HEMATOLOGIC CHANGES OBSERVED AFTER EXTRACORPOREAL CIRCULATION DURING OPEN-HEART OPERATIONS*

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HEMATOLOGIC studies were performed to detect whether or not alterations occurred in the formed elements of the blood in 12 consecutive patients who underwent open-heart operations with the use of heart-lung machines. The rotating disk types of oxygenator were used, the Björk, the Kay and Cross, and the Melrose. Eight of the patients were children less than 14 years of age, and four were adults. The duration of the extracorporeal circulation ranged from 9 to 24 minutes and averaged 18 minutes.

Methods and Technic

The following hematologic determinations were made prior to operation and usually repeated on the first, third, and seventh postoperative days: hemoglobin content of the blood, erythrocyte and leukocyte counts, differential leukocyte count, hematocrit value, icterus index, reticulocyte percentage, platelet count (Rees-Ecker method), bleeding time (Ivy method), coagulation time (Lee-White method), clot retraction, and one-stage prothrombin time. Additional determinations, such as plasma hemoglobin, fibrinogen, fibrinolytic activity, serum bilirubin value, Coombs reaction, and protamine titration, were made when indicated. For several patients, hematologic determinations were made periodically for six months after operation.

Analysis of Results

A review of the data indicates that no serious hematologic changes occurred in the 12 patients whose circulation was maintained by the oxygenator during open-heart operations.

The clinical examinations and the laboratory studies disclosed no hematologic disorders prior to operation. Three patients had a moderate, and one patient, a severe, hypoxemic erythrocytosis (hematocrit value of 72 ml. per 100 ml. of blood) which disappeared after surgical correction of the congenital cardiac defect. During extracorporeal circulation all of the patients received sufficient heparin to increase the blood coagulation time to several hours.

The significant findings are summarized according to three categories: (1) anemia and hemolysis, (2) leukocytic changes, and (3) hemorrhagic studies.

**Open-heart operations were performed by the open-heart team: Donald B. Effler, M.D., Department of Thoracic Surgery, and Willem J. Kolff, M.D., Department of Artificial Organs.*

(*1*) *Anemia and hemolysis.* In eight patients a mild or moderate decrease of erythrocytes, hemoglobin, and hematocrit value occurred within the week after operation. The anemia was normocytic and normochromic in type. Study of the Wright-stained blood films revealed no cytologic abnormalities of the erythrocytes. Spherocytic red blood cells and "target" cells were not observed. In nine patients the hematocrit values decreased no more than 5 volumes per cent below the preoperative values. In one patient the hematocrit value decreased from 42 cc. to 30 cc. because of hemorrhage. In two patients the erythroid elements were slightly increased.

Evidence of marked hemolysis was not observed in any of the 12 patients. There was no visible hemoglobinemia or hemoglobinuria. The plasma hemoglobin value was not quantitatively determined in all patients. In two of the patients the plasma hemoglobin values were 91 mg. per 100 ml., and 101 mg. per 100 ml., respectively, during the period of extracorporeal circulation.

Jaundice was evident in one patient in whom there was bleeding into the pericardial space which produced cardiac tamponade requiring reoperation. In that patient the icterus index was 25 units, indirect serum bilirubin was 2.8 mg. per 100 ml., and the reticulocyte count was 2.7 per cent. These findings suggest that the jaundice was the result of absorption of blood pigments from the pericardial space and was not due to excessive intravascular hemolysis. The icterus index was elevated to 13 and to 18 units, respectively, in two patients during the postoperative period. In the other nine patients the icterus index was unchanged.

A mild reticulocytosis occurred in eight patients during the first week after operation; the highest value recorded was 10 per cent. The data suggest that the marrow had responded to a mild postoperative anemia. The osmotic fragility of the erythrocytes was found to be normal in four of the patients.

The hematologic findings, however, do not exclude the presence of some increased hemolysis as a result of trauma of the erythrocytes by the oxygenator.

(*2*) *Leukocytic changes.* The leukocyte count increased to moderate values in 10 of the patients, the highest count being 23,500 per cu. mm., and several ranging between 15,000 and 20,000 per cu. mm. The leukocytosis was due to an increase of neutrophilic granulocytes. A shift to the left was usually observed. One patient had a transitory neutropenia. No cytologic abnormalities of the granulocytic cells were observed on the stained blood films. There was no significant quantitative change in the eosinophils. The monocytic cells in two patients contained conspicuous cytoplasmic vacuoles during extracorporeal circulation.

There were no significant quantitative changes in the lymphocytes, but in five patients (four children and one adult) "atypical" or prolymphocytes were conspicuous. The number of prolymphocytes ranged between 5 and 10 per cent of the differential leukocyte count; they appeared to be similar to those observed in patients with infectious mononucleosis. In one child these cells reached a peak of 22 per cent of the leukocyte count and persisted for three months. There was no clinical evidence of infectious mononucleosis and the heterophil agglutination titer was 1:8.

(*3*) *Hemorrhagic studies*. The platelet count was slightly decreased in four of the patients during the first three days after operation, but without clinical evidence of excessive bleeding. The lowest platelet count was 100,000 per cu. mm. No significant qualitative changes of the platelets were observed on the stained blood films. In the other eight patients no depression of the platelet count occurred. There was no significant abnormality of clot retraction in this series of patients.

The coagulation time 24 hours after operation was slightly prolonged in two of the patients. The coagulation time was 22 minutes in one patient and 24 minutes in another, compared to the normal range of from 10 to 20 minutes. The patient whose coagulation time was 24 minutes had a large pericardial hemorrhage that was thought to be due primarily to a technical failure rather than to a defect in the clotting mechanism.

Recently, in 10 additional patients there has been no prolongation of the coagulation time on determinations performed four hours after the completion of the open-heart operations. Moreover, in each case the retraction of the clot was adequate. In our series of 12 patients reported here, the one-stage prothrombin time was slightly prolonged in five patients in the seven-day postoperative period. The values ranged from 15 to 18 seconds, as compared to the normal value of 14 seconds. The longest prothrombin time observed was 21 seconds and occurred 24 hours after operation in the patient previously described who had pericardial hemorrhage. This was the only patient in the 12 of this group in whom coronary sinus blood sucked from the open heart was reintroduced into the circulation.

There was evidence of slight transitory fibrinolysis in two of the patients. There was no significant change in the fibrinogen value of any of the patients.

Comment

One child in our group of 12 patients died after a second open-heart operation. The other patients survived, and follow-up hematologic studies on four of these, for periods as long as eight months, revealed no significant change except the presence of "atypical" lymphocytes. The observations for this small group of patients suggests that no serious disturbances of the formed elements of the blood occur after the use of the rotating disk type of oxygenators for extracorporeal circulation.

Summary

Hematologic studies in 12 consecutive patients who underwent open-heart operations with extracorporeal circulation disclosed the following changes in the postoperative period: (1) mild anemia, (2) minimal hemolysis of erythrocytes, (3) leukocytosis, (4) "atypical" lymphocytes, (5) slight reticulocytosis,

and (6) minimal prolongation of the prothrombin time. No major manifestations of hemolytic anemia or hemorrhagic diatheses were observed.

Acknowledgment

The technical assistance of Miss Mary Stepien, Miss Mary Potter, and Miss Rose Litturi is gratefully acknowledged.