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HEMOLYTIC TRANSFUSION REACTIONS *

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THE development of blood banks has made the use of whole (citrated) blood transfusions rather commonplace. One cannot afford to lose sight of the fact, however, that although a compatible transfusion may be life saving, an incompatible one may cause death. The contributions of Landsteiner (1), Jansky (2), and Moss (3), relative to the four major blood groups laid the foundation for the use of blood transfusions as a therapeutic measure (table 1). Additional fundamental knowl-

TABLE 1
AGGLUTINOGENS AND AGGLUTININS IN FOUR MAJOR BLOOD GROUPS

Classification International	Agglutinogen in Cell	Agglutinin in Serum	Percentage of Population
O	O	$\alpha\beta$	43
A	A	β	40
B	B	α	10
AB	AB	O	7

Subgroups A₁, A₂, A₁B, A₂B.

85 per cent white population have Rh factor in red blood cells. Rh positive.

15 per cent white population lack Rh factor in red blood cells. Rh negative.

edge regarding the use of sodium citrate as an anticoagulant (4, 5), the subgroups of A (6, 7), the Rh factor (8-14), high titer typing serum (15), and the employment of the more efficient ACD mixtures (16, 17), for the storage of blood has materially reduced the danger of blood transfusion to the recipient. That a small but ever-present hazard does exist can be seen from the following statistical study (table 2). Until it has been shown that blood transfusions carry no risk to the

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TABLE 2
TRANSFUSION STATISTICS

	Year of Report	No. of Transfusions	No. of Hemolytic Reactions	Deaths
	Fresh Blood			
Wiener *	1917-1941	19,275		39
Kilduffe and DeBakey †	1917-1941	43,284	80	45
	Stored Blood			
Wiener *	1939-1941	8,236		9
N. E. Deaconess Blood Bank	1942-1946	13,000	2	1
Mass. Mem. Blood Bank	1940-1946	6,464	1	0
Hartford Hosp. Blood Bank	1941-1946	16,000	2	0
Mass. Gen. Hosp. Blood Bank	1942-1946	28,588	8	2
Peter B. Brigham Blood Bank	1945-1946	2,140	3	0
Children's Hosp. Boston Blood Bank	1946	1,200	1	0
Boston Lying-In Blood Bank	1946	452	1	0
Total		76,080	18	12

* These are the totals of a group of statistics collected by Wiener and presented in his book (Ref. 20).

† These are the totals of a group of statistics collected by Kilduffe and DeBakey and presented in their book (18).

TABLE 3
INDICATIONS FOR TRANSFUSIONS

1. Increase Oxygen-Carrying Capacity, Hemorrhage, Anemia, Poisonings
2. Restore Blood Volume in Prevention or Treatment of Shock
3. Restore Clotting Mechanism to Normal
 - A. Hypoprothrombinemia
 - B. Hemophilia
 - C. Platelets and Other Blood Clotting Elements
4. Correct Hypoproteinemia, Liver Disease, Nephritis, Ulcerative Colitis, Carcinoma of Stomach
5. Supply Immune Bodies in Treatment of Infectious Diseases, Septicemia, Bacteremia, Puerperal Sepsis

patient, they should be administered only when a real indication exists (table 3).

The purpose of this paper is to discuss the etiology, signs, symptoms, prognosis and treatment of hemolytic transfusion reactions, and present our experience with three such reactions.

ETIOLOGY

Many errors related to the grouping and cross matching of the donor and recipient can be made and these generally cause the patient to receive incompatible blood (table 4). The use of low titer typing serum, which may have been weak from the outset or deteriorated because of improper storage or bacterial contamination, is a common source of

error. This is particularly important in determining the group to which red blood cells belong whose agglutinin sensitivity is naturally low, such as those belonging to the subgroups of A, that is A₁, A₂, A₁B, and A₂B. One of our patients, Group A₂B, was incorrectly typed as Group B and given three transfusions of B blood, each of which was followed by a minor transfusion reaction. It was definitely shown by the use of a high titer typing serum that he was a Group A₂B. The routine retyping of the patient's serum against known A and B cells is helpful in detecting some of these low titer subgroups of A.

TABLE 4
SOURCE OF ERROR IN BLOOD TRANSFUSIONS

- I. Errors in Grouping and Cross Matching
 - A. False negative reactions—weak typing sera
 1. Low titer from outset
 2. Deterioration from improper storage
 3. Deterioration from bacterial contamination
 - B. False positive reactions
 1. Pseudo-agglutination (rouleaux formation)
 2. Auto-agglutination
 - a. Cold agglutinins act on all bloods
 - b. Warm agglutinins
 3. Iso-agglutination—cold iso-agglutinins act only on certain blood
- II. Clerical Errors in Handling of Blood at Bank
 - A. Incorrect labeling of pilot tube
 - B. Wrong blood released from bank
 - C. Mix-up in administering blood to patients

Those interested in an exhaustive discussion on ways to overcome errors caused by pseudo-agglutination, auto-agglutination and irregular iso-agglutination are referred to more detailed works on the subject (18-20). Pseudo-agglutination or rouleaux formation can generally be eliminated by using the test tube method of grouping and cross matching which allows for the proper dilution of the patient's serum. The use of this method, which is carried out at 37 C., will generally eliminate the influence of cold agglutinins when they are present in the serum and thus forestall errors caused by auto-agglutination and irregular iso-agglutination (21).

Too much cannot be said, however, about the importance of clerical errors which have in our experience resulted in the greatest number of transfusion reactions. It is questionable whether this group of errors can ever be entirely eliminated, but they can be materially reduced by placing the responsibility for the collection of blood from the recipient and donor on the technical staff of the blood bank. All too often the responsibility for the collection of blood is haphazardly placed on members of the visiting staff, interns, residents and general duty nurses. Because of these clerical errors it is possible for a patient to have a hemolytic transfusion reaction even though the grouping and cross matching tests have been correctly performed. This can, and frequently does occur, because a mistake has been made in labeling the

recipient's pilot tube. In such a case, blood drawn from A finds its way into the pilot tube marked with the name of B. This mistake gives the wrong blood grouping for B, but a cross matching which is compatible for the blood in tube B but not compatible with the blood in the circulation of patient B. One way to eliminate such mistakes is to take a specimen of blood from the patient for the blood grouping and then obtain a second specimen for the cross matching. If a labeling error has occurred, it will be detected in the cross matching.

Labeling errors may be made at the blood bank when the blood is collected from the donor by incorrectly labeling either the bottle containing the blood or the pilot tube. Obviously, when an error of this nature is discovered, it means that two flasks of blood are incorrectly labeled and the entire stock must be investigated. When it is realized that such errors may and do occasionally occur, the importance of obtaining a specimen of the blood the patient is receiving at the time a transfusion reaction is suspected, becomes obvious. Otherwise, a recheck, using the incorrectly labeled pilot tube, simply reduplicates the error. To clarify a situation of this type, it is absolutely essential that a fresh specimen of blood be obtained from the donor and the recipient and the laboratory work rechecked.

Similarity in patients' names may lead to confusion in the release of blood from the blood bank or the distribution of the blood on the ward. Only by careful examination of the labels on the bank's blood, plus routine questioning of the nurse in charge, as well as the patient, and careful scrutiny of the patient's chart, can these errors be eliminated. It is essential that more than one person check this information as all too frequently in the haste of an emergency a slip-up can occur.

Elimination of the aforementioned errors along with the dangerous universal donor (Group O whose anti-A or anti-B titer is above 1 to 32) and the routine use of Rh compatible blood should go far toward preventing hemolytic reactions (22-25).

SIGNS AND SYMPTOMS

A conscious patient who receives incompatible blood may show subjective signs and symptoms almost immediately, or the reaction may be delayed and the initial manifestations develop several hours after the completion of the transfusion. *When incompatible blood is given to a patient under general anesthesia, however, there are no signs and symptoms to indicate what has happened unless by chance one should examine the urine and discover it to contain precipitated hemoglobin.** Usually, in a conscious patient, 10 cc. of incompatible blood will cause a reaction and this is the basis for the "biologic" test (that is, care-

* There may be a profound drop in blood pressure with an associated rise in pulse rate. Some have observed moderate to severe hemorrhagic tendencies associated with the administration of incompatible blood while the operation is in progress.

fully observing the patient during the administration of the first 50 to 100 cc. of blood). The earliest complaints registered by the person receiving incompatible blood are generalized tingling sensations, discomfort, anxiety, fullness of the head, precordial pressure and a sense of constriction in the chest or difficulty in breathing. The next most characteristic features are pain in the lumbar and chest regions and a chill which is generally followed by a high fever. In addition, signs of shock become evident, such as rapid pulse, cyanosis, nausea and vomiting, and a fall in blood pressure (18). In one of our patients who had a fatal transfusion reaction after receiving 175 cc. of incompatible blood, the first evidence of reaction was a sudden, profound vascular collapse.

DIAGNOSIS

The reactions associated with blood transfusions may be divided into three groups: (1) chemical and physical, (2) allergic and (3) hemolytic. In addition, the possibility of transmitting malaria, syphilis and infectious hepatitis in transfused blood must be constantly guarded against (table 5). Most of the chemical reactions can be

TABLE 5
CLASSIFICATION OF TRANSFUSION REACTIONS

- I. Physical and Chemical Reactions
 - A. Chemical
 1. Foreign material in apparatus
 2. Pyrogens
 3. Coagulative changes in transfused blood
 - B. Physical
 1. Rapid administration of cold blood
 2. Air embolism
 3. Pulmonary edema from too rapid administration
- II. Allergic or Urticarial Reaction
- III. Hemolytic Reactions (intravascular agglutination and hemolysis)
 - A. Intra-group type
 1. Rh factor
 2. "Cold" hemagglutinins

{	cirrhosis of liver
	acute infectious—virus pneumonia,
	paroxysmal cold hemoglobinuria
 - B. Gross incompatibility
 - C. Dangerous "universal" Group "O" donor
- IV. Transmission of Disease—Malaria, Syphilis, Infectious Hepatitis

prevented by using pyrogen-free distilled water, eliminating foreign material from the transfusion apparatus and preventing bacterial contamination when the blood is collected. Physical reactions can be prevented by allowing banked blood to reach room temperature, administering it slowly to patients with organic heart disease and being ever on guard against air embolism. Allergic reactions can be held to a minimum by paying strict attention to the allergic history of the donor and recipient and establishing a routine of collecting blood from donors at least six hours postprandial.

The watchword of all blood banks should be the complete prevention of hemolytic reactions. Should these reactions occur, however, a pre-conceived plan of investigation should immediately be invoked which would afford an accurate, early diagnosis so that immediate, prompt, intelligent treatment could be instituted. There is no way to differentiate a coincidental reaction from one caused by hemolyzed red blood cells except by following a prescribed routine of investigation. All too often the possibility of a hemolytic transfusion reaction is not considered until anuria has developed. One of our fatal cases had only a mild, chilly sensation with a 20 point elevation in pulse rate, and no elevation of temperature after receiving 350 cc. of incompatible blood. Therefore, it would seem that an attempt to classify transfusion reactions according to the associated temperature elevation is not only valueless but can be extremely misleading. Neither can we expect the pathologist, given a large group of patients dying from uremia, to differentiate the kidney lesions on the basis of etiology in every case for, as Herbut (26) has shown, the lesions in the kidneys of patients dying from transfusion anuria, bichloride poisoning, shock, and so forth, were all the same provided a period of hypotension had been noted during their illness. Therefore, no matter how insignificant a transfusion reaction may appear, a sample of the patient's blood must be obtained at once, preferably during or shortly after the chill, and the serum examined for hemoglobinemia (27). If a specimen of the blood being administered can be obtained, its grouping and cross matching along with the Rh factor should immediately be determined. If the entire transfusion has been administered, special studies of the recipient's blood should be made for evidence of incompatible cells.

The urine must be examined carefully for any evidence of hemoglobinuria (28). While these observations are being made, a complete check of the original grouping, cross matching and clerical work pertaining to the handling of the blood should be undertaken. It goes without saying, of course, that on even the slightest suspicion of a transfusion reaction, the administration of the blood should be stopped immediately. Once a transfusion has been discontinued because of a suspected reaction it should not, under any consideration, be started again until absolute certainty of its compatibility has been established. Because it is so difficult to remove foreign material (clotted blood, etc.) from rubber tubing, we are now using in one hospital a commercially prepared, dispensable plastic tubing to overcome this difficulty and thus reduce the number of febrile transfusion reactions.*

When multiple transfusions are used, a valuable compatibility check is obtained by cross matching a specimen of the last blood the patient received with the contemplated transfusion. When incompatibility is discovered by this procedure, especially if the blood is being administered to an anesthetized patient, earlier treatment can be instituted.

* Venoset, Abbott Laboratories.

PROGNOSIS

When mild transfusion reactions occur, such as chills and fever without urinary suppression, recovery is generally the rule. The prognosis following hemolytic transfusion reactions, however, seems to depend on the following: (1) the amount of blood administered; (2) the functional capacity of the kidneys; (3) the general condition of the patient, and (4) the relative degree of sensitivity of the patient. In Bordley's series (29), the 5 patients who recovered received an average of 314 cc., while for the 10 patients who died, the average was 565 cc. Once a typical hemolytic reaction with uremia occurs, however, whether as a result of intra-group or extra-group incompatibility of the blood, the prognosis should be guarded. In Goldring and Graef's series (30), 3 of 7 patients died; in Bordley's series, 11 of 17 patients died, while in our own experience, 2 of 3 patients died who had hemolytic transfusion reactions. Death from uremia usually occurs between the sixth and the eleventh day; however, in a few instances death from exsanguination, owing to the development of a hemorrhagic tendency immediately after the incompatible transfusion, has been reported (31). Many theories have been brought forth in an effort to elucidate the exact etiology of the renal lesions and anuria caused by incompatible blood. Bordley summarized the four most significant theories as follows: (1) Mechanical blockage of renal tubules. According to this concept, hemoglobin is precipitated in the renal tubules upon contact with acid urine. (2) On the basis of certain observations, a theory of anaphylaxis has been formed, that is, that the kidneys are sensitized to a substance contained in the incompatible blood. (3) The renal changes and consequent metabolic disturbances brought about by the transfusion reaction are based on the hypochloremia resulting from persistent vomiting. (4) Irritating or toxic substances, produced by the incompatible blood, cause the pathological and functional renal changes. Mason and Mann (32) demonstrated a constricting action of hemoglobin on the renal vessels when incompatible blood was administered intravenously to dogs. They believe that on this basis the disturbance in renal function is the result of vasospasm of the renal arteries and smaller arteries, which result in parenchymal ischemia.

TREATMENT

When it is established that the reaction is caused by the recipient's having received incompatible blood, vigorous treatment should be instituted at once. There can be little general agreement on the proper mode of treatment to use until the mechanism of transfusion anuria is better understood (33).

Although urinary alkalinization has not proved a cure-all, enough evidence exists in its favor to demand its immediate institution (34).

The urine can be made alkaline by the administration of sodium bicarbonate or potassium citrate orally, or sodium bicarbonate, sodium racemic lactate or sodium citrate intravenously (35). If the urine is kept at a pH of 7.5 to 8, hemoglobin stays in solution, but if an acid pH of 4.6 to 5.4 is reached, the hemoglobin is precipitated (36, 37). The urine should be kept alkaline as long as hemoglobinuria is present, and during this time the patient should be carefully observed for symptoms of alkalosis, such as lassitude, dizziness, headache, vomiting, and muscular cramps or tetany. The intake and output must be carefully observed, and it is thought that an intake of 2,000 to 2,500 cc. each twenty-four hours is necessary to wash the hemoglobin out of the kidneys. If, however, the patient becomes oliguric and edema appears, the intake should be reduced to prevent further formation of edema. When fluid is not tolerated orally, it can be given intravenously. Since damaged kidneys handle salt poorly, it should be withheld and 5 to 10 per cent dextrose in distilled water administered.

The retransfusion of compatible blood is important to counteract the severe hemolytic anemia and shock associated with these reactions. It is believed by Hesse and Filatov (38) that the renal vasospasm already mentioned is also counteracted by the immediate transfusion of compatible blood. As plasma possesses a high salt content which is poorly handled by the damaged kidneys, it is advisable to remove the plasma and resuspend the red blood cells in normal saline solution. It is also advisable to administer albumin for the restoration of the albumin-globulin ratio rather than to use commercial plasma which has a high salt content.

A new mode of treatment suggested by L. K. Diamond (39) may be helpful if applied within the first few hours of the occurrence of the reaction. This entails the use of Witebsky's (40) A and B group specific substances to neutralize the alpha or beta agglutinins, or both, that are present in the patient's serum. As much as 30 to 50 cc. of this material* may be given intravenously to any Group O patient who has received incompatible Group A or Group B blood and this will neutralize the alpha and beta agglutinins in the patient's serum to prevent the sudden agglutination and hemolysis of the remaining incompatible cells that are still in the recipient's circulation. After such treatment these incompatible cells can gradually be eliminated and will not cause the severe renal damage that would attend their sudden elimination which is associated with an unaltered hemolytic reaction.

General supportive measures should not be neglected. In order to maintain the normal concentration of the constituents of the blood from day to day, it is absolutely essential that careful, detailed studies be made daily. Recovery from anuria of from ten to twelve days' duration and an elevation of the nonprotein nitrogen to 200 mg. per 100 cc.

* Sharp and Dolme Laboratories kindly supplied this material to Dr. L. K. Diamond who made it available for the treatment of our patient.

of blood has been reported. Since the glomeruli suffer only secondarily, renal function may be restored once the tubules become patent. Hypertonic dextrose is thought by some to be helpful in promoting diuresis. Administration of penicillin is advisable to forestall pulmonary infection which is so prone to develop in these patients who are on the borderline of pulmonary edema or in a semiconscious state. The terminal hypertension associated with uremia can be moderated by the intravenous use of magnesium sulfate (41).

In spite of an early diagnosis and adequate vigorous treatment, the collected mortality as reported by Hesse (42) in 1935 was 52.5 per cent in 200 patients. These deaths were due either to hemolytic shock or to urinary suppression which goes on to fatal uremia. Because of isolated reports of an occasional dramatic result associated with splanchnic block, spinal anesthesia or the use of diathermy over the kidneys, one should not fail to consider these therapeutic ventures. There is real need for some scientific investigation as to the value of these therapeutic procedures in the treatment of uremia.

Although decapsulation of the kidney is recommended as a form of treatment of anuria (43), no real evidence is available of its having beneficial action on renal function. Theoretically, Peters (44), believes that early bilateral decapsulation is the proper treatment for anuria resulting from poisoning by bichloride of mercury, transfusion kidney, and the crush syndrome. Bywaters (45), who was aware of this theoretical value, found from a practical aspect that decapsulation failed to relieve the anuria associated with ischemic muscle necrosis (crush syndrome) in patients encountered in World War II. Talbot (46), studied the effects of unilateral decapsulation in a young woman in whom anuria developed following a transfusion reaction. Both ureters were catheterized and the urinary output from the decapsulated kidney was found to be no different than that from the untouched organ. Six weeks after recovery, special studies on kidney function showed a slightly better performance by the untouched kidney.

Recently a ray of hope has appeared on the horizon for those patients in whom this apparently fatal type of uremia develops. Fine, Frank and Seligman (47) have perfected a method for the treatment of acute renal failure by peritoneal irrigation which may eliminate the clinical and chemical evidence of the uremic state without injury to the peritoneal structures.

CASE REPORTS

Case 1.—A 47-year-old man, Group O Rh positive, received 350 cc. of incompatible Group A Rh positive blood on the day of operation. This mistake was caused by an error in labeling the pilot tubes of two recipients, one Group O Rh positive, the other Group A Rh positive. The Group A Rh positive patient received a Group O Rh positive blood without reaction. The patient receiving the incompatible blood complained of a chilly sensation and his pulse rose 20 beats

per minute. There was no chill or elevation of temperature on the day he received the transfusion but he did have a chill the following day. The signs and symptoms of this hemolytic reaction were no doubt greatly modified by the spinal anesthesia the patient received for his operation. On the fourth postoperative day it was learned that the transfusion had been incompatible. During this interval there had been persistent nausea and vomiting with an associated progressive diminution in the urinary output. In spite of vigorous treatment with intravenous dextrose and alkalis plus albumin to restore the albumin globulin ratio and the administration of three compatible transfusions to combat the hemolytic anemia, he died on the ninth day. During this time oliguria developed which went on to a complete anuria. Associated with this was an elevation of the nonprotein nitrogen of the blood to 147 mg. per 100 cc. Autopsy confirmed the clinical impression of a hemolytic transfusion reaction with severe kidney damage that caused anuria.

Case 2.—A 75-year-old man, Group O Rh positive, had received two transfusions of Group O Rh positive blood without reaction in conjunction with an abdominoperineal resection for carcinoma of the rectosigmoid. Nineteen days later he underwent a transurethral prostatic resection because of a persistent postoperative urinary obstruction resulting from benign prostatic hypertrophy. At the completion of this second operation, 500 cc. of blood was collected from a professional donor, citrated and its administration to the patient begun. He was awake and rational but he had not fully recovered the use of his legs after the spinal anesthesia which was employed for the operation. No signs of incompatibility were noted until he had received 200 cc. of blood. Then a profound vascular collapse was noted, with a fall in blood pressure to 56 mm. systolic and 30 mm. diastolic, and the patient vomited. Transfusion was discontinued. Supportive treatment in the form of intramuscular epinephrine, oxygen and 5 per cent dextrose in distilled water intravenously was instituted. The blood pressure returned to normal and alkalization of the urine was begun by intravenous administration of sodium bicarbonate. Hemoglobinuria was evident by this time, however. On rechecking the grouping and cross matching, it was learned that the donor was Group A Rh positive. This mistake was the result of a series of errors in the laboratory. A compatible transfusion with Group O Rh positive blood was started, and after 300 cc. had been administered, the patient had a second chill. This transfusion was discontinued and 500 cc. of commercial plasma was administered. Alkalinization of the urine was continued by administration of sodium racemic lactate along with 5 per cent dextrose in distilled water intravenously. After twenty-four hours, sodium bicarbonate orally was substituted for the sodium racemic lactate. Heat in the form of diathermy was applied over the kidneys. In spite of the relatively small amount of incompatible blood received, the early diagnosis and early vigorous treatment, anuria developed and the patient died five days later. The nonprotein nitrogen reached 106 mg. per 100 cc. of blood twenty-four hours before death.

Case 3.—While being operated on for a benign giant cell tumor of the right humerus, a 17-year-old male, Group O Rh positive, was given 500 cc. of incompatible Group A Rh positive blood. Several hours after operation a second transfusion was thought indicated because of persistent oozing of blood from the operative site plus a rapid pulse and profuse sweating. The contemplated second transfusion was cross matched with the blood from the pilot tube of the first transfusion and obvious incompatibility of the two bloods was discovered. The

grouping was repeated on the original blood and it was found to be Group A Rh positive. The patient's urine was immediately alkalinized by the administration of sodium racemic lactate intravenously. Forty cubic centimeters of Witebsky's A and B specific substances was given intravenously and a compatible transfusion of red blood cells resuspended in saline solution was administered to combat the hemolytic anemia which had reduced the hemoglobin to 6 Gm. per 100 cc. A large amount of precipitated hemoglobin was passed in the urine during the first ten hours and the nonprotein nitrogen of the blood rose to 55 mg. per 100 cc. During this time the patient became jaundiced and had a serum bilirubin of 3 mg. per 100 cc. The intensive treatment with alkalis had to be moderated as signs of tetany were noted and a carbon dioxide combining power of 102 volumes per cent was discovered. The urine was kept alkaline for eight days. Grossly, there was no hemoglobinuria after twenty-four hours. Five days after the transfusion reaction, a transfusion of 500 cc. Group O Rh positive blood was given, without untoward reaction. Although there were complaints of nausea and anorexia for a few days, this patient made an uneventful recovery and left the hospital with normal blood and urinary findings and without detectable kidney damage.

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SUMMARY

In our experience, clerical errors have caused the greatest number of hemolytic transfusion reactions.

When incompatible blood is administered to a patient under general anesthesia there are no reliable signs or symptoms to indicate what has happened. Examination of the urine for the presence of hemoglobinuria offers the anesthesiologist a simple means for the early detection of such reactions.

Until the exact mechanism of transfusion anuria is understood it is unlikely that a single form of specific therapy for hemolytic transfusion reactions and their sequelae will be discovered. Therefore, our greatest efforts should be toward prevention of these reactions.

A new mode of treatment is suggested which may be helpful if applied within the first few hours of the occurrence of the reaction.

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JOINT MEETING OF THE PHILADELPHIA SOCIETY OF
ANESTHESIOLOGISTS AND THE AMERICAN SOCIETY
OF ANESTHESIOLOGISTS, INC.

BELLEVUE-STRATFORD HOTEL, PHILADELPHIA, PENNA.

October 7, 8, and 9, 1948

PROGRAM

THURSDAY, OCTOBER 7, 1948

9:00 a.m. Registration.

9:30 a.m. to 12:00 p.m. Clinics and Laboratory Demonstrations.

2:00 p.m. to 5:00 p.m. Formal papers—Chairman, Curtiss B. Hiekoex, M.D.

1. The Evaluation of Cardiac Patients in Anesthesia, George D. Geckeler, M.D.
2. The Physiology of Cerebral Circulation, Seymour S. Kety, M.D.
3. The Physiology of Pulmonary Circulation, Julius H. Comroe, M.D.
4. The Pathological Findings in Sudden and Unexpected Death, J. B. Gregory, M.D.
5. Anoxia, Carl F. Schmidt, M.D.

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