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Danger of Overwarming Blood by Microwave

James F. Arens, MD, and George L. Leonard, MD

Microwave blood warmers have a number of advantages over the currently used plastic coils immersed in water. A single warmer may be used to service several operating rooms simultaneously and the blood is warmed within a matter of minutes. Although three independent studies indicate that the red blood cells are not altered when subjected to microwaves, we have experienced difficulties. Five units of blood were obviously overheated and hemolyzed in spite of our observing recommended precautions. Four units were transfused to three patients.

EVER since it was noted that cardiac arrest due to hypothermia may result following the rapid, massive transfusion of refrigerated blood, various methods of warming have been developed.[1] The most common method consists of passing the blood through plastic coils immersed in a warm-water bath. This method has numerous drawbacks. The introduction of microwave blood warmers has been hailed as a distinct advance with numerous advantages. A single, centrally located warmer may be used to service all the operating rooms in a surgical suite. The inconvenience and expense of having individual, disposable coils for each patient are eliminated. The blood may be warmed within minutes by operating room personnel and transfused as rapidly as required without inducing hypothermia. Reports in three independent studies have indicated that the microwaves exert no deleterious effects on the blood cells.[2,3]

The unit we have been using delivers 1,100 microwaves through the blood in a plastic bag at a frequency of 2,450 megahertz (2,450,000,000 cycles per second) for a maximum of three minutes or until the temperature of the blood is sufficient to inactivate the machine, ie, 95 F. The bag is placed in a rigid acrylic cylinder rotated at 50 rpm during warming. A thermistor probe within the cylinder wall presses snugly against the plastic bag and activates a timer to stop the cycling when warming is complete. Only plastic bags completely filled with whole blood (450 cc of blood plus acid citrate dextrose or citrate phosphate dextrose anticoagulant) can be properly accommodated by the apparatus.

Five units of blood have seemingly been overheated by the warmer; four were actually transfused to three patients. The fifth, a seven-day-old Rh-positive unit, felt warm to the touch upon removal from the apparatus. After it had been left standing for ten minutes the temperature of the exterior was 97 F (36.1 C) when the probe was placed in the folds of the bag. The hemoglobin content of the plasma was 180 mg/100 ml. The plasma in the segment of tubing retained by the blood bank was clear, indicating no hemolysis. The unit was not transfused.

The following are case reports of three patients who evidenced hemolysis after receiving blood warmed in the microwave unit. Apparently this was due to overheating; no other single cause for the hemolysis could be identified. Examination of the unused blood in the bag showed gross hemolysis while that in the pilot tubes retained by the blood bank showed no hemolysis.

Report of Cases

CASE 1.—A 54-year-old man underwent a bilateral aortocoronary bypass for occlusive arteriosclerotic coronary artery disease. He was given a transfusion while surgery was in progress and no hemolysis was noted.

Several hours later, in recovery, the patient received 5 units of blood warmed in the microwave unit. The fifth unit was warmed and administered at approximately 6 PM. This unit, four days old, was group A, Rh-positive. The segment tubing had not been detached from the bag prior to warming. The nurse noted that the bag felt warm to touch but did not call this to anyone's attention. The patient had received 400 cc of the total 517 cc (blood plus acid citrate dextrose anticoagulant) in the bag when it was noted that his urine was dark. The transfusion was stopped. A sample of the patient's plasma drawn at this time was pink and contained hemoglobin (2.6 gm/100 ml). Chocolate-colored clots adhered to the sides of the bag. The plasma of the blood in the pilot segment of tubing retained by the blood bank contained no significant quantity of free hemoglobin. Samples of blood before and after transfusion were retyped and recross-matched to exclude the possibility of incompatibility between donor and patient. The direct and indirect Coombs test remained negative following transfusion. Mannitol was promptly administered intravenously. After several hours the urine was clear; the patient made an uneventful recovery.

CASE 2.—A 59-year-old man underwent a bilateral aortocoronary bypass procedure for coronary artery occlusive disease and congestive heart failure. He was admitted to the recovery room at 2:45 PM, at which time 5 units of whole blood warmed in the microwave unit were administered. The urine was noted to be dark after 250 cc of the fifth unit had been transfused and the transfusion was stopped. The serum hemoglobin in a specimen drawn promptly after the urine was noticed to be dark contained 160 mg/100 ml. The blood remaining in the bag was totally hemolyzed, containing 11 gm/100 ml. The segment of tubing had not

From the departments of anesthesiology (Dr. Arens) and pathology (Dr. Leonard), Ochsner Clinic and Ochsner Foundation Hospital, New Orleans.

Reprint requests to 1514 Jefferson Hwy, New Orleans 70121 (Dr. Arens).

been removed from this bag before warming, nor had the nurse noted whether or not the bag felt warmer than usual. The blood was one day old, group A, Rh-negative. The plasma in the segment tubing retained by the blood bank showed no evidence of hemolysis. Tests for incompatibility, including the Coombs' test, were negative.

CASE 3.—A 52-year-old man underwent a bilateral aortocoronary bypass for coronary artery disease. Toward the end of the operation, when the cardiopulmonary bypass was discontinued, massive hemolysis was noted. The urine was dark red. During the next several days the patient underwent reexploration for bleeding. He died of bilateral confluent bronchopneumonia on the tenth postoperative day.

Two units of blood warmed in the microwave unit added to the cardiopulmonary pump showed evidence of hemolysis. The interior of the blood sets was covered with small, chocolate-colored clots. The quantity of blood that remained in the bags was not sufficient for analysis of plasma hemoglobin; instead, it was centrifuged in micropipettes. The supernatant plasma was reddish-pink; the hemoglobin content was estimated to be approximately 200 mg/100 ml. The blood remaining in the bag of course had not been in the pump nor in the patient. The patient's serum hemoglobin level was not determined following the episode. Both units of blood were type O, Rh-positive; one was two days old and the other ten days old. The blood in the segment of tubing retained by the blood bank revealed no plasma hemoglobin. Therefore, it was concluded that the blood underwent hemolysis in the warmer.

Comment

This report is made to alert others to the possibility of gross hemolysis of blood secondary to overheating of blood bags with microwave blood warmers. The warmer had been used for 18 months, during which time approximately 800 units were warmed.

Leonard and co-workers[2] after studying serum haptoglobin levels, red blood cell (RBC) survival, and adenosine triphosphate concentrations in blood warmed by microwaves (Ohio blood warmer used), reported that no deleterious effects resulted from the warming. Milam and associates[3] measured plasma potassium and hemoglobin levels in 40 units of blood before and after microwave warming (Taurus blood warmer used). They noted no increase in any of these components after warming. We measured plasma, potassium, hemoglobin, and lactic acid dehydrogenase levels in 25 units before and after warming (Ohio blood warmer used) and detected no significant change. These three studies, each performed independently of the other, indicated that RBC subjected to heating by microwaves undergo no apparent alteration.

Prior to placing the unit into use, we also conducted some trials using outdated blood. It was observed that if the blood bag were placed in the container with the label in direct contact with the probe, the blood became overheated. Furthermore, when the label was removed, overheating was still possible if the probe came into contact with the mucilage from the label coating the surface of the bag. The blood also became overheated if the double-edged plastic side of the bag or one of the segments of tubing from the bag came into contact with the probe. If paper tape came in contact with the sensory probe (Taurus blood warmer used), overheating occurred. Even though the aforementioned pitfalls were avoided, overheating was still encountered. After warming, the temperature of each unit was measured with a thermometer. In three units the temperatures were 105 F (40.6 C) and in one unit 108 F (42.2 C) and possibly warmer, since this was as high a temperature as the thermometer registered. Gross hemolysis was evident in these units. Although we do not have absolute assurance that the blood was warmed properly, we have little reason to suspect that it was not after making these observations.

Staples and Griner[4] have reported overheating due to malfunction of the rotator in the warmer. Malfunction was not a problem in the aforementioned cases. We have discontinued using the Ohio microwave warmer for the present although we are not condemning it. We urge manufacturers to modify existing apparatus in order that these pitfalls may be avoided. It is essential that these units be as "fool-proof" as possible. Using the precautions mentioned below, the Taurus blood warmer has been used for three months for approximately 150 units of blood without difficulty.

We suggest that the following precautions be observed by those using microwave blood warmers. First, the responsibility of using the device should be delegated only to nurses or doctors specially trained in its use. Second, the temperature of the bag should be determined by placing the recording probe in the folds on the exterior and recording this temperature. Third, daily, or perhaps twice daily, plastic units of saline solution should be warmed to determine whether or not the device is functioning properly.

Since microwaves pose hazards to patients with pacemakers and since they have been associated with the development of cataracts, these devices must be provided special shields to protect both patients and personnel.

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