整形外科手術患者における大量自己血漿の術前貯血と返血

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Original Article

Large Volume Autologous Plasma Predonation and Retransfusion in Orthopedic Surgical Patients

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Abstract Background : Intraoperative washed autologous transfusion of the scavenged blood can reduce the deterioration of anemia, even during the operation with a comparatively large blood loss. On the other hand, plasma level can not be collected by this system. The preoperative donation and perioperative retransfusion of autologous plasma may reduce the plasma dilution. Purpose : The influence of a large volume plasma predonation and perioperative retransfusion on the plasma protein level was investigated. Methods : Thirteen patients (63.2 ± 13.2 yr, 70.3 ± 12.1 kg) were examined regarding their serum protein (SP), IgG, coagulation systems, colloid osmotic pressure (COP), blood cell count before, just after, 2 h after and 7 days after the donation of 900 ml plasma by plasmapheresis with a simultaneous volume replacement. Twenty surgical patients (52.8 ± 17.3 yr, 72.6 ± 16.6 kg, the mean predonated autologous plasma : 2100 ml) with intra- and postoperative retransfusion of autologous plasma were examined perioperatively for SP, IgG, coagulation systems and COP. These parameters were compared with that of the predonated plasma. Results : All data including SP, coagulation and COP, with the exception of IgG, completely recovered within 7 days after preoperative plasmapheresis. Perioperatively, autologous washed blood transfusion system was used. The retransfused volume of autologous predonated plasma was 1740 ml on average. Although about 4 l of blood on average was lost perioperatively, only one patient out of 20 patients had to be administered homologous red blood cell transfusion. The levels of most parameters, except for COP, constantly recovered in accordance with the autologous plasma transfusion. Differences in the patterns of improvement were also observed between the parameters. Conclusion : A 900 ml plasma predonation can therefore be safely performed with an interval of not less than a week between the last donation and the operation. Autologous plasma retransfusion is thus considered to improve the protein levels.

Key words : autologous blood transfusion, plasmapheresis, plasma donation

Introduction

Although the preoperative donation of autologous blood has been widely performed[1)~4)], the effects of a large volume autologous plasma predonation and retransfusion has not yet been fully discussed. The technological progress of apheresis has made it possible to obtain a programmed volume of any blood component[5)6)]. The amount of plasma, which can be drawn at one time, is larger than that of red blood cells (RBC), since a decrease in the plasma protein level promotes a shift in the protein from the tissue immediately and accelerates the production of itself. The stored frozen plasma is clinically

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available for up to at least one year. Therefore, it is possible to plan the plasma donation schedule even if the operation will not be performed within a restricted period.

The preoperative autologous blood donation system has been established at the Rehabilitation Hospital Ulm, Germany since 1984. Predonation from orthopedic patients are programmed and performed under the control of anesthesiologists[7)8)]. Every patient is informed, in detail, about the risks and benefits of predonation and all give their written consent. Nine hundred ml of plasma with or without 300 ml to 500 ml of RBC is donated at one time by plasmapheresis, with a simultaneous fluid replacement. The number of donations are planned based on the expected volume of perioperative blood loss and the patient's plasma protein level and hemoglobin concentration. Plasmapheresis is performed on patients who have a serum protein level of 6 $g \cdot dl^{-1}$ or more, with an interval between donations of not less than a week, in principle. There has been performed from 800 to 1,000 predonations per year, without severe complications except for occasional vaso-vagal reflex. These clinical experience seems to indicate the safety of this protocol. The predonated autologous plasma is retransfused both during and after the operation with a comparatively large blood loss, in order to not only supply coagulation factors and immunoglobulins, but also to maintain the intravascular volume effectively. The indication of autologous plasma may be extended as compared with the homologous fresh frozen plasma. By using the washed autotransfusion system of the scavenged blood, autologous RBC can be used. Therefore, the complex of preoperative donation of autologous plasma and intraoperative washed autotransfusion system seems to be an ideal method. This autologous blood system is suitable for the patients with the following conditions : (1) Perioperative blood loss is prospected to be 1.5 l or more, which usually needs blood transfusion. (2) The waiting period for the operation can be prolonged over a month, in which period, two or three times of the plasma predonation are performed. (3) The washed autologous transfusion of the scavenged blood can be used during and after the operation. The Rehabilitation Hospital Ulm, in which only orthopedic surgery is performed, has a lot of patients with the above conditions. However, this system may induce the stress on the patient's plasma by the preoperative plasma deposit. The cost of the plasmapheresis is higher than the whole blood donation, because the circuit of the plasmapheresis is relatively expensive. It has not yet been fully elucidated to what extent the patient' s plasma protein is diluted by plasma predonation, and compensated by perioperative plasma retransfusion.

In this study, we evaluate the influence of a large amount of plasma donation and the effect of perioperative retransfusion of autologous plasma by examining the changes in the patient's plasma protein levels. In the first place, this study aims to investigate the effect of a 900 ml plasma donation on the serum protein and also to determine the extent that the serum protein level recovers within a week. Secondly, we also studied the effect of the perioperative retransfusion of autologous predonated plasma on the serum protein.

Methods

Study 1

From all orthopedic patients in the Rehabilitation Hospital Ulm who preoperatively donated autologous plasma, 13 consecutive patients (Table 1), with American Society of Anesthesiologists (ASA) physical status 1 to 3, with an interval since the last donation of not less than 14 days and with a follow-up data of 7 days after the donation, were selected for this study. The estimated blood volume (BV) and the plasma volume (PV) for each patient were calculated according to the following formulae[9)] :

BV (male) = 604 + 0.0003668 × height $(cm)^3$ +

Table 1 Characteristics of patients undergoing plasma predonation

N		13
sex	(M/F)	7/6
age	(y.o.)	63.2 ± 13.2
body weight	(kg)	70.3 ± 12.1
height	(cm)	167.5 ± 7.1
proposed operative procedure		
total hip replacement		6
total hip exchange		2
total knee replacement		1
spondylodesis		4
estimated total blood volume	(ml)	4406 ± 654
estimated total plasma volume	(ml)	2524 ± 368

mean ± standard deviation

$32.2 \times$ body weight $(kg)^3$

BV (female) = $183 + 0.000356 \times$ height $(cm)^3 + 33 \times$ body weight $(kg)^3$

PV = BV $\times$(1 − Hematocrit (%) / 100)

The patients donated 900 ml of plasma at a time by plasmapheresis, on an outpatient basis, for weeks or months before the operation. The automated collection was performed with the PES® (Haemonetics) using the Latham bowl (volume of 225 ml, centrifugation at 4800 rpm). CPD-A was added as an anticoagulant at a ratio of 1 : 16. One thousand ml of Ringer's lactate and 500 ml of 6% Hydroxyethylstarch (HES) were infused both during and after plasmapheresis. The collected plasma was frozen immediately and stored at − 30 to − 40 ℃ until the operation. The serum protein level (SP), electrophoresis of SP, IgG, colloid osmotic pressure (COP), prothrombin time (PT), activated partial thromboplastin time (aPTT), fibrinogen, anti-thrombin III (AT-III), blood cell count of the patients were examined at the following points : before, just after, 2 h after and 7 d after the donation, respectively. The same parameters of the donated plasma were also examined. Chemical determinations were performed at a clinical laboratory room in the hospital. The total serum protein was determined by the Biuret method. Serum protein electrophoresis was performed with cellulose-acetate strips in barbital buffer (pH 8.6) followed by densitometric quantitation. The concentration of each fraction of serum protein (albumin, α_1-, α_2-, β-, γ-globulin) was calculated by multiplying the distribution percent by the concentration of the serum protein.

Student's t-test was used for the statistical analysis. Probabilities of less than 0.05 were considered to indicate significant differences. The results are expressed as the mean and the standard deviation.

Study 2

Twenty-patients (Table 2) who had undergone orthopedic surgery (8 : total hip replacement, 4 : total hip exchange, 8 : spondylodesis) in the Rehabilitation Hospital Ulm, ASA status 1 to 3, with autologous blood predonation, were studied. All patients had donated 900 ml of plasma either with or without 500 ml of RBC at a time, for 1 to 3 time (s) while waiting for the operation. The donated volume of plasma and RBC in the patients were 2100 ± 592 ml (mean ± SD) and 320 ± 291 ml, respectively. In principle, 3.5% gelatin was infused for fluid replacement during the operation until the beginning of the wound closure. Then 600 ml of autologous plasma was retransfused at the ending of the operation and the rest of the plasma was transfused in the recovery room and/or the intensive care unit until the next morning. The autologous predonated RBC and washed shed RBC was retransfused to maintain the hemoglobin level over than 6 $g \cdot dl^{-1}$. SP, electrophoresis of SP, IgG, COP, PT, aPTT, fibrinogen and AT-III of the patients were examined at the following points : before operation, before retransfusion of autologous plasma, and after 600 ml, 1200 ml, or 1800 ml (n = 12) of autologous plasma transfusion, on the first postoperative day (1POD), on the 2nd POD and on the 3rd POD, respectively. The same parameters of the predonated plasma were also examined for each donation and the mean values between donations were calculated for each patient. The chemical determinations and the statistical analyses were performed as shown in study 1.

Table 2 Characteristics of patients, preoperative donation and perioperative transfusion of autologous blood and blood loss

N		20
sex	(M/F)	11 / 9
age	(y.o.)	52.8 ± 17.3
body weight	(kg)	72.6 ± 16.6
height	(cm)	169.2 ± 7.3
performed operation		
total hip replacement		8
total hip exchange		4
spondylodese		8
estimated total blood volume	(ml)	4540 ± 781
estimated total plasma volume	(ml)	2830 ± 446
preoperative donation		
autologous fresh frozen plasma	(ml)	2100 ± 592
autologous red blood cells	(ml)	320 ± 291
perioperative transfusion and infusion		
autologous fresh frozen plasma	(ml)	1740 ± 547
autologous red blood cells	(ml)	200 ± 220
autologous washed red cells	(ml)	884 ± 790
colloidal solution	(ml)	2525 ± 1491
blood loos		
intra-operative	(ml)	2490 ± 1920
post-operative	(ml)	1492 ± 679

mean ± standard deviation

Results

Study 1

Characteristics of the patients for the study 1 are shown in Table 1. The amount of plasma drawn by a plasmapheresis corresponded to one third of the mean estimated total plasma volume of the patients. The donation was well tolerated by all donors. No adverse side effect, such as vaso-vagal reflex, occurred. The levels of all parameters in the patients' plasma at each point and the donated plasma are presented in Table 3. Figure 1 shows the changes in each parameter level expressed as the ratio to the initial patient level. The hematocrit level significantly decreased to 93 % just after the donation and thereafter recovered to the initial level 2 h after the donation. The serum protein level significantly decreased to 69 ± 6 % just after, 78 ± 8 % at 2 h and then recovered almost completely (97 ± 8 %) at 7 d. There were differences in the change between SP fractions. Regarding the albumin level, the decrease rate after the donation was the smallest, while the recovery rate at 7 d was the highest. On the other hand, the recovery of γ-globulin and IgG levels at 7 d were only 90 ± 23 % and 90 ± 6 %, respectively, of the initial level. The fibrinogen level at 7 d overwhelmed that of the initial level. The donated plasma decreased to 72～78 % of the level in the initial patients' plasma, regarding the serum protein, IgG, COP, PT, fibrinogen and AT-III levels.

Study 2

The perioperative blood loss and transfusion volume are shown in Table 2. Although about 4 l of blood on average was lost perioperatively, only one patient out of 20 patients, who lost 5500 ml and 1200 ml of blood during and after the operation, respectively, had to be administered a 1200 ml homologous RBC transfusion. The retransfused volume of autologous predonated plasma and RBC were 1740 ± 547 ml and 200 ± 220 ml, respectively. In addition, 884 ± 790 ml of mechanical washed RBC were retransfused perioperatively.

The levels of all parameters in the patients' plasma at each point and the mean levels in the donated plasma are presented in Table 4. Figure 2 shows changes of each parameter levels, expressed as the ratio of the values at each point to the levels of the donated plasma. Levels of almost all parameters except for COP deteriorated the most at the point just before the beginning of retransfusion and constantly recovered in accordance with the autologous plasma transfusion. From 1 POD to 3 POD, all parameters improved day by day. However, There were substantial differences in the change between the parameters involved in this study. The parameters could be divided into 5 groups according to the effect of autologous plasma retransfusion on the patients plasma (Table 5).

(1) The γ-globulin and IgG levels of the patient plasma before the retransfusion were significantly lower than that of the predonated plasma and

Table 3 The effect of plasmapheresis on the serum protein level, IgG, colloid osmotic pressure and coagulation system of the patients' plasma and the donated plasma.

	before	just after	2 h after	7 d after	donated plasma
serum protein ($g \cdot dl^{-1}$)	7.23 ± 0.50	4.95 ± 0.39*	5.60 ± 0.58*	7.01 ± 0.47	5.66 ± 0.40*
albumin ($g \cdot dl^{-1}$)	4.55 ± 0.33	3.29 ± 0.46*	3.67 ± 0.43*	4.53 ± 0.30	3.46 ± 0.26*
α_1-globulin ($g \cdot dl^{-1}$)	0.22 ± 0.04	0.15 ± 0.03*	0.16 ± 0.03*	0.21 ± 0.04	0.17 ± 0.04*
α_2-globulin ($g \cdot dl^{-1}$)	0.62 ± 0.15	0.41 ± 0.10*	0.46 ± 0.12*	0.60 ± 0.15	0.49 ± 0.20*
β-globulin ($g \cdot dl^{-1}$)	0.86 ± 0.15	0.57 ± 0.12*	0.63 ± 0.12*	0.83 ± 0.15	0.59 ± 0.11*
γ-globulin ($g \cdot dl^{-1}$)	0.98 ± 0.20	0.67 ± 0.12*	0.68 ± 0.12*	0.86 ± 0.13	0.95 ± 0.21
IgG ($g \cdot dl^{-1}$)	1.03 ± 0.15	0.68 ± 0.12*	0.76 ± 0.13*	0.92 ± 0.13*	0.76 ± 0.11*
colloid osmotic pressure (mmHg)	26.6 ± 3.0	20.9 ± 2.0*	22.3 ± 2.9*	26.1 ± 2.5	18.9 ± 1.5*
PT (%)	97.6 ± 4.2	84.5 ± 7.6*	88.7 ± 6.7*	98.1 ± 3.6	75.8 ± 9.8*
aPTT (sec)	31.2 ± 2.2	39.1 ± 3.7*	36.7 ± 3.5*	30.4 ± 2.2	37.7 ± 2.8*
fibrinogen ($mg \cdot dl^{-1}$)	320 ± 100	220 ± 70*	230 ± 60*	380 ± 110*	240 ± 70*
AT-III (%)	93.3 ± 16.8	61.1 ± 12.0*	71.0 ± 16.7*	97.7 ± 15.3	73.2 ± 12.6*
Hb ($g \cdot dl^{-1}$)	13.9 ± 1.9	13.1 ± 2.0*	13.7 ± 2.3	13.7 ± 1.8	0.0 ± 0.0*
Ht (%)	42.4 ± 5.1	39.3 ± 5.5*	41.7 ± 5.9	41.4 ± 4.5	0.1 ± 0.1*
platelet cell ($\times 10^3 \cdot \mu l^{-1}$)	267 ± 83	221 ± 59*	253 ± 67	286 ± 135	6 ± 8*
WBC ($\times 10^3 \cdot \mu l^{-1}$)	6.7 ± 1.7	6.4 ± 1.8	7.1 ± 1.6	6.3 ± 1.7	0.0 ± 0.0*

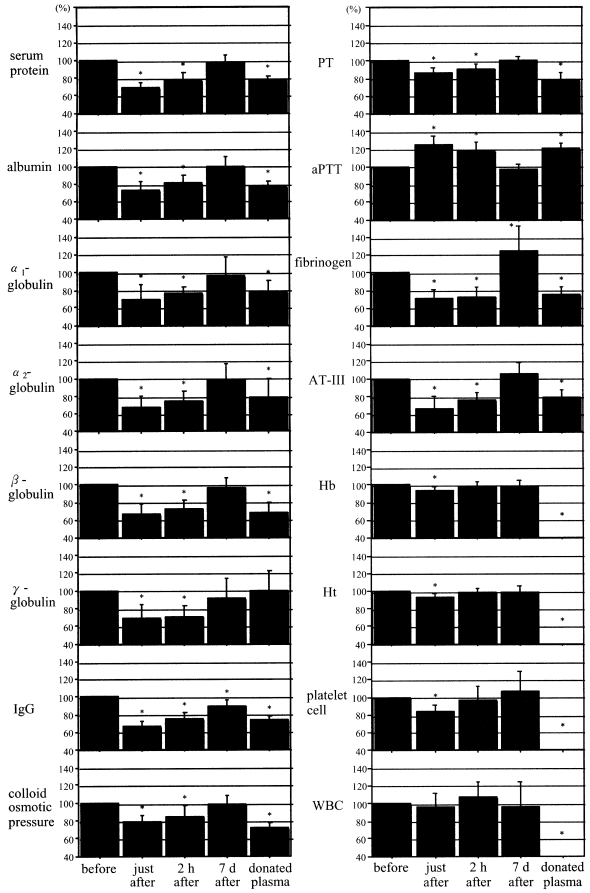

Fig. 1 Each parameter of the patients' plasma and the donated plasma expressed as the percentage to the level of the patients' plasma before the plasmapheresis. *$p < 0.05$ vs before the plasmapheresis

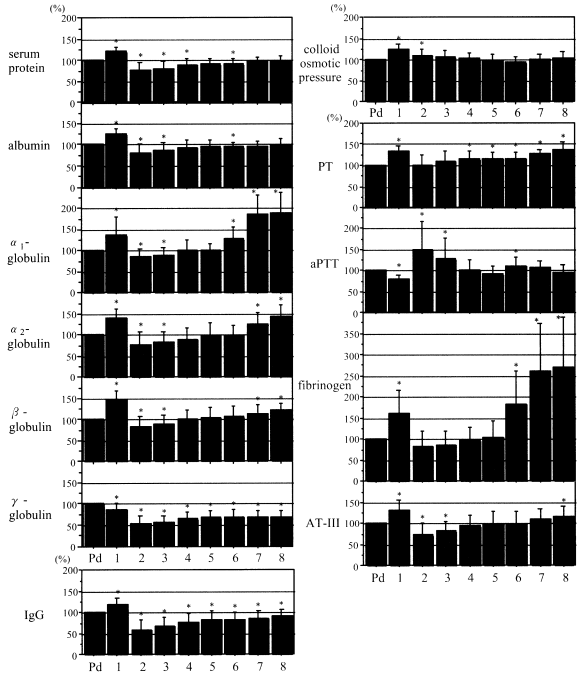

Fig. 2 Changes in each parameter level. The level of each parameter in the patient at following points: before operation (1), before the retransfusion of autologous plasma (2), after 600 ml (3), after 1200 ml (4), after 1800 ml of autologous plasma retransfusion (5), on the first postoperative day (6), on the second postoperative day (7) and on the third postoperative day (8) were expressed as the ratio to the donated plasma (Pd). *$p < 0.05$ vs the donated plasma

Table 4 The effect of retrasnfusion of autologous predonated plasma on each parameter

	donated plasma	before operation	intraoperative retransfusion of autologous plasma				after operation		
			before	600 ml	1200 ml	1800 ml	1 POD	2 POD	3 POD
serum protein ($g \cdot dl^{-1}$)	5.60 ± 0.44	6.80 ± 0.74*	4.22 ± 1.12*	4.51 ± 1.04*	5.00 ± 1.04*	5.08 ± 1.04	5.13 ± 0.73*	5.37 ± 0.71	5.53 ± 0.73
albumin ($g \cdot dl^{-1}$)	3.46 ± 0.31	4.32 ± 0.50*	2.78 ± 0.77*	3.00 ± 0.72*	3.26 ± 0.79	3.32 ± 0.68	3.28 ± 0.47*	3.29 ± 0.47	3.40 ± 0.46
α_1-globulin ($g \cdot dl^{-1}$)	0.15 ± 0.04	0.20 ± 0.07*	0.13 ± 0.04*	0.13 ± 0.04*	0.14 ± 0.03	0.14 ± 0.03	0.19 ± 0.06*	0.27 ± 0.07*	0.27 ± 0.07*
α_2-globulin ($g \cdot dl^{-1}$)	0.42 ± 0.10	0.59 ± 0.14*	0.32 ± 0.11*	0.34 ± 0.11*	0.37 ± 0.11	0.40 ± 0.13	0.41 ± 0.13	0.52 ± 0.14*	0.60 ± 0.13*
β-globulin ($g \cdot dl^{-1}$)	0.53 ± 0.10	0.79 ± 0.18*	0.45 ± 0.13*	0.47 ± 0.13*	0.54 ± 0.13	0.55 ± 0.14	0.57 ± 0.14	0.60 ± 0.14*	0.66 ± 0.12*
γ-globulin ($g \cdot dl^{-1}$)	1.02 ± 0.29	0.90 ± 0.25*	0.54 ± 0.20*	0.56 ± 0.20*	0.66 ± 0.19*	0.66 ± 0.23*	0.68 ± 0.19*	0.68 ± 0.20*	0.70 ± 0.17*
IgG ($g \cdot dl^{-1}$)	0.79 ± 0.17	0.94 ± 0.26*	0.47 ± 0.20*	0.54 ± 0.20*	0.62 ± 0.21*	0.66 ± 0.25*	0.66 ± 0.20*	0.68 ± 0.20*	0.72 ± 0.18*
colloid osmotic pressure (mmHg)	19.3 ± 1.5	24.4 ± 2.4*	21.3 ± 2.8*	20.5 ± 2.8	20.0 ± 2.7	19.3 ± 2.8	18.2 ± 2.0	19.3 ± 2.5	20.1 ± 2.6
PT (%)	72.9 ± 10.3	94.9 ± 7.6*	72.4 ± 21.7	79.3 ± 19.9	82.6 ± 15.9*	83.2 ± 13.8*	85.1 ± 12.9*	91.7 ± 11.8*	97.6 ± 5.5*
aPTT (sec)	39.2 ± 5.1	31.5 ± 4.0*	58.3 ± 29.1*	50.0 ± 22.5*	39.4 ± 11.2	35.4 ± 7.4	44.0 ± 10.6*	41.2 ± 9.3	37.8 ± 9.9
fibrinogen ($mg \cdot dl^{-1}$)	270 ± 100	390 ± 110*	210 ± 110	230 ± 110	250 ± 110	280 ± 120	440 ± 100*	610 ± 90*	630 ± 60*
AT-III (%)	75.9 ± 13.4	98.7 ± 18.6*	54.2 ± 24.2*	61.3 ± 16.8*	71.6 ± 21.9	77.5 ± 25.3	75.5 ± 22.8	83.2 ± 20.2	88.6 ± 22.3*
Hb ($g \cdot dl^{-1}$)	0.0 ± 0.0	12.3 ± 1.6*	8.2 ± 1.8*	7.6 ± 1.6*	8.4 ± 1.6*	8.3 ± 1.2*	8.6 ± 1.4*	8.5 ± 1.2*	8.3 ± 1.3*
Ht (%)	0.1 ± 0.1	37.3 ± 4.6*	25.3 ± 5.4*	23.6 ± 4.9*	25.6 ± 4.9*	25.4 ± 3.7*	26.5 ± 4.4*	26.2 ± 4.0*	25.6 ± 4.1*
platelet cell ($\times 103 \cdot \mu l^{-1}$)	12 ± 13	298 ± 119*	186 ± 60*	191 ± 67*	181 ± 58*	155 ± 52*	182 ± 60*	187 ± 60*	215 ± 76*
WBC ($\times 103 \cdot \mu l^{-1}$)	0.0 ± 0.0	6.3 ± 1.9*	5.2 ± 2.0*	6.7 ± 2.2*	8.6 ± 4.1*	8.9 ± 5.3*	8.2 ± 3.0*	7.8 ± 2.6*	6.7 ± 2.7*

Table 5 Groups of parameters according to the effect of retransfusion of autologous predonated plasma

group	parameters	balance at the beginning of retransfusion	change in Pp	balance at the 3rd POD
1	γ-globulin IgG	Pd > Pp	improve	Pd > Pp
2	serum protein albumin aPTT	Pd > Pp	improve	Pd = Pp
3	α_1-globulin α_2-globulin β-globulin AT-III	Pd > Pp	improve	Pd < Pp
4	PT fibrinogen	Pd = Pp	improve	Pd < Pp
5	colloid osmotic pressure	Pd < Pp	decrease	Pd = Pp

Pd : the predonated plasma, Pp : the patients' plasma

improved gradually after the retransfusion of autologous plasma, and thus continued to be significantly smaller than that of the predonated plasma throughout the course.

(2) The serum protein, albumin and aPTT levels of the patients plasma before the retransfusion were significantly lower and/or less active than that of the predonated plasma and improved step by step. Finally, on the 3 POD, no significant differences were observed in the levels between the patient plasma and the predonated plasma.

(3) The α_1-, α_2-, β-globulin and AT-III levels of the patient plasma before retransfusion were lower than that of the predonated plasma and had overwhelmed the predonated plasma level during the course of the retransfusion.

(4) There were no differences in the levels of PT and fibrinogen before the retransfusion between the patient plasma and the donated plasma. Both levels of the patient plasma had increased during the course and were significantly higher than that of the predonated plasma on the 3rd POD.

(5) The COP of the patients was significantly higher than that of the predonated plasma before the retransfusion but it decreased slightly during the course. Finally, there were no significant differences in the levels on the 3rd POD between the patients and the predonated plasma.

Discussion

In the Rehabilitation Hospital Ulm, autologous plasma predonation volume has been settled 900 ml per donation. A standard plasmapheresis from a volunteer is 600 ml in Germany. A 900 ml of plasmapheresis in this study is therefore relatively larger than that from a volunteer.

Moreover, surgical patients requiring preoperative autologous blood donation include the elderly and patients with organ dysfunction. Therefore, the safety of such predonation should be thoroughly discussed. The effect of frequent donations from a healthy donor has been reported in detail[10]. The Food and Drug Administration has limited the maximum volume of plasma that may be drawn from one donor to 1 l/week and 50～60 l/year. On the other hand, many European countries set a safer standard of 10～15 l/year. In either case, the volume drawn at a time is not allowed to be more than 1 l and the interval, not shorter than 1 week. Therefore, our protocol is nearly the same as this upper limit for a healthy frequent donors. There may be differences in the protein turnover between the chronic phase of the repeated donations and the beginning of the initial donation[11)12)]. This study seems to be important for providing the trend data with the plasma protein level during short time intensive donations and thus confirmed the safety of this protocol in view of the protein levels. However, it is important to emphasize that large volume autologous plasma predonation in the Rehabilitation Hospital Ulm has been performed by trained nurses under the supervision of anesthesiologists with the continuous monitoring of blood pressure, ECG, respiratory rate and oxygenation.

Fluid replacement during the donations using crystalloid and colloid solution dilutes the plasma. The hematocrit level decreased to 93 % of the initial level just after the donation, but already began to recover 2 h after the donation. This change indicated that, a 900 ml plasma donation with the simultaneous volume replacement of 1000 ml of Ringer's lactate and 500 ml of 6% HES caused transient hypervolemic dilution just after the plasmapheresis, and then circulating blood had led to normovolemia 2 h after plasmapheresis. Because 900 ml of plasma corresponded to one third of the estimated total plasma volume of the patients on the average, plasmapheresis might cause a 35 % reduction in the plasma immediately. However, the recovery rate of the serum protein level at 2 h already reached 78 %. These results indicate that the plasma protein level is partially compensated within a few hours after the donation and almost fully recovers by 7 d after the donation. The mechanisms seem to be compensated by the shift from the tissue in an early phase and by the increase in the production and the decrease in the metabolism within several days[14)].

This study showed that the differences regarding the recovery speed following plasma donation among the plasma components, coincided with previous reports[11)～18)]. The recovery of immunoglobulin was slower than that of albumin, α_1-, α_2-, β-globulin, fibrinogen and AT-III. The decrease in the plasma level of immunoglobulin itself does not promote the increase in its production to any great extent[14)15)]. The humoral immunity as expressed by immunoglobulin takes more than 1 week to recover completely after plasma donation. Therefore, it is better that the interval between the last donation and the operation be at least one week.

In order to collect more concentrated plasma, volume replacement should be performed after the end of the donation. However, when 900 ml of plasma is drawn at one time, a sufficient fluid replacement during the donation is necessary to prevent hypovolemic complications. The albumin concentration of the donated plasma in this study ($3.46 \pm 0.26\ g \cdot dl^{-1}$) was lower than that of the fresh frozen plasma (FFP) provided by the Japan Red Cross Center ($4.0 \pm 0.3\ g \cdot dl^{-1}$: Japan Red Cross Personal Communication). The purpose of autologous plasma transfusion during the operation are partly different from those of FFP in volunteers. While the latter mainly requires the replacement of coagulation factors, another aim of autologous plasma retransfusion is to expand the intra-vascular volume effectively. Therefore, the autologous plasma may not be as concentrated as FFP. In study 2, we evaluated the effect of autologous plasma retransfusion during and after the operation on the plasma

protein level, by comparing the protein levels between the donated plasma and a series of patient plasma. We investigated to what extent the plasma proteins were diluted after a comparative blood loss during the operation following fluid replacement and whether or not the patient plasma level recovered after the autologous plasma retransfusion. While the levels of all parameters in the patients before operation except for γ-globulin were significantly higher than the levels of the donated plasma, the levels of all parameters at the beginning of retransfusion, except for PT, fibrinogen and COP, were all significantly lower than the donated plasma. The levels of all parameters except for COP gradually improved step by step during the retransfusion of the autologous plasma. The autologous plasma retransfusion showed the greatest influence on the changes in the γ-globulin and IgG, because the serum level became diluted and was not immediately compensated following blood loss. Without autologous plasma retransfusion, the γ-globulin and IgG level might show a poorer recovery. The levels of serum protein, albumin and aPTT had recovered step by step during the course and thus the levels on 2 POD were not significantly different from those of the donated plasma. On the other hand, the levels of α_1-, α_2-, β-globulin, PT and fibrinogen on 2 POD were significantly higher than those of the donated plasma. In general, the plasma protein levels improved after autologous plasma retransfusion. Especially, the fibrinogen and α_1-globulin levels increased rapidly to levels higher than those before operation. These acute reactive proteins increase following trauma or surgical stress and reach a peak level within a few days. Therefore, a large retransfusion of autologous plasma may also have an over-compensatory effect on them. Complications including thrombosis due to high fibrinogen levels should be monitored especially in patients developing an inflammatory reaction during the preoperative period[19]. The COP level was maintained at a high level during the operation, since gelatine was used in order to keep the intravascular volume in this study. Because gelatine is metabolized quickly, it should thus be infused intraoperatively, while autologous plasma should be retransfused after the operation to maintain the COP level.

Although plasma protein levels recovered within 7 days after preoperative plasmapheresis, we can not expect that the plasma protein levels might recover to the same extent without plasma retransfusion after the operation. Because perioperative blood loss of 4 l on average induced a larger amount of plasma loss than the predonation of 900 ml. This study has a limitation that the effect of plasma retransfusion of autulogous plasma on the patient's plasma protein levels was not compared with the patient who had no plasma retansfusion. However, this study revealed that the levels of the most parameters in the donated plasma were higher than in the patient's plasma at the beginning of retransfusion, and indicated that retransfusion of autologous plasma promote the recovery of the plasma protein levels.

In conclusion, a 900 ml plasma predonation was found to be safely performed with an appropriate volume replacement. All data including the SP, coagulation and COP, with the exception of IgG, completely recovered within 7 days. However, the volume replacement performed during plasmapheresis does tend to dilute the donated plasma. The perioperative retransfusion of autologous plasma improved the protein levels and coagulation system by replacing the removed plasma components, and is therefore considered to be especially useful for sustaining the level of γ-globulin, albumin, IgG and aPTT.

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（和文抄録）

整形外科手術患者における大量自己血漿の術前貯血と返血

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［背景］術中，回収式自己血輸血法により赤血球成分を，術前貯血により血漿成分を補うことで，比較的大量出血の手術にも同種血を用いずに管理できるが，貯血時および周術期の血漿成分値の推移は明らかではない．［目的］比較的大量の自己血漿を術前に貯血し，周術期に返血することが血漿蛋白に及ぼす影響を検討した．［方法］13 人（年齢 63.2 ± 13.2 歳，体重 70.3 ± 12.1kg）の術前患者から輸液を同時にしながら成分分離装置を用いて 900ml の血漿を採取したときの血漿蛋白，IgG，凝固系，膠質浸透圧，血算の推移を血漿採取前，採取後２時間後，７日後で調べた．20 人（年齢 52.8 ± 17.3 歳，体重 72.6 ± 16.6kg，平均術前採取血漿 2100ml）の整形外科手術患者で術中・術後に術前貯血の自己血漿を返血したときの血漿蛋白，IgG，凝固系，膠質浸透圧，血算の推移を経時的に調べた．これらの項目について採取血漿の値と比較した．［結果］IgG 以外の血漿蛋白，凝固系，膠質浸透圧の検査値は血漿採取７日後には元の値に回復していた．周術期に回収式自己血輸血を用いた．返血した自己血漿の平均値は 1740ml で，平均出血量は 4l であった．20 症例中 1 症例で同種血輸血を要した．自己血漿返血に応じて，膠質浸透圧以外のほとんどの項目で検査値は改善した．項目間で血漿返血による検査値の回復過程に相違が認められた．［結論］900ml の術前血漿採取は手術までの期間を 1 週間以上あければ安全に施行できる．自己血漿の返血により周術期の血漿蛋白値は改善される．