During the past three years we have used ultraviolet blood irradiation therapy in 151 unselected serial cases of acute pyogenic infection as a method of controlling infection. The Knott technic which was employed in all cases consists of withdrawing and citrating a carefully predetermined amount of a patient's blood and immediately passing it through a hemo-irradiator, a machine that properly irradiates the citrated blood and returns it intravenously to the patient. The hemo-irradiator is by design so constructed as to regulate all dosage factors and, by the precision of its operation, makes the administration of this therapy a safe and efficient procedure. In this paper we shall briefly review a few known biochemical and physiological effects of ultraviolet energy, give the essential details of the Knott technic, and present the results obtained by us in controlling acute pyogenic infection. A correlation of the observed clinical effects of this therapy with several established biochemical and physiological effects of ultraviolet will be made wherever this is possible.

Since 1877, when Downes and Blount first described a marked bactericidal effect of ultraviolet light, many biochemical and physiological effects of ultraviolet have been discovered and utilized. The high bactericidal properties of ultraviolet have been conclusively demonstrated due to the excellent early work of Downes and Blount, Ward, and more recently, of Coblentz, Bayne-Jones, Wyckoff, Bachem and Dushkin, and others.

According to reports of Jodlbauer and von Tappeiner, and Noguchi, and later, to the original studies made by Macht, Schubert, and Welch, it becomes clearly evident that ultraviolet has a very powerful detoxification effect. The rapid and complete inactivation of snake venoms and bacterial toxins are excellent examples of what may be accomplished by ultraviolet.

The production of peripheral vasodilation following external application of ultraviolet in animals and humans has been shown by Balderrey and Barkus, T. Lewis, Krogh, Ellinger and Kawaguchi.

The ability of blood irradiated with ultraviolet to absorb oxygen more readily than nonirradiated blood has been demonstrated by Mayerson and Laurens, and Harris.

The presence of secondary emanations in blood following its exposure to primary emanations of ultraviolet has been detected and reported by Wels. Becker and Szendro and Rahn.

In 1897, Raab first noticed and described the lethal action of acridine on paramecia exposed to light contrasted with its nonlethal action in the absence of light. This phenomenon was called photodynamic action or photosensitization. Jodlbauer and von Tappeiner soon afterward followed up this discovery with a series of brilliant experiments showing that sensitization of a biological system to visible and ultraviolet light can be produced by various fluorescent dyes. In our work today we are most concerned with the fact that sulfadiazine drugs produce photosensitization and phototoallergic effects in man. This latter principle has been described by Epstein and Blum. We have reported recently the presence of untoward photosensitive
effects such as convulsive seizures, renal shut-down and a rapid increase in toxic symptoms when sulfanilamide, sulfathiazole or sulfapyridine were given within the first four or five days following ultraviolet blood irradiation therapy and the complete absence of such effects when ultraviolet blood irradiation therapy was given as soon as an hour after blood levels of these drugs had been ascertained to be at a maximum.

Finally, the effect on general resistance has been the subject of extensive work and has been reviewed carefully by Clark.28 It is common knowledge that certain, as a rule, minimal erythematous doses of externally applied ultraviolet radiations stimulate the general resistance of animals and human beings to infection.

In addition to these references, work in this field has been well described by Blum,29 Duggar,30 and Ellis, Wells and Heyroth.31

In attempting to use these known effects therapeutically, it had been found necessary to depend on external application. Valuable though such a method may be when local effects are desired, it is, nevertheless, subject to many disadvantages contingent upon any attempt to obtain general or systemic effects by the external use of therapeutic agents. It is apparent, then, that if ultraviolet energy could be administered directly to the blood stream (i.e., intravenously) safely and efficiently in easily controlled dosage, one might expect the elimination of certain disadvantages of external application, such as irregular absorption in rate and amount of energy with inconstant, negative or overdosage effects. Furthermore, in such event one might hope for the constant and safe production of certain of the beneficial physiological effects already mentioned, e.g., the bactericidal effect, a detoxification effect, a rise in general resistance.

**TECHNIC AND DOSAGE**

In 1934, Knott and Hancock32 reported the rather spectacular recovery of two apparently moribund cases—one of septicemia, one of brain abscess—following the ultraviolet irradiation of a predetermined amount of the individual's blood and immediate reinjection of that blood. The
technic of this method of irradiating blood has since been somewhat modified by Knott and in its modified form is that between the irradiation chamber and the mercury burner.

The water-cooled type of mercury-

referred to in this paper as the Knott technic of ultraviolet blood irradiation therapy.

The irradiation of blood with ultraviolet energy with a hemo-irradiator (Fig. 7) is made possible by a combination of three devices: (1) a modified Knott irradiation chamber, (2) an automatic transfusion pump, and (3) a water-cooled, mercury-quartz burner.

The irradiation chamber is a silver, disk-shaped, quartz-windowed container through which the blood passes and in which it is irradiated.

The automatic transfusion pump allows blood to be pumped by propulsion through rubber tubing and through the Knott chamber at whatever rate is desired, thus carefully controlling the time of exposure to ultraviolet energy of each cubic centimeter of blood as it passes through the chamber. An intermittent exposure is obtained by a rotating shutter interposed quartz burner is used and is fastened approximately 1 cm. from the quartz window of the irradiation chamber through which the blood is pumped. The ultraviolet rays are confined to a closed, highly polished steel housing and have the same intensity as if at actual contact.

The clinical application of this combination consists of withdrawing a predetermined amount of venous blood from an individual, citrating it (one part 2.5 per cent sodium citrate to five parts blood) and immediately returning it to the same individual through the hemo-irradiator to the vein from which it was withdrawn. The immediate return to the venous circulation of irradiated blood through a closed system obviates the rapid loss from irradiated blood of ultraviolet energy, which occurs if blood is, for example, spread out in open flat receptacles during irradiation.

In using this method it is necessary to be sure that three important factors are kept

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**Fig. 2.** Ultraviolet blood irradiation therapy was administered to this young woman suffering from postpartum septic endometritis and acute pyelitis when toxic symptoms began to increase rapidly over a period of forty-eight hours starting on the fifth postpartum day. Within twenty-four hours following blood irradiation a complete detoxification effect was observed and an eventful eleven-day convalescence ensued.
Fig. 3. A, B and C, following exploratory laparotomy in this patient, a ruptured tubal abscess with generalized peritonitis was found. Culture of the purulent peritoneal exudate was found to be Streptococcus hemolyticus; the same organism was found on blood culture. Seventy-two hours after operation, when the patient was apparently moribund, ultraviolet blood irradiation therapy was instituted. Four applications of this therapy were required before detoxification was complete. During this time the abdominal incision had ruptured and evisceration had to be checked by adhesive strapping. The patient recovered, had a secondary abdominal closure, and left the hospital in apparently excellent condition on the thirty-seventh day following the appearance of the final detoxification effect.
constant. These are: (1) the amount of blood withdrawn and irradiated, (2) the time of exposure to ultraviolet energy, and (3) the intensity and the wave-length of the spectral energy used.

The amount of blood to be used is calculated from the formula \( A = KW \), where \( A \) is the amount in cubic centimeters to be withdrawn, \( K \) is a constant (1.5 in this work), and \( W \) is weight expressed in pounds.
The amount of blood used rarely exceeded 300 cc., as can readily be seen from the formula.

The time of exposure is considered to be the time required for the passage of 1 cc. of blood through the Knott irradiation chamber while exposed at contact to the ultraviolet emanation described below; the average time of exposure in this work was ten seconds.

In irradiating blood, ultraviolet wavelengths within the range from 2,399 to 3,654 angstrom units, were used. The intensities corresponding to the wavelengths used are shown in this table:

<table>
<thead>
<tr>
<th>Wave Lengths, Angstrom Units</th>
<th>Intensities, mW/cm.²</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,399</td>
<td>55,000</td>
</tr>
<tr>
<td>2,483</td>
<td>88,000</td>
</tr>
<tr>
<td>2,536</td>
<td>273,000</td>
</tr>
<tr>
<td>2,652</td>
<td>239,000</td>
</tr>
<tr>
<td>2,753</td>
<td>86,000</td>
</tr>
<tr>
<td>2,804</td>
<td>139,000</td>
</tr>
<tr>
<td>2,897</td>
<td>96,000</td>
</tr>
<tr>
<td>2,967</td>
<td>224,000</td>
</tr>
<tr>
<td>3,022</td>
<td>435,000</td>
</tr>
<tr>
<td>3,125-32</td>
<td>718,000</td>
</tr>
<tr>
<td>3,342</td>
<td>73,000</td>
</tr>
<tr>
<td>3,573</td>
<td>41,000</td>
</tr>
<tr>
<td>3,650-54</td>
<td>1,538,000</td>
</tr>
</tbody>
</table>

It can be observed from the above method of estimating dosage and keeping it relatively constant that the fundamental laws underlying the mechanism of photochemical processes have been carefully taken into consideration. The Grotthus-Draper law, known also as the first law of photochemistry, stating that only light which is absorbed can act chemically, the Bunsen-Roscoe law which states that a photochemical change is proportional to the intensity and time of illumination, Stokes' law stating that the wave-lengths of secondary, emitted rays are greater than the primary exciting rays, Einstein's photochemical equivalence law which states that each absorbed quantum should cause one light absorbing molecule to react chemically, and the production of chain reactions by secondary emanations, are all as applicable to biochemical reactions as to chemical reactions in general.

RESULTS IN CONTROLLING ACUTE PYOGENIC INFECTION

The above described technic of irradiating blood with ultraviolet has been used in 151 cases of acute pyogenic infection as a method of controlling such infection and its toxemic manifestations.

These cases have been classified in three groups, according to the degree of clinical toxicity as follows:

1. Early, in which temperature, pulse and respiratory rates are not greater than 101° to 102°F., 100 to 110 and 24 to 25, respectively, and toxic symptoms such as nausea, vomiting, restlessness, irritability and mental confusion are minimal or absent.

2. Moderately advanced, in which temperature, pulse and respiratory rates exceed 101° to 102°F., 100 to 110 and 24 to 25, respectively, and such toxic symptoms as nausea, vomiting, restlessness, irritability and mental confusion are excessive.

3. Apparently moribund, in which the symptoms present are a combination of those advanced symptoms commonly considered near terminal, or terminal, namely, coma, rapidly falling blood pressure in some instances, cardiac irregularity, irregular and shallow respirations, obvious loss of thermotactic control and often an associated septicemia.

TABULATION OF RESULTS

This report includes all patients with acute pyogenic infection given ultraviolet blood irradiation therapy at Hahmann Hospital, Philadelphia, up to January 1, 1942. Of these 151 the majority received no form of chemotherapy, neither before nor after irradiation; a minority were admittedly chemotherapeutic failures.

In Table 1 we present three classifications of patients suffering from various acute pyogenic infections—according to the severity of the toxic symptoms present at the time of the first irradiation—namely, early, moderately advanced, or apparently moribund.
### TABLE 1
RESULTS IN 151 CASES OF ACUTE PYOGENIC INFECTION
GIVEN ULTRAVIOLET BLOOD IRRADIATION THERAPY
AT THE HAHNEMANN HOSPITAL IN PHILADELPHIA FROM NOVEMBER 1, 1938 TO DECEMBER 31, 1941

<table>
<thead>
<tr>
<th>Condition</th>
<th>No. of Cases</th>
<th>Recovered</th>
<th>Died</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Puerperal sepsis</td>
<td>15</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Acute streptococcal hemolyticus oropharyngitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Acute pyelitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Wound infections</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Acute suppurative hemorrhagic cystitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Acute streptococcal hemolyticus oropharyngitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Fever of undetermined origin</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Moderately Advanced:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Puerperal sepsis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Incomplete septic abortion</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Pelvic abscesses, pelvic periostitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Pyelonephritis, cystitis, secondary to parotitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Acute suppurative hemorrhagic cystitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Apparently Moribund:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Puerperal sepsis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Incomplete septic abortion</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Incomplete septic abortion, hemorrhagic shock</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Appendiceal abscess</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Pelvic abscesses, pelvic periostitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Wound infections</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Fever of undetermined origin</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Lobar pneumonia</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Bronchopneumonia</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Pyelonephritis, cystitis, secondary to bladder carcinoma</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Mesenteric thrombosis, large pararectal and gluteal abscess, diabetes mellitus</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Acute extensive phlegmonous ileitis, seccotomy</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Rectal abscesses, cistitis, ileitis, advanced arteriosclerosis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Bacillus coli abscess of scrotum</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Streptococcal hemolyticus oropharyngitis</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Extensive trauma, terminal broncho-pneumonia</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Acute hepatitis and colitis of unknown origin</td>
<td>15</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Pelvic abscess secondary to carcinoma of sigmoid</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Extensive bilateral pyynephros secondary to renal tuberculosis</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Summary

<table>
<thead>
<tr>
<th>Condition</th>
<th>No. of Cases</th>
<th>Recovered</th>
<th>Died</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septicemias: Staphylococcus aureus and albus septicemia</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Streptococcus nonhemolyticus</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Streptococcus viridans subacute bacterial endocarditis</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Streptococcus nonhemolyticus endocarditis</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The results of the use of this therapy in the conditions noted are indicated in this Table, which reports, in summary, the recovery of 100 per cent of the early, of 98 per cent of the moderately advanced, and 42 per cent of the apparently moribund (55 per cent nonsepticemic, 19 per cent septicemic) cases. Obviously, the earlier ultraviolet blood irradiation therapy was applied the better were the results obtained.

In no case treated by this Knott technic of ultraviolet blood irradiation therapy have there been observed any harmful delayed effects such as deleterious effects on the blood itself, on kidney function nor on any body function. Normal red and white cell count and structure, and normal hemoglobin content is a consistent observation in patients checked up to three years after initial blood irradiation.

Although it is not the purpose of this paper to discuss these effects of this therapy, it may well be added that these findings correspond with those of other workers in this field, e.g., Rebeck, Knott and Hancock, as well as with our own findings in the more than 500 other patients who have received blood irradiation.
irradiation here for diseases of a more chronic nature. It is interesting to note that the results obtained in using ultraviolet blood irradiation therapy as a control of infection in cases of puerperal sepsis and incomplete septic abortion very closely parallel the results reported by Rebbeck in his excellent original reports of the use of this method in these two obstetrical complications.

For the purpose of a more detailed observation of the results of this treatment there follows a series of brief abstracts of
case histories of a few selected cases from Table 1:

T. G., No. 69618, a fifty-six-year old white male, was admitted to the Hahnemann Hospital complaining of pain in both feet. Examination of his feet revealed a dry gangrene of the right great toe and a swollen tender area on the medial side of his left heel. Both ankles were swollen. On May 14, 1941 neither tibial nor dorsalis pedis pulses were palpable. The patient gave a history of having had his feet frozen several times in the last ten years. During the past summer the patient apparently had symptoms of intermittent claudication. In November, the patient noticed that the right great toe was sore and this continued until April, 1941, when he injured this toe and it became infected. The toe was incised to establish drainage but the toe only became worse and turned black. He came to the accident ward seeking help and was admitted on May 14, 1941. The urinalysis, blood count, blood sugar and blood urea were all normal. Wassermann and Kahn tests were normal. Blood culture was sterile after 120 hours' incubation. Temperature was relatively normal except for a small rise in temperature to 99°F. each evening. Treatment was instituted as follows:

5 per cent saline were given daily for three days and then three times weekly. On May 16, 1941 the vacuum pressure boot was started on both legs. The saline and the boot seemed to aggravate the condition so that they were stopped on May 22, 1941 and the patient was advised amputation of the right leg above the knee because of the mortification setting in half way to the right knee. On May 25th under cyclopropane-oxygen anesthesia the right extremity was amputated just above the knee using the guillotine method. Good hemostasis was obtained, the flaps approximated and the incision closed with drainage.

Following this operation the patient was very much improved and had very little discomfort. The sutures and drains were removed May 31st and the patient was ordered out of bed. Dressings were changed daily.

On June 12th the patient began to complain of the left heel which had apparently been healed. Whirl-pool bath was ordered daily. The patient then began having pain in the stump and the heel and on June 14th a nerve block was ordered. Since the whirl-pool bath...
apparently aggravated this pain, it was discontinued.

On June 17th a lumbar sympathetic nerve block was done; just before the block an abnormally high skin temperature was recorded. The patient was not relieved of pain and the temperature of the leg did not change. This was repeated on the 19th without relief to the patient. The patient complained almost constantly of pain in the left heel which had now become swollen and edematous. Pain continued until blood irradiation was performed June 27th. Following this irradiation the swelling went down in the left foot and the area on the left heel began to heal and granu-

block was done; just before the block an abnormally high skin temperature was recorded. The patient was not relieved of pain and the temperature of the leg did not change. This was repeated on the 19th without relief to the patient. The patient complained almost constantly of pain in the left heel which had now become swollen and edematous. Pain continued until blood irradiation was performed June 27th. Following this irradiation the swelling went down in the left foot and the area on the left heel began to heal and granu-

late. The stump of the right leg was almost completely healed following this and the drainage was negligible.

On July 3rd the patient was discharged free of pain both in the right amputation stump and in the left heel, along with slight drainage from the left heel and the stump of the right leg.
E. J., No. 69619, a twenty-two-year old black female, was admitted to the hospital on August 20, 1941. The diagnosis was Streptococcus hemolyticus septicemia and generalized peritonitis secondary to ruptured tubo-ovarian abscess. On admission she was complaining of severe abdominal pain and gave a history of sudden onset. Physical examination revealed a markedly tender, rigid abdomen characteristic of an acute intra-abdominal condition. Her pulse was 110, respiration 30, temperature 101°F. Pelvic examination revealed presence of fluid in the cul-de-sac. Laboratory examinations revealed negative urinalyses, hemoglobin 14.3 Gm., red cells 4,700,000, white cells 12,300. A diagnosis of ruptured ectopic pregnancy was made and laparotomy was performed soon after admission of the patient. At operation generalized peritonitis was found which was obviously due to a ruptured tubo-ovarian abscess. The abdomen was closed with adequate drainage and aldonil was given. The patient's temperature, pulse and respirations rose to 105°F., 140 and 36, respectively. Sulfathiazole was started the second postoperative day, August 22nd; the patient became extremely nauseated and vomiting appeared; her condition was grave. Sulfathiazole was stopped. Twelve hours later ultraviolet blood irradiation therapy was instituted, August 23rd. At this time blood culture taken on the day of admission was found to be positive, showing a pure and luxuriant growth of Streptococcus hemolyticus. The next forty-eight hours the patient seemed generally improved, temperature, pulse, respiration falling to 99°, 102 and 30, respectively.

On August 26th, the wound began to break down and the following day, because of a rise in respiratory rate to 38, ultraviolet blood irradiation therapy was repeated. The following day the temperature continued to rise as did the pulse and respiration, to 103.2°F., 148 and 46, respectively. On August 29th a third blood irradiation was administered.

On August 29th x-ray examination of chest failed to show any definite pulmonary disorder but the patient was put in an oxygen tent because of marked dyspnea and the presence of râles throughout the chest. The patient's condition remained stationary and on September 2nd ultraviolet blood irradiation therapy was given for the fourth time. The following day her temperature rose to 105°F.; forty-eight hours later it began to fall. At this time, September 4th, it was believed that the oxygen tent should be removed because of the apparent deleterious effects of mechanical irritation and overventilation. On removal of the oxygen tent respiratory rate fell to a level between 24 and 30. Shortly after this a large, subcutaneous and subfascial abscess ruptured. On September 6th the patient was definitely out of danger and continued to convalesce uneventfully till October 4th when her temperature rose to 101.2°F. There was a daily temperature rise to 101° or 102°F. for three days following, during which time an inflammatory area appeared in the lateral region of the left buttock. On October 17th this ruptured and her temperature fell to normal. The patient convalesced uneventfully from this point on and was discharged in good condition on November 2nd.

A. W., No. 69406, a twenty-year old white female, finally diagnosed as having puerperal sepsis and septic endometritis complicated by acute pyelitis, was admitted to the obstetrical ward November 24, 1941 at full term. Midforceps delivery was performed; third degree lacerations of the peritoneum occurred. The first four days following delivery the patient ran a moderately septic course, temperature ranging from 100° to 103°F. On the fifth postpartum day, her temperature, pulse, and respirations rose to 105.8°F., 138 and 34, respectively; severe chills were present; urinalysis showed 30 to 40 pus cells per H.P.F. The chills continued for forty-eight hours; the patient became nauseated, delirious and increasingly toxic. On the seventh postpartum day, ultraviolet blood irradiation therapy was instituted. The following day no chills occurred, nausea was absent, the patient was mentally alert, and her temperature, pulse and respiration fell to normal levels; her toxic symptoms had generally subsided. This improvement was maintained with the result that she convalesced uneventfully, leaving the hospital on the seventeenth postpartum day, in apparently excellent condition, ten days after a single irradiation.

S. C., No. 69978, a white woman of fifty-two years was admitted to Hahnemann Hospital on August 11, 1941. The final diagnosis was incomplete septic abortion complicated by lobar pneumonia. When admitted she was complaining of chills, fever and abdominal bleeding,
giving a history of approximately ten days of chills and fevers. Physical examination revealed a markedly toxic patient with a temperature of 103°F., pulse 120, respiratory rate of 20. Pelvic examination revealed a lacerated external os and vaginal bleeding. Laboratory examination revealed hemoglobin 11.2 Gm., red cell count 4,000,000, white count 12,350, sedimentation rate 7 mm. in fifteen minutes, 30 mm. in forty-five minutes; culture of the cervix showed the presence of Staphylococcus aureus and Bacillus diphtherodeus. Sulfathiazole was started immediately on admission. Within a few hours her respiratory rate rose to 40 and some cyanosis was present. The following day an x-ray examination of the chest, showed the presence of consolidation characteristic of early lobar pneumonia. The patient's general condition continued to deteriorate, her dyspnea and cyanosis increased, mental confusion, nausea and vomiting appeared and her temperature (Fig. 1), pulse and respiratory rates remained elevated. Therefore, because after seventy-two hours of sulfathiazole therapy it was believed that the patient's condition had been in no way improved by sulfathiazole, and that, on the contrary, it had become very critical, sulfathiazole was discontinued. Several hours later ultraviolet blood irradiation therapy was instituted; within a few minutes the patient's dusky cyanosis began to disappear and in its place was seen a definitely pinkish skin coloration, a grossly discernible peripheral flush (which, incidentally, persisted up to the time of her discharge). On the following day the patient's temperature began to fall, as did her pulse and respiratory rate; her mental confusion, nausea, vomiting and dyspnea disappeared. This marked detoxification effect was most striking. Forty-eight hours later, pulse, temperature and respirations were normal and the patient was obviously out of danger. She convalesced uneventfully and left the hospital on August 25th, ten days after a single blood irradiation.

In order to show a more detailed picture of the effect of ultraviolet blood irradiation therapy on septic temperatures, a series of graphs of daily peak temperatures selected from cases reported in Table 1 (Figs. 1 to 6) are shown. These are typical of the whole group presented in this paper. As might be expected, abnormally high temperatures fell both by lysis and by crisis.

**GENERAL CLINICAL OBSERVATIONS**

During this work several rather outstanding clinical events were noted, and their relation to the known physiological effects of ultraviolet mentioned earlier in this paper have been correlated insofar as possible. These may best be summarized as follows:

1. The bactericidal effect has been noted throughout this work. A complete disappearance of the invading bacterial organism was found to occur except in cases of Staphylococcus aureus septicemia and in cases of acute or subacute bacterial endocarditis.

2. The detoxification effect has been the most striking of all effects observed in cases of acute pyogenic infection following ultraviolet blood irradiation therapy. There occurs in these cases almost uniformly, twelve to seventy-two hours following this therapy, a pronounced subsidence of toxic symptoms, such as nausea, vomiting, delirium, fever, general malaise, rapid pulse, rapid respiration, etc. In this connection we have observed that there often occurs a marked fall in abnormally high temperatures by lysis or by crisis. If, however, abscess formation is present or occurring the abnormally high temperature will drop to a level slightly above normal; in such cases all toxic symptoms usually disappear and the elevated temperature drops to normal upon drainage of the abscess. In fact, we have found a disappearance of toxic symptoms in combination with a slightly elevated temperature following ultraviolet blood irradiation therapy to be pathognomonic of abscess formation. In bronchopneumonia the temperature has been observed to fall by lysis.

3. Grossly discernible peripheral vasodilation has been observed in over 75 per cent of all individuals given ultraviolet blood irradiation therapy. This occurs within five to ten minutes after the irradiated blood has been returned to
the venous circulation and persists in some individuals for more than thirty days.

4. Photosensitization and photodynamic effects have been carefully considered in this work, although there is neither time nor space here to present these studies. We have made a few fundamental observations regarding the combined use of chemotherapeutic agents, especially sulfanilamide derivatives, quinine and iodides with ultraviolet blood irradiation therapy. These are, briefly: (a) Ultraviolet blood irradiation therapy can be given safely and with impunity following the administration of sulfanilamide derivatives, quinine and iodides; (b) sulfanilamide, sulfapyridine and iodides cannot be given safely within the first five days following ultraviolet blood irradiation therapy without risking a probable photosensitive reaction in the form of markedly increased toxemia, pulmonary edema and renal shut-down. In the one case of photodynamic action observed with sulfathiazole (given seven days after ultraviolet blood irradiation therapy) marked convulsions were seen; no serious effects have been seen with the administration of quinine in the first few days following this therapy; (c) those patients who have only blood irradiation have a much shorter convalescent period than those who receive both sulfa drugs and ultraviolet blood irradiation therapy.

5. The ability of ultraviolet irradiated blood to absorb oxygen has been studied and in this work it was found that in patients with abnormally low venous oxygen values who received ultraviolet blood irradiation therapy, there was a marked increase in the uptake of oxygen as shown by a definite rise toward normal of venous oxygen values.

6. Secondary emanatory phenomena present difficult problems for careful analysis. At this time no statement can be made. Knott was able to fog a photosensitive film in a dark-room with the serum of blood irradiated according to the above described technic.

7. General resistance, as may be expected in the light of the previously mentioned observations, was obviously increased.

8. A complete absence of deleterious effect has been noted in this work. Earlier it was reported that in individuals with initially normal red cell, white cell and hemoglobin values there was observed to be little, if any, change one to thirty-six months following ultraviolet blood irradiation therapy carried out strictly in accordance with the technic and dosage described above. Similarly, we may add that in patients receiving blood irradiation for acute pyogenic infection and having abnormal hemoglobin, red cell and white cell values before treatment all these disappear, changing to normal following hemo-irradiation. We have been unable to find delayed harmful effects of any nature in well over 1,000 applications of the Knott technic of ultraviolet blood irradiation.

Up to the time of the writing of this paper, in the treatment by blood irradiation of cases of acute pyogenic infection uncomplicated by septicemia we have never seen an infection progress to the point where a septicemia has ensued.

We have often seen, as have others, a complete failure of chemotherapeutic agents insofar as controlling the infection is concerned. Many of these cases have responded to ultraviolet blood irradiation therapy subsequent to chemotherapeutic failure. We have yet to witness a case in which ultraviolet blood irradiation failed and chemotherapy succeeded.

The above clinical observations are in close agreement with those made by others working with the Knott technic of ultraviolet irradiation of blood, notably Hancock, Rebbeck and Barrett.

**SUMMARY**

1. A method of irradiating human blood, originally devised and recently modified by Knott, is described. This consists of withdrawing and citrating a predetermined amount of a patient's venous blood and immediately returning it intravenously...
through a closed system containing a Knott irradiation chamber at which point intense ultraviolet irradiation is applied.

2. The amount of blood used (predetermined according to approximate body weight), the time of exposure (optimally ten to twelve seconds in the treatment of acute pyogenic infections), and the wavelengths and intensity of the spectral energy used form the basis for estimating and maintaining a relatively constant dosage.

3. A report of 151 cases of acute pyogenic infection treated at Hahnemann Hospital over a period of three years is given; the clinical response has been consistently excellent.

4. A rapid subsidence of toxic symptoms with subsequent recovery in all of the early cases, all but one of the moderately advanced cases, and in some of the apparently moribund cases of acute pyogenic infection was found to occur. Other beneficial physiological effects, e.g., bactericidal effect, vasodilation, venous oxygen increase, were observed to occur following this therapy.

5. As yet, no case of acute pyogenic infection uncomplicated by septicemia, after receiving ultraviolet blood irradiation therapy according to the Knott technic, has progressed to a septicemia.

CONCLUSIONS

1. The Knott technic of irradiating blood with ultraviolet must be considered, in view of the method of its administration and of the various physiological effects it produces, as a method of applying ultraviolet energy intravenously.

2. This method has been found to be valuable for controlling acute pyogenic infections rapidly and efficiently. The earlier it is applied in the course of an acute pyogenic infection the better have been the results obtained.

3. The technic described is essentially a hospital procedure at present. It requires careful training in its use and when properly administered is without harmful after-effects.

4. Experience with the Knott technic of irradiating blood has convinced us that when available it offers more to the patient suffering from acute pyogenic infection than any other therapy yet known.

5. As a control of infection it is the obvious method of choice in those cases of acute pyogenic infection in which chemotherapy has failed.

6. In general it may be said that wherever a bactericidal, detoxification or vasodilation effect is needed, as well as such other physiological effects of ultraviolet as increased ability of the blood to absorb oxygen and increased general resistance, the Knott technic of ultraviolet blood irradiation therapy is indicated.

REFERENCES


In the sterile uterus there should be no hesitancy in performing vaginal hysterectomy both to relieve the active symptoms and also from a prophylactic standpoint.