Comparison of the effectiveness of blood transfusion and reinfusion

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Abstract. Studies by atomic force and scanning electron microscopy have shown that erythrocytes of foreign blood have morphological defects. The sequestration of foreign erythrocytes makes it difficult for the erythron to selfrepair. The actual solution to this problem is the application of the blood reinfusion technique using the Cell Saver apparatus. Transfusion of autoerythra suspension, harvested using the Cell Saver apparatus during the operation, stabilizes red blood counts in the early post-transfusion period in patients and reduces the manifestation of massive hemotransfusion syndrome. Hardware reinfusion of erythrocytes is effective and safe for massive blood loss in obstetrics. Reinfusion dictates the need for parallel correction of all blood parameters. Application of the principles of patient blood management can reduce the transfusion load, improve the quality of medical care.

1. Introduction
Donor blood transfusion in obstetric practice is characterized by large volumes. Transfused erythrocytes, especially those of long shelf life, are rapidly destroyed in the recipient’s bloodstream, which contributes to the development of postoperative anemia.[1]

2. Experiment and methods
To explain the complications from the transfusion of large doses of donor erythrocytes, we studied the structure of normal and donor erythrocytes membranes using atomic force microscopy (afm, surface topography and morphometry) with large scanning fields on the equipment of the Regional Center of Probe Microscopy of Collective Use of the Ryazan State Radio Engineering University named after V. F. Utkin at the probe laboratory ”Negra -Aura” (NT MDT SI, Russia). AFM processing was performed using builtin software. Various forms of erythrocytes have been analyzed.

Atomic force microscopy allows analysis of the object with a probe, with the of nanometer curvature radius. The atomic force microscope can obtain a truly three-dimensional relief of the surface.[2] This method opens up opportunities for studying adhesion, molecular binding, electrostaticity, elasticity and mobility of cell membranes. Blood cells were one of the first biological objects studied by the AFM method. Usage of large scanning fields helps to obtain a comprehensive stereometric characteristic of whole erythrocytes. In the taping mode with nanometer resolution protruding protein globules on the membrane surface were differentiated.[3] The differences in the
elastic properties of individual sections of the membrane of these shaped elements were revealed with phase contrast method. A change in the geometric properties of erythrocytes was found when they were exposed to various substances.

Innovative microscopy methods make it possible to obtain new data in the pathomorphology of massive blood transfusion syndrome. It was found that under the action of EDTA (Ethylenediaminetetraacetic acid), which is used as an anticoagulant [4], the erythrocyte membrane changes. There are outgrowths in the form of thorns on the erythrocyte, which loses the elastic function of the membrane. It is very important when the erythrocyte passes through the lumen of the capillary. Similar violations occur during the procurement and storage of donated blood. It was found that transfused erythrocytes, especially long-term storage, have uneven areas, broken edges, which affects the transfer of oxygen and disrupts the gas transport function of the red blood cell. The increased moisture content of the erythrocyte leads to the symptom of "wet erythrocyte" [5], which leads to sticking together and sludge syndrome, closure of the capillary by microconglomerates with the subsequent ischemia of cells and tissues. The described changes in erythrocytes were studied in women whose pregnancy was complicated by preeclampsia.

To explain the complications arising from the transfusion of large doses of donor erythrocytes, we studied the structure of the membrane of normal and donor erythrocytes using AFM (surface topography and morphometry) methods using large scanning fields. The experiments were carried out at the Ntegra-Aura probe laboratory (NT-MDT SI, Russia). Processing and construction of AFM images was carried out using built-in software. Various forms of erythrocytes have been studied in the experiments.

According to the results of hemoscanning, the majority of erythrocytes had a rounded shape. The diameter of the erythrocyte, calculated by studying the profile of the cell, corresponded to the average known values. The depth of the depression of normocytes was 0.25 ± 0.06 nm. When studying the ratio of the diameter of the erythrocyte to the diameter of the cavity, the value was 21 ± 2 units.

When studying donor erythrocytes, differences in the shape of erythrocytes were found. Elongated cells were observed, which is associated with a violation of the elasticity of the membrane. The passage of such an erythrocyte through the microvasculature is difficult. An increased content of cytoplasmic bridges between cells was also found, which promotes stasis, sludge and then thrombosis. Discocytes with a crest, discocytes with outgrowth, discocytes with multiple outgrowths, and discocytes in the form of an irregular oval were found. The curvature and depth of the central platform is different. The depth of the depression of normocytes was 0.15 ± 0.06 nm. When studying the ratio of the diameter of the erythrocyte to the diameter of the cavity, the value was 11 ± 2 units. These types of altered erythrocytes cannot be restored and are irreversibly deformed. They cannot take part in the process of oxygen transportation and are destroyed in the microvasculature.

The sequestration of foreign erythrocytes makes it difficult for the erythron to self-repair.[6] The actual solution to this problem is the application of the blood reinfusion technique using the Cell Saver apparatus. Comparative analysis of the effectiveness of reinfusion in comparison with blood transfusion was carried out using the example of typical cases.

3. Results and discussion
Blood transfusion for blood loss of 2700 ml. Blood counts before transfusion: Hb = 54g/l (liters), erythrocytes = 1.65 * 10^{12}/l, Ht = 14.9%, leukocytes = 16.0 * 10^9/l, thrombocytes = 70.6 * 10^9/l. Transfusion: ffp = 1780ml, erythrocyte suspension = 870ml.

Blood parameters after transfusion: Hb = 84g/l, erythrocytes = 2.7 * 10^{12}/l, Ht = 23.6%, leukocytes = 14.7 * 10^9/l. Blood parameters values for different groups are presented in table 1.

Blood transfusion with blood loss 4000 ml. Blood parameters before transfusion: Hb = 39g/l, erythrocytes = 1.3 * 10^{12}/l, Ht = 11.5%. Transfusion: ffp = 2980 ml, erythrocyte suspension = 1825 ml, reinfusion of washed erythrocytes using the Haemonetics Cell Saver-5 apparatus was 982ml.
Figure 1. Normal erythrocyte size

Figure 2. Canned erythrocyte (25-30 days of storage)

Table 1. Dynamics of blood parameters during reinfusion.

| Group             | Before transfusion | Immediately after transfusion | 18 hours after transfusion | 24 hours after transfusion | 34 hours after transfusion |
|-------------------|--------------------|-------------------------------|---------------------------|----------------------------|---------------------------|
| Hemoglobin g/l    | 54                 | 84                           | 80                        | 58                         | 50                        |
| Erythrocytes 10^{12} /l | 1.65              | 2.72                         | 2.5                       | 1.8                        | 1.62                      |
| Leukocytes 10^{9} /l   | 14.9               | 14.7                         | 18.1                      | 11.1                       | 11                        |
| Thrombocytes 10^{9} /l   | 70.6               | 90                           | 86                        | 62                         | 63                        |

Figure 3. Donated erythrocytes before storage

Figure 4. Donor erythrocytes after 42 days of storage

Table 2. Dynamics of blood parameters during reinfusion.

| Group             | Before reinfusion | Reinfusion | 7 hours after reinfusion | 10 hours after reinfusion | 24 hours after reinfusion | 34 hours after reinfusion |
|-------------------|-------------------|------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Hemoglobin g/l    | 39                | 186        | 95                       | 84                       | 74                       | 71                       |
| Erythrocytes 10^{12} /l | 1.3               | 5.2        | 3.2                      | 2.8                      | 2.53                     | 2.18                     |
| Leukocytes 10^{9} /l   | 20.1              | 11.5       | 11.5                     | 9.6                      | 4.9                      | -                        |
| Thrombocytes 10^{9} /l   | 258               | 154        | 159                      | 103                      | 100                      | -                        |
Blood counts after transfusion: Hb = 186g/l, erythrocytes = 5.2 * 10^{12}/l, Ht = 55.5%, leukocytes = 20.1 * 10^9/l, thrombocytes = 258 * 10^9/l. Blood parameters values for different groups are presented in table 2. Reinfusion is characterized by a decrease in hemoglobin (by 9g/l, 10g/l and 3g/l), smooth and slow, in contrast to the methods of introducing donor erythrocyte mass (by 22g/l, 8g/l). 72 hours after the transfusion of blood products, a significant decrease in hemoglobin, erythrocytes, leukocytes and thrombocytes was noted. However, with reinfusion, the decrease was smoother and did not reach the initial low values.

Reinfusion of donor erythrocytes is cost-effective as well. So 1 dose of fresh frozen plasma costs 18,752 rubles, 1 dose of erythromass — 15,337 rubles, 1 dose of autoerythrocytes corresponds to 2-3 doses of donor hermass.

4. Conclusion
Transfusion of autoerythra suspension, harvested using the Cell Saver apparatus, stabilizes red blood counts in the early post-transfusion period and reduces the manifestation of massive blood transfusion syndrome. Hardware reinfusion of erythrocytes is effective and safe for massive blood loss in obstetrics. Reinfusion dictates the need for parallel correction of all blood parameters. Application of the principles of patient blood management can reduce the transfusion load, improve the quality of medical care.

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