of the fact that nearly every wound made by the surgeon may be proved to be contaminated with Staphylococci from the air—should we not apply the same "debacterializing" method? Objections on the basis that it would be a messy, unsurgical and unnecessary procedure that would violate the great surgical principle of keeping the wound as dry as possible, and would militate against ideal wound repair, are annihilated by actual trial of the method in over 200 instances, proving that instead of militating against primary union, it actually insures ideal wound repair and lowers the incidence of clinical wound infection practically to the vanishing point.

There will always be instances of secondary wound infection, as uncontrollable factors are involved entirely aside from the presence of bacteria in the wound. Whether the "debacterialization" of a clinical wound is accomplished before closure by this method or by the Hart method is immaterial; I am convinced that surgeons should and will use one or the other until something better offers. We have been hypnotized too long by the phrase "the aseptic chain technic," overlooking the factor of direct air contamination which Hart and others are again calling to our attention. Any surgeon who doubts the verity of these contentions may, and should, repeat the tests under the supervision of a bacteriologist and forever be disabused of the idea that it is all nonsense.

Dr. Waltman Walters (Rochester, Minn.): It seems to me that this epochal study, clinically as well as experimentally, deserves more consideration by this Society as well as by other surgical societies than has resulted to date. It carries a great deal of economic as well as medico-legal significance. I would like to see this topic chosen for presentation at a symposium at the next meeting of this Society. To change the set-up in operating rooms throughout the country will entail considerable expense, which must be borne by the patient in the long run. It will be interesting to note the results which other surgeons obtain in closed, irradiated operating rooms.

At the Mayo Clinic, we are able to obtain consent for postmortem examination in approximately 90 per cent of cases. For 14 years, I have studied the causes of death after operations on the biliary tract and stomach, and the outstanding thing has been the infrequency with which infection of wounds or intraperitoneal infection has played a part, unless there was an associated toxemia or debility or unless a severely infected lesion was being operated upon. In the cases which I studied, the failure to recover after surgical procedures was caused principally by pulmonary complications such as infection, infarcts or embolism.

Doctor Hart stated that, in the late summer months, when perspiration is more active than at other times, the incidence of infections increases. Might that not be a matter of lowered resistance of the patients after passing through extremely hot weather, in which we know the physiologic resistance of the patient as well as of the doctor is reduced, rather than an increase in the frequency or virulence of the infection? Doctor Hart has stated, I believe, that the temperature and pulse rate indicate the degree of infection. Might it not be that infections in other parts of the body, in the respiratory tract and urinary tract particularly, which frequently occur immediately after operation, are partly responsible for fever or increase of pulse rate?

There is another factor in the study which I think deserves consideration. What is the effect of such irradiation in a closed operating room over long periods each day on the people who work in that room, such as the nurses, interns, anesthetists and the surgeons? We are studying the effect of a strong light used in the operating field, on fatigue of the eyes of the surgeon and assistants. There are many possibilities for studying the effects of the performance of surgical procedures on the surgical team itself, such as the effects on the surgeon's blood pressure after two or three operations have been carried out, the fatigue of the eyes, muscles and nerves, and so forth. Has Doctor Hart studied these questions in relation to irradiation of the operating room as far as the personnel of the operating room is concerned? That, it seems to me, should be an important part of the study. If this method of sterilization of the surgical field plays a rôle in the reduction of incidence of infection, we must be prepared to withstand criticism for failure to use it, if infections of wounds should develop. I hope that there will be some surgeons who also will study this problem from the points of view of the set-up of operating rooms in general use to-day.

DR. ISADORE COHN (New Orleans, La.): There are two or three thoughts which have occurred to me, and I believe many of them could be answered very definitely almost by a rising vote. Do the members of this Society have, generally, so large a percentage of wound infections, not under irradiated conditions? The men who are operating in smaller towns have to consider the expense of introducing this apparatus. I believe further, that if we sincerely feel this is an essential thing, is it not our duty when we get home to insist that hospitals do this? Are we going to revert to the time of Lister and his carbolic spray?

I think Doctor Walters' suggestion of a symposium is an excellent thing. I wonder if there is not some possibility of a lawyer taking a case for somebody with a burn which they might say might be accounted for by irradiation.

DR. FRANK STRICKLER (Louisville, Ky.): As I see it, this question simmers down to two propositions. We can sterilize the operating room, the dressings, the instruments, but we still have the patient to consider. We all know that we have foci of infection in the gallbladder, teeth, tonsils, intestinal tract, *etc.* The problem is, if we sterilize all these other agencies, how are we going to sterilize the patient? If we make a wound and he has a lot of bacteria circulating in the blood stream, he is likely to develop infection, and I do not believe we can ever overcome that. Up in Kentucky we do not have so many infections. Once or twice I have inadvertently punctured a glove, and the patient got well without infection. I do not understand why we get so many infections in certain parts of the country. Maybe we are careless and do not watch things so well, but the patients heal up all right. There are many angles to be considered.

DR. DERYL HART (Durham, N. C., in closing): I agree with what Doctor Jackson has said, and I think that washing out the wound is a valuable procedure. We have followed this technic for many years and find that it washes out much débris, particularly loose particles of fat, coagulated serum, and blood. Before beginning sterilization of the air we washed out all large wounds very thoroughly, but were disappointed in that we could not eliminate the occasional infections by such a technic. I want to emphasize again that I think it would be a great detriment to surgery if, for any reason, we should give up any of the generally accepted practices of good surgery such as sterility, avoidance of trauma, meticulous hemostasis, obliteration of dead space, avoidance of irritating sutures or drains where possible, immobilization of the wound, *etc.* Sterilization of the air attacks only one source of infection—the air—highly contaminated probably because of the inadequacy of our operating room masks. Organisms on the skin, or if by chance in the blood stream, or those introduced by contact contamination, may not be affected by air sterilization, so we must maintain our best surgical technic, and cannot assume that the wound is free of bacteria even if the air is completely sterilized.

Again may we emphasize that our principal objective has been to prove the importance of the air as a source of wound contamination. Bactericidal radiation was adopted as the only practical means of sterilizing the air in order to prove the importance of this source of contamination by its elimination. The results given in this paper, in our opinion, prove that the contamination in the air of our operating rooms is at the present time the greatest source of danger of wound infection in clean operations.

In reply to Doctor Walters, we can say that so long as the law requires that "a man have the skill and use the precautions such as are accepted by the profession in the community where he works" he will have no need to fear the lawyers. Until sterilization of the air is more universally accepted as part of the operating room technic, no lawyer will have a case even though it could be proved that the infection came from the air. For the patient or his lawyer to prove that any specific infection came from a definite source would be all but impossible. If the time comes when sterile air is generally accepted as a requirement of good operating room technic, the lawyer then may have a case. In the meantime, for the doctor who is convinced that most of his infections come from the air, his conscience may be more annoying than his patient's lawyer.

In reply to the question of expense making the use of bactericidal radiation prohibitive, these tubes now retail for $10.00 each, so the cost of equipping a room is probably less than the cost of a good operating room light. They consume only about 10 watts of current per tube and our tubes, that have been in use for over two years, show less than 10 per cent depreciation in output of bactericidal radiation.

In regard to the type of operations in which the air should be sterilized, we do not consider it imperative in small incisions. For arthroplasties, extrapleural thoracoplasties, radical mastectomies, large ventral herniae in obese patients, *etc.*, we feel it is indispensable. As time goes on, probably we will not be content with compromise in our sterile technic, regardless of the small size of the operation or the presence of other possible sources of contamination.

We do not believe that all the postoperative temperature elevation comes from the patient's reaction to bacteria in the wound, but after two and one-half years' experience in eliminating the bacteria from the air we are convinced that they play a major rôle in its production.

The question of eye fatigue has been raised. There would be no fatigue from the radiation itself, since the ray is invisible. However, it is necessary to protect the eyes by glasses or goggles and unless these are optically satisfactory they might cause symptoms. The radiation does not penetrate plain glass to any appreciable degree, but a high grade of pyrex glass may transmit a small percentage. We have made some blood studies on individuals working in a field of bactericidal radiation but have been unable to detect any change.

In regard to our "high percentage of infections" without bactericidal radiation, we feel that our rate of 4 per cent (exclusive of thoracoplasties) is about as low as we can expect.

Doctor Strickler made the statement that "we cannot sterilize the patient in one way and do not want to sterilize him in another." We make no claim that this radiation will kill the bacteria on the skin, since they might be protected in the crevices, and would never expect any effect on the bacteria within the body or its epithelial lined spaces. However, since this ray has very little penetrating power, we can at least feel assured that there is no danger of sterilizing the patient in any other way.

As already stated, I see no immediate or remote prospect of eliminating every source of wound contamination, such as from the skin or blood stream of the patient. This, however, should not deter us from eliminating a known source that in our opinion is of far greater importance.