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A Study of Acute Normovolemic Haemodilution and Autologous Blood Transfusion.

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ABSTRACT

Background: Autologous transfusion has advantage over homologous blood transfusion. With autologous transfusion there is avoidance of complications associated with allogenic transfusion and conservation of blood resources. Aim: To study the advantages of autologous blood transfusion in comparison with homologous blood transfusion. It is also intended to know the fall of the haematocrit levels both in Autologous blood re-infusion and homologous blood transfusion cases. It is also aimed to study the advantages of acute normovolemic haemodilution. **Methods:** 50 patients undergoing elective orthopaedic surgical procedures were studied and compared with 50 control patients. The study group undergoing haemodilution with 3.5% polygeline (haemaccel) and autologous blood transfusion, and the control group which received homologous blood transfusion were included in this work. Hematocrit was measured preoperatively, intraoperatively and twenty four hours after reinfusion of blood for autologous transfusion group and preoperatively and twenty four hours after surgery for homologous group. Postoperatively all the patients were closely observed for vitals and any collection of blood via drain. All the complications were noted. **Results:** In the study group it was observed that the haematocrit levels maintained well above safety margin levels. **Conclusion:** Acute normovolemic haemodilution improved tissue oxygen perfusion and micro circulation by lowering the blood viscosity. And autologous blood transfusion eliminated the blood transfusion reactions and transmission of diseases while maintaining haematorit above safe levels.

Keywords: Autologous transfusion, homologous transfusion, acute normovolemic haemodilution, haematocrit.

INTRODUCTION

Autologous transfusion is not a new concept. Reinfusion of shed blood was employed as early as 1818 and preoperative donation of autologous blood was advocated in the 1930s when the first blood banks were established. However, the last few decades have brought a marked increase in the use of autologous transfusion. Complex operative procedures such as open heart surgery and organ transplantation have prompted the search for alternatives to allogenic (homologous) transfusion and technologic advances have made possible the development of safe, easy -to-use devices for blood salvage.

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There is little doubt, however, that the major stimulus for the growth of autologous transfusion programs has been the fear of transfusion-transmitted diseases.

There are three types of autologous transfusion: preoperative blood donation, acute normovolemic haemodilution, and intraoperative and postoperative blood salvage. The advantages and disadvantages, applications and potential complications vary with the techniques. Appropriate use of autologous transfusion is but one aspect of an integrated blood conservation programme. Other measures include meticulous surgical haemostasis, acceptance of lower haematocrits and employment of pharmacological agents to decrease blood loss.

The two major reasons for employing autologous transfusion are avoidance of complications associated with allogenic transfusion and conservation of blood resources. The altruistic public has thus far donated sufficient blood to meet the needs of virtually all patients. However, when population increases are considered, blood collection rates have declined. In addition, approximately 5% of collection units must be

destroyed because of positive laboratory tests for viral disease.

The first transfusion associated case of AIDS was diagnosed and reported in 1982, and testing for antibody to the human immunodeficiency virus (HIV) was introduced in 1985.

Avoidance of the immunosuppressive effects of allogenic transfusion may be an important benefit of autologous transfusion. An increasing body of evidence indicates that allogenic transfusion is associated with increased rates of solid tumor recurrence. The association of transfusion and decreased disease-free survival is independent of tumor stage and size, duration of the surgical procedure, and patient demographics. Immune suppression secondary to allogenic transfusion also appears to increase the risk of postoperative infection. A five-fold decrease in postoperative infection has been reported in patients undergoing spine surgery who receive only autologous blood or are not transfused.

Additional benefits of autologous transfusion are elimination of alloimmunization, allergic and febrile reactions, and acute and delayed haemolytic reactions. Although the incidences of fatal transfusion reactions are only about, 1.5 per million red blood cell (RBC) transfusions, the incidence of transfusion errors is closer to 1 in 12,000. Approximately 50% of the errors are solely due to failure to properly identify the patient prior to transfusion.

Patients with rare blood phenotypes can also benefit from autologous transfusion because compatible allogenic blood may not be available. Under some circumstances, blood loss occurs so rapidly that the only means of providing a sufficient volume of blood is intraoperative blood salvage. Preoperative phlebotomy with acute normovolemic haemodilution is the only practical source of fresh whole blood for transfusion.

MATERIALS AND METHODS

Patients- 50 patients undergoing elective orthopaedic surgical procedures were studied and compared with 50 control patients. Patients varying in ages from 12-79 years were included of either sex. The weigh range was 28-80 kg. Patients were thoroughly investigated for the presence of systemic diseases. Those with cardiovascular, severe respiratory disorders, neurological disorders and bleeding disorders were excluded from the study. Routine investigations were done in all these patients along with packed cell volume ranged from 32-48%.

The study group undergoing haemodilution with 3.5% polygeline (haemaccel) and autologous blood transfusion, and the control group which received homologous blood transfusion were included in this work. Consent was taken after explaining the procedure to the patients including the benefits of autologous blood transfusion.

Anaesthesia - The aim of anaesthetic technique was to use agents which would be least likely to prevent the increase in cardiac output which must occur when the patient is haemodiluted. General anaesthesia using relaxant, oxygen and nitrous oxide technique was given in all patients.

Monitoring- Clinical monitoring was supplemented with electrocardiographic monitoring. Blood pressure was measured by non invasive technique. Urine output was also measured. Hematocrit was measured preoperatively, intraoperatively and twenty four hours after reinfusion of blood. It was considered important to make this measurement for blood volume replacement. The hematocrit was used as it is an easy measurement to carry out, and can be converted to approximate haemoglobin concentration by dividing the hematocrit by three. Blood loss was estimated by weighing the surgical packs, measuring the volume of blood in the suction bottles, and estimating the blood loss on the surgical drapes. Oxygen saturation was monitored with pulse oximetry and also pulse rate.

Technique of haemodilution and auto transfusion - Before the induction of anaesthesia, while the patient was kept on the operating table, 50 patients had 300 ml of autologous blood collected in standard disposable blood collecting bags (penpol bags).

This blood volume was replaced simultaneously with 3.5% polygeline 300 ml per unit of blood collected. The blood was collected through median cubital vein with 18 gauge venous cannula. This allowed collection of blood at a reasonable rate of about one unit of blood per fifteen minutes. The autologous blood is stored at room temperature. Blood loss during surgery was immediately replaced with equal volumes of blood and crystalloids. The maintenance of normal blood volume was confirmed by continual reassessment of cardiovascular parameters. Reinfusion of the autologous blood was given intraoperatively for four patients because of significant blood loss and in remaining at the end of surgery.

Postoperative care - Recovery was uneventful in all the cases. Postoperatively all the patients were closely observed for heart rate, blood pressure, oxygen saturation, electrocardiogram, urine output and any collection of blood via drain. The patients were then followed until the discharge from hospital. All the complications were noted. Further blood volume replacement requirements were assessed clinically and no further replacement was required in study group.

Non-diluted and homologous blood transfusion patients (Control group)- These patients were given similar anaesthetics and monitored in the same way during the operation as described for the study group. Blood loss during surgery was replaced with

homologous blood transfusion. Haematocrit values were done preoperatively and twenty four hours after surgery.

Selection of cases- The selection of Orthopaedic cases was done on the basis that they are free from other systemic diseases other than fractures etc. Majority patients belong to younger age group. So, these patients are otherwise normal. The lowest haemoglobin level taken was 9 gm/dl.

RESULTS

The present study which included hundred patients out of which fifty patients have received autologous blood transfusion and remaining fifty patients have received homologous blood transfusion. The packed cell volume values of all the patients both in study and control group were shown in [Table 1]. The mean intraoperative blood loss in both the study and control groups were tabulated in [Table 2].

During procedure the parameters like pulse rate, blood pressure, electrocardiogram, oxygen saturation were observed throughout. There was no significant change in pulse rate, blood pressure and oxygen saturation in study group. The average blood loss is 155 ml in study group. About four patients in study group received intraoperative reinfusion, because of significant blood loss. All these patients never had any major or mild transfusion reactions. Remaining forty six patients received immediate postoperative blood transfusion and no blood transfusion reactions were noted among them.

In the study group it was observed that the haematocrit levels maintained well above safety margin levels as indicated by Martin et al[1]. About three patients, in the study group developed hypotension, bradycardia and sweating at the time of blood collection. So, collection of blood stopped immediately and continued after ten minutes without any treatment.

In the control group of fifty patients, the packed cell volume values before operation and twenty four hours after surgery with homologous blood transfusion were shown in table-4. All the patients received intraoperative homologous blood transfusion, because of significant blood loss. About six patients in this control group developed significant blood transfusion reactions of which immediate hypotension was noted in three cases and laryngeal oedema in one case postoperatively, which required immediate intervention.

All the data in these two groups were analysed statistically by using Chi- Square test. P value is less than 0.001. This P value is less than 0.05 which has to be taken significant.

There were two patients in the study group who belong to "Jehovah Witnesses", who rejected homologous blood transfusion because of their religious beliefs. They were given autologous blood transfusion.

Table 1: Time for fracture union.

S. No.	Autologous Blood Transfusion			Homologous Blood Transfusion	
	PCV before haemodilution %	PCV after haemodilution %	PCV 24hrs. after reinfusion	PCV before surgery %	PCV 24hrs. after surgery %
1	48	40	46	38	28
2	36	28	32	30	26
3	46	44	45	32	26
4	40	36	38	34	26
5	34	29	32	34	25
6	42	38	38	31	26
7	41	36	38	28	20
8	44	38	40	29	23
9	46	38	40	33	26
10	40	32	34	39	31
11	38	30	34	32	26
12	38	30	32	30	27
13	45	38	49	33	28
14	40	38	38	40	28
15	45	35	38	40	28
16	45	36	40	38	32
17	42	36	38	35	29
18	38	28	34	36	31
19	36	28	30	29	22
20	35	28	32	34	28
21	42	38	40	38	30
22	38	30	33	39	30
23	35	30	32	40	31
24	42	36	40	38	29
25	40	36	38	32	24
26	38	32	36	36	30
27	34	28	30	38	30
28	36	32	34	35	30
29	43	38	40	39	30

30	38	33	36	33	28
31	44	40	41	36	28
32	38	35	36	38	32
33	41	36	38	34	28
34	39	33	37	31	26
35	35	29	32	37	30
36	38	32	35	32	25
37	38	32	35	34	27
38	33	28	30	30	25
39	38	30	32	32	27
40	35	30	32	34	28
41	40	36	38	36	30
42	38	33	35	39	31
43	32	28	30	41	34
44	36	30	32	40	35
45	39	33	36	38	36
46	35	30	32	33	28
47	36	32	34	38	30
48	34	28	30	31	25
49	36	30	32	35	27
50	33	28	30	36	29

Table 2: Mean intraoperative blood loss.

Mean intraoperative blood loss	
Study cases	Control cases
155 ml	180 ml

Table 3: Autologous blood transfusion.

Mean Haematocrit In 50 Haemodiluted Patients (Mean Values)	
Before haemodilution	0.39
After haemodilution	0.32
24hrs after operation	0.36

Table 4: Homologous blood transfusion.

Mean Haematocrit In 50 Patients (Mean Value)	
Before operation	0.34
24 hrs after operation	0.28

Table 5: Decrease in packed cell volume.

Type of transfusion	</=5	>5	Total
Autologous blood transfusion	44(88%)	6(12%)	50
Homologous blood transfusion	13(26%)	37(74%)	50

P value <0.001 (significant)

DISCUSSION

The present study was under taken at our institute. This study included fifty patients in whom acute normovolemic haemodilution and autologous blood transfusion has been carried out. The haematocrit values in the study group was maintained well above the safety levels, that is twenty five percent (Martin et al)[1] .

Preoperatively, blood of higher haemoglobin concentration is removed and saved for later reinfusion as needed. Simultaneously, the volume of blood withdrawn is replenished with equal amount of 3.5% polygeline (haemaccel). The blood then lost during surgery has a lower haemoglobin concentration. Hence, less haemoglobin is lost. Similarly, in the presence of a low haematocrit value, there is a reduction in the red cell mass lost during intraoperative bleeding as opposed to when the haematocrit is high or normal. Besides, the body tolerates red cell loss better than exclusion of fluid volume (Fontana et al. 1995[2]; Perez et al, 1991; Van Workers et al, 1992; Weiskopf 1995[3]). Thus, normovolemic haemodilution has the potential to decrease the need for allogenic transfusion (Martin et al, 1987)[1] .

Blood loss and haemodilution bring about a reduction in oxygen binding capacity (Hint, 1968) on the other hand, during normovolemic haemodilution, the compensatory mechanisms of the body overcome the drop in oxygen carrying capacity. In healthy individuals, these mechanisms guarantee oxygen delivery to tissues even when the systemic haematocrit is twenty percent, provided the patient is isovolemic (Hauser et al, 1980; Henry et al, 1996; Zander, 1988). The tissue oxygen pressure is not usually compromised until the haematocrit level falls below twenty percent (Messmer et al, 1973[4]). In normovolemic haemodilution, reducing the haematocrit to twenty five percent, or lower, does not change the peripheral oxygenation of tissues (Fire et al, 1995; Hauser et al, 1980; Messmer et al, 1973[4]). In this study the haematocrit values maintained well above twenty five percent in all the cases.

In normovolemic haemodilution, the oncotic pressure may fall due to a reduction in albumin concentration. The remedy for this situation is the administration of a colloid plasma volume substitute that is 180- oncotic with plasma (Fiore et al, 1995). In this study, replacement of removed blood volume was done by administering equal amount of 3.5% polygeline.

When taking into account the clinical consequences of normovolemic haemodilution, the three elementary issues to keep in view are (Fontana et al, 1995)[2].

1. The lowest tolerable limit of global oxygen delivery, the critical limit of oxygen delivery is

lower during normothermic normovolemic haemodilution than when there is a reduction in cardiac output. (Fontana et al, 1995[2]; Van Workens et al, 1992).

2. Associated changes in oxygen extraction and in the oxyhaemoglobin dissociation curve - Apart from a possible shift to the right of the oxyhaemoglobin dissociation curve, the compensation increase in blood flow is the most efficient mechanism for maintaining oxygen delivery. Peripheral oxygen extraction undergoes suitable adoptation when normovolemic haematocrit decreases to below twenty five percent (Von Restorff et al, 1975[5]; Tarnow et al, 1979[6]).
3. Systemic circulatory effects with special focus on myocardial function: As cardiac output increases in normovolemic haemodilution, there is a remarkable increase in coronary blood flow implying a marked fall in coronary vascular resistance (Jan and Chien, 1977).

Autologous blood transfusion determined the magnitude of potential reductions in allogenic transfusion (Weiskopf, 1995)[3].

Thus, normovolemic haemodilution allowed a greater volume of surgical blood loss without any derangements, particularly when the haematocrit level drops below thirty percent.

Flow Dynamics -

Several well designed studies (Messmer et al, 1972[7,8]; Sunder Plasmann and Messmer, 1979[9]) demonstrated that normovolemic haemodilution increases perfusion and oxygenation of tissues by bettering blood flow properties. This dynamic augmentation of blood flow, especially in the micro circulation, is due to a decrease in blood viscosity. Red blood cells when they arrive at a bifurcation, choose the capillary that has the highest flow velocity due to the network Fahraeus effect (Jenny, 1996; Pries et al, 1992).

Blood flow to the heart, brain, duodenum and pancreas increases in line with increase in cardiac output (Fiore et al, 1995). The corticoretinal, hepatic, muscle and cutaneous blood flow remains unchanged during normovolemic haemodilution. Besides, normovolemic haemodilution does not adversely affect the body's immune system (Martin et al, 1987[1]; Stehling, 1990[10]). Consequently, the procedure is associated with a lower incidence of post operative infections (Fire et al 1995). On the other hand homologous blood transfusion may suppress the immune system (Arora and Pahwa, 1992; Fiore et al, 1995; Henny, 1996; Messmer, 1988) and increase the danger of post operative infections in the ‘at risk’ patient which were observed in this study.

Physiological Effects -

The adequacy of oxygen supply is the result of an increased red cell velocity in the micro circulation and enhanced flow motion (Lindbom et al, 1986; Lipowski and Fitrell, 1986). The increased venous return and reduced after load, resulting from these cascading haemodynamic changes enhance the cardiac output favorably (Flower and Holmes, 1975; Messmer, 1975[11]; Murray et al, 1969). The increase in cardiac output is in direct proportion to the decrease in haematocrit.

There is greater decrease in viscosity following normovolemic haemodilution. Therefore viscosity decreases maximally in the micro circulation (Messmer, 1975[10]). The ensuing improvement in oxygen perfusion enhances oxygen transport capacity to over compensate for the reduced haematocrit. Both the heart and brain usually do better than most other organs (Fan et al, 1980[12]).

Safe Limit - A safe haematocrit clearly at a value of twenty five percent, there is more than adequate clinical evidence that the patient's recovery is not jeopardized by a decreased oxygen carrying capacity. The tissue oxygen pressure is usually not compromised until the haematocrit level falls way below twenty percent (Fontana et al, 1995[2]; Messmer et al, 1973[4]).

The reinfusion of autologous blood has avoided many of the homologous blood transfusion complications like blood transfusion reactions, risk of disease transmission including AIDS, risk of alloimmunization. Autologous blood transfusion also provides blood cover for "Jehovah's witnesses" which was documented in this study. Where as in control group blood transfusion reactions have been observed and documented.

The administration of 3.5% polygeline (haemaccel) has provided good cardiovascular stability in all the patients in study group which are explained by heart-rate and blood pressure. No anaphylactic reactions were noticed with haemaccel.

In homologous blood transfusion most of red blood cells are stored and the viability of RBC is doubtful and that explains the lack of maintenance of haematocrit in control group. That poses threat of decrease in 2-3 DPG levels and decrease in coagulation factors which was explained by fall in oxygen saturation.

The patients who received autologous blood transfusion did not require blood grouping, compatibility and preservation and threat of haemolytic reactions. The autologous blood which was kept at room temperature maintains clotting factors well. In stored homologous blood there may be deficiency of clotting factors especially factor V and VIII.

In this present study it is clearly evident that the autologous blood transfusion maintained the haematocrit values well intraoperatively and post operatively. Whereas on homologous blood

transfusion there is marked fall in haematocrit in majority cases which were shown in [Table 5].
The mean fall in haematocrit value in study group was only five percent, where as in control group it was more than five percent. The P value for this study was 0.001 showing the significance.

CONCLUSION

1. Acute normovolemic haemodilution improved tissue oxygen perfusion and micro circulation by lowering the blood viscosity.
2. Blood which was lost during surgery was diluted blood only.
3. Autologous blood transfusion eliminated the blood transfusion reactions and transmission of diseases.
4. Since the autologous blood was kept room temperature while the surgery is in progress, platelet function and coagulation factors were preserved.
5. The mean fall of haematocrit level in autologous blood transfusion was not more than five, where as it is note than five percent in homologous blood transfusion because of stored blood.
6. It provided blood cover for two cases of "Jehovah's witnesses".

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