Pre-operative autologous blood donation: clinical parameters and efficacy

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Pre-operative autologous blood donation (PABD) aims to provide a supply of safe blood for patients undergoing surgery who might need a blood transfusion while at the same time increasing the patient's total red blood cell (RBC) mass due to the PABD-induced stimulation of erythropoiesis before scheduled elective surgery. This can, however, only be accomplished if the determinants of RBC regeneration are understood. The improvement of viral safety of allogeneic blood products following the introduction of molecular techniques has led to a decline in the use of autologous blood conservation (ABC) measures, and in particular in the use of PABD. More rational and restrictive indications for allogeneic blood transfusion have evolved and led to a further decrease in the relevance of PABD.

Interestingly, among European countries some with an above average rate of allogeneic blood usage per 1,000 population also favoured PABD, while others not favouring PABD had an above average, average or below average rate of allogeneic blood transfusion use per 1,000 population[1,2]. This raises questions about the rational indications for both PABD and allogeneic blood transfusion.

Demographic prognoses and projections have forecasted a continuous decline in the overall population, but an increase in the population over 65 years old associated with the aging of the most numerous sector of the population. These changes are already underway and will continue in the decades to come[3-8]; they are valid for both European countries, possibly with a delay of one decade among single European countries[3-7], and the USA[7,8]. These demographic changes are associated with both a decrease of volunteer donors, resulting in a shortage of allogeneic blood products, and an increased need of blood products for surgical and non-surgical/ oncological patients[3-6,8]. These changes will create pressure on clinicians to make prudent decisions on the indications for blood transfusion, and, besides other measures, exploit ABC alternatives, such as PABD. Rationally and prudently applied, ABC could become an adjunct to meeting future blood transfusion requirements[9]. "From euphoria to reason - clinical practice based on scientific knowledge"[10]: this could be the starting point to give PABD a new chance.

Meta-analyses on PABD have shown that this practice: (i) reduces the use of allogeneic blood transfusion by 63%, (ii) increases overall RBC transfusions (i.e. allogeneic and autologous RBC units) by 30%, and (iii) causes a decline of patients' haemoglobin (Hb) concentration by more than 1 g/dL from before commencing PABD to immediately prior to surgery[11-13]. All the meta-analyses did, however, criticise the flawed design of the clinical studies which had serious methodological weaknesses, inadequate randomisation techniques, unblinded measurements and subjective outcome variables[11-13].

The wastage of unneeded PABD units varied from 18% to above 50%; however, over-transfusion and re-transfusion of autologous blood at Hb levels above 9 g/dL was also reported[14-16]. The more efficacious the PABD programme, the higher the pre-operative haematocrit (Hct) and the greater the allowable blood loss from pre-operative to minimal Hct, and, therefore, the lesser the need for re-transfusion of PABD units. There is, therefore, a paradox of more effective PABD being associated with increased wastage of PABD units. Rational indications for PABD is necessary.

Various conclusions can be drawn from the data so far. The RBC mass regenerated by PABD is smaller than the RBC mass predeposited. Besides questioning the physiological quality of the PABD programmes applied, the rational indications for both PABD and re-transfusion are also challenged. It is essential to determine rational indications for PABD and measures

to optimise this practice; this can best be done by understanding the physiological principles of erythropoiesis, and adapting the PABD procedure to these physiological basics.

In many publications in the literature, the outcome measure used to define the efficacy of an ABC measure is the reduction of allogeneic blood transfusion; this is comprehensible from the clinician's point of view. However, besides the already mentioned criticism of the methodological quality of most ABC studies, confounders and selection bias can also influence the results, even in randomised controlled trials[17]. We, therefore, decided to define "efficacy" impartially by "the increase in RBC mass (+RBC) in response to the ABC measure applied" and "effectiveness" by "the maximal allowable RBC/blood loss that can be compensated by this +RBC due to the appropriate ABC alternative, exclusively, in addition to a colloid to maintain both a given minimum Hct level and normovolaemia"[18-23]. Since a mathematical model avoids confounders and bias, it enables objective evaluation, assessment and comparison of various autologous alternatives under identical and controlled conditions and reveals "true efficacy" of the ABC alternatives.

Besides physiologically available iron, which is essential for Hb synthesis, only two clinical parameters have been demonstrated to have a decisive impact on RBC regeneration in response to PABD (+RBC): (i) the time interval between PABD and surgery and (ii) the Hb/Hct level at/after PABD[21,22,24].

There are only very few studies that have systematically analysed PABD with respect to the physiological principles of erythropoiesis, and attempted to optimise PABD programmes by adapting them according to these principles[21,22,24]. Table I summarises the baseline data from orthopaedic patients who underwent one and two PABD. The increase in total RBC mass deposited induced an increase in +RBC (one PABD versus two PABD) (Table I). The time-interval "1st PABD - surgery" differed statistically significantly between patients who made one predeposit and those who made two. Furthermore, the time-interval "1st PABD - surgery" in patients with one PABD differed from the intervals "1st PABD - 2nd PABD" and "2nd PABD - surgery" in patients with two PABD. This descriptive statistical analysis does not allow any conclusions to be drawn on parameters determining the efficacy of PABD; however, these baseline data served for detailed analyses of the parameters, as shown in Tables II - IV.

Table I - Baseline data and data on RBC regeneration in response to pre-operative autologous blood donation of one or two units.

	1 PABD	2 PABD
Patients (n)	439	265
EBV (L)	4.5 ± 07	4.8 ± 0.8
Initial Hct (%)	38.7 ± 3.3** [a]	40.0 ± 3.3** [b, c]
d RBC total (mL)	169.3 ± 20.2**	339.5 ± 35.5**
d RBC in 1st PABD (mL)	169.3 ± 20.2**	176.7 ± 19.3
d RBC in 2nd PABD (mL)	-	162.8 ± 18.5
Hct at 2nd PABD (%)	-	37.6 ± 3.1 [b]
T1 - S (days)	21.8 ± 9.5** [, d]	35.8 ± 8.8**
T1 - T2 (days)	-	16.3 ± 6.0 [d]
T2 - S (days)	-	19.5 ± 7.3 [c]
Pre-operative Hct (%)	36.8 ± 2.6** [a]	37.1 ± 2.7** [c]
+RBC total (mL)	109.3 ± 85.2**	250.2 ± 93.0**
+RBC to 1st PABD (mL)	109.3 ± 85.2**	88.8 ± 81.9** [, e]
+RBC to 2nd PABD (mL)	-	161.4 ± 87.8 [e]
+RBC(% d RBC)	67.6 ± 53.4*	75.1 ± 29.4*

PABD=pre-operative autologous blood donation; EBV=patient's estimated blood volume (calculated); Hct=haematocrit; d RBC=RBC mass deposited by PABD; T1 - S=time-interval between first PABD and surgery; T1 - T2=time interval between first and second PABD; T2 - S=time interval between second PABD and surgery; +RBC=increase (regeneration) of RBC mass in response to PABD; +RBC(% d RBC)=increase in RBC mass calculated as a percentage of RBC mass deposited. *p<0.01. **, a, b, c, d, e p<0.001. Calculations were based on systemic Hct (systemic Hct=venous Hct x 0.914). Data drawn from Singbartl *et al.* (2007)[21].

A positive relation was found between +RBC and the period of time between PABD and surgery (Table II). We demonstrated an absolute increase in +RBC over time and, relatively, with respect to the RBC mass deposited. These data emphasise the importance of considering the physiological time course of erythropoiesis in order to plan an efficacious PABD programme. In both PABD groups, the Hct decreased significantly from its initial level to the level before undergoing surgery.

According to physiology, it takes between 21 and 30 days from the first appearance of erythroid progenitor cells in the bone marrow to the appearance of mature RBC in the peripheral blood[25]. Indeed, there is even a report that a period of up to 6 months is required for the regeneration of one withdrawn RBC

Table II - Increase in RBC-mass to praeoperative autologous blood donation of one and two units in dependence on time-intervall.

		One PABD (n=439)		
Patients (n)	124	135	89	91
T1-S (days) (weeks)	12.2±2.6 ≤2	18.7±2.2 >2-≤3	24.9±2.1 >3-≤4	36.6±6.2 >4
+RBC (mL)	58.1±68.9 [a]	110.2±71.3 [a]	141.0±90.4 [a]	146.6±85.2 [a]
+RBC (% d RBC)	34.3	65.1	83.3	88.6
		Two PABD (n=265)		
Patients (n)	52	80	77	56
T1 - S (days) (weeks)	24.3±4.1 2* + ≤2	32.2±2.0 2* + >2/≤3	38.9±2.3 2* + >3/≤4	47.4±7.2 2* + >4
+RBC mass (mL)	199.6 ±101.2 [b, c]	244.2±76.9 [b]	256.1±95.1 [b]	297.4±78.6 [c]
+RBC (% d RBC)	58.7	71.9	75.4	87.6

PABD=pre-operative autologous blood donation; T1 - S=time-interval between first PABD and surgery; +RBC=increase (regeneration) in RBC mass in response to PABD (total); +RBC (% d RBC)=increase in total RBC mass in response to PABD, calculated as a percentage of the RBC mass deposited. 2*=average time-interval between first and second PABD was 16.6 days (2.4 weeks); data are given as mean±SD. [a]P<0.01 with respect to increase in RBC mass in response to one PABD for the time-interval "T1 - S" of ≤2 weeks versus >2, >3, >4 weeks. [b]P<0.05 and [c]P<0.01 with respect to increase in RBC mass in response to two PABD for the time-interval "T1 - S" of 2* + ≤2 weeks versus 2* + >2, 2* + >3, 2* + >4 weeks. Calculations were based on systemic Hct (systemic Hct=venous Hct x 0.914). Data drawn from Singbartl *et al.* (2007)[21].

unit[26]. In another study of male volunteers, between 20 and 59 days (with a mean of 36±11 days) were needed for complete RBC regeneration of one PABD unit[27]. Nevertheless, even extremely short intervals between RBC deposit and surgery (2.4 and 5.3 days) were reported for a one unit PABD programme[28].

Although the total RBC mass that regenerated increased with time (Table II), only a small proportion of patients regenerated the total RBC mass they had deposited: 25.5% (n=112/439) of those who made one PABD (Table II), and 20.3% (n=54/265) of those who made two PABD. Even beyond 4 weeks after the (last) PABD, on average less than 90% of the total RBC mass deposited had been regenerated (Table II). Patients who made one PABD regenerated on average less than 70% of the RBC mass they deposited, while patients who predeposited two units regenerated on average a total of more than 70% (Table I). Comparable data in the literature vary between less than 50% and more than 70% although extremes of between 3.1% and 94% RBC regeneration can be calculated from published data[28,23]. Our data showed a large variability of +RBC[21,22]. Gender was not demonstrated to have an effect on the efficacy of PABD.

Analysing in detail the patients with two PABD showed the following (Table I): +RBC in response to the first PABD was approximately 50% of the RBC mass deposited (88 of 176 mL, while +RBC in response to the second PABD was essentially 100% (161/162 mL). Thus, approximately one-third of the total +RBC in this "two unit PABD-programme" was regenerated after the first unit deposited, and two-thirds after the second unit. Though statistically significant, the difference in time-interval between the first and second deposits ("T1 - T2") and between the second deposit and surgery ("T2 - S") was only 3 days. Interestingly, while the Hct before the second PABD was statistically significantly lower than the initial Hct (40.0±3.3% versus 37.6±3.1%,

Table III - Daily RBC regeneration rate in response to PABD of one or two units with respect to time-intervals.

One PABD (n = 439)				Two PABD (n = 265)				
Time interval		RBC generation (mL/day)	P value Within 1 PABD	Time interval		RBC generation (mL/day)	P value within 2 PABD	P value between 1and 2 PABD
(weeks)	*(days)*			*(weeks)*	*(days)*			
T1 – S	21.8 ± 9.5	5.2 ± 4.3[a, b]		T1 – S	35.8 ± 8.8			<0.000
T1 – 2						7.2 ± 3.0		<0.001
				T1 – T2	16.3 ± 6.0		<0.001	
				T2 – S	19.5 ± 7.3			
				T1 – T2		5.6 ± 5.8[a]	<0.001	ns
				T2 – S		8.7 ± 5.7[b]		<0.001
T1 – S (<3 weeks)	18.7 ± 2.2			T2 – S[c] (<2 weeks)	11.3 ± 3.1		<0.001	
T1 – S (>4 weeks)	36.6 ± 6.7		<0.001	T2 – S[d] (>4 weeks)	33.0 ± 4.5			
		5.8 ± 3.7		T2 – S (<2 weeks)		9.8 ± 8.4	<0.05	
		4.2 ± 3.4	<0.001	T2 – S (>4 weeks)		7.0 ± 2.3		

PABD=pre-operative autologous blood donation; T1 – S=time-interval between first PABD and surgery; T1 – T2=time interval between first and second PABD; T2 – S=time interval between second PABD and surgery; ns=not statistically significant. Data are given as mean ± SD; [c, d]: corresponding time-interval 'T1 – T2': [b] 17.7 ± 6.9 versus [c] 15.1 ± 5.8 days; P=ns. Data drawn from Singbartl *et al.* (2007)[21].

respectively; P<0.001), the pre-operative Hct reached the level present before commencing the second PABD (37.1±2.7% versus 37.6±3.1, respectively; P=ns). These findings might also be suggestive of the relevance of a low Hct on RBC generation.

Detailed analysis of the time-data of our results provided some insights into changes of daily RBC regeneration rate over time[21]. While total +RBC increased with time (Table II), the daily RBC regeneration rate decreased with time after PABD (Table III). The daily RBC regeneration rate did not only differ between patients with either one or two PABD (5.2±4.3 versus 7.2±3.0 mL/day; P<0.001; Table III), but also between different periods of time within the "two unit PABD-group": the regeneration rates for the period between the first and second PABD (T1 - T2) and the second PABD and surgery (T2 - S) were 5.6±5.8 versus 8.7±5.7 mL/day; P<0.001; Table III). Within the patients with two PABD, the daily RBC regeneration rate was also higher for those who had a T2 - S of less than 2 weeks compared to those who had a T2 - S of more than 4 weeks (9.8±8.4 versus 7.0±2.3 mL/day; P<0.05; Table III); despite there being no statistically significant difference between the corresponding time-intervals between the first and second PABD (17.7±6.9 versus 15.1±5.8 days; P=ns).

With respect to planning a PABD programme according to the determinants of its efficacy, the data presented above make it reasonable to focus on the time-interval "last PABD - surgery" as the period of greater RBC generation. In addition, the total time-interval "1st PABD - surgery" should also be geared to the upper limit of the possible storage time. Modern storage solutions allow time-intervals of up to 49 days. Although there is no doubt that morphological changes occur as the storage time increases ("storage lesion"), 'there is no consensus in the literature on possible adverse effects of "older" blood"[29].

Besides the time-dependency of +RBC, the above results also point to an impact of the Hct level and its changes during RBC regeneration on the +RBC. We analysed +RBC in response to PABD in orthopaedic patients with respect to their initial Hct before commencing PABD[21]; the patients were separated by gender and according to the World Health Organisation definition of gender-specific anaemic and non-anaemic initial Hct (Table IV). While time-data were comparable among anaemic and non-anaemic patients, the +RBC in anaemic patients was not only statistically significantly higher than that in non-anaemic patients, but was also more clinically relevant, both in females and males (approximately 60 to 70 mL). The RBC mass deposited was completely regenerated in anaemic patients, while it was far from regenerated in non-anaemic patients. According to physiology, erythropoiesis is stimulated more strongly in anaemic than in non-anaemic patients: this was demonstrated by the smaller difference between pre-operative Hct and initial Hct (ΔHct) in anaemic versus non-anaemic patients (Table IV).

The results analysed above have two implications for the development of rational and efficacious PABD programmes: (i) the patient's Hb/Hct level should be lowered acutely and strongly by the PABD, within a

Table IV - Comparison of baseline, time, and efficacy data in patients with an anaemic versus a non-anaemic initial haematocrit level before commencing PABD of one or two units.

	Anaemic (Hct <37%)		**Non-anaemic (Hct =37%)**	**Anaemic (Hct <40%)**		**Non-anaemic (Hct =40%)**
One PABD (n = 439)		**Female (n = 286)**			**Male (n = 153)**	
Patients, n (%)	122 (42.7%)	*	164 (57.3%)	64 (41.8%)	*	89 (58.2%)
Initial Hct (%)	35.0±1.2	*	39.5±2.1	37.9±1.7	*	42.8±2.0
Pre-operative Hct (%)	34.6±1.7	*	36.4±1.8	37.5±2.2	*	39.9±2.1
ΔHct (%) (pre-op Hct –initial Hct)	-0.4±1.8	*	-2.8±1-7	-0.4±1.5	*	-2.7±1.9
T1-S (days)	23.7±10.5	ns	21.7± 9.8	22.4±7.4	*	19.1±8.1
+RBC mass (mL)	148.3±67.6	*	73.8±65.8	170.5±81.6	*	77.0±93.9
+RBC (% d RBC)	101±48	*	44±39	101±48	*	40±49
Two PABD (n = 265)		**Female (n = 134)**			**Male (n = 131)**	
Patients, n (%)	34 (25.4%)	*	100 (74.6%)	45 (34.4%)	*	86 (65.6%)
Initial Hct (%)	35.6±1.0	*	39.5±2.0	38.0±1.4	*	43.4±2.2
Pre-operative Hct (%)	34.7±1.3	*	35.9±2.1	36.7±1.8	*	39.6±2.3
ÄHct (%) (pre-op Hct –initial Hct)	-0.8±1.5	*	-3.3±2.2	-1.1±1.5	*	-3.4±2.2
T1-S (days)	36.8±8.2	ns	36.5±9.4	37.7±8.6	*	33.7±8.2
T1-T2 (days)	17.5±4.7	ns	16.8±6.4	16.6±5.3	ns	15.6±6.8
T2-S (days)	20.3±6.4	ns	19.7±8.0	21.2±7.2	ns	18.1±6.8
+RBC mass to 1st PABD (mL)	132.9±78.9	*	73.3±71.2	104.0±65.1	ns	81.5±95.2
+RBC mass to 2nd PABD (mL)	162.1±82.6	ns	152.7±78.3	195.4±87.5	ns	153.1±97.0
+ RBC mass total (mL)	295.0±58.5	*	226.0±79.7	299.9±82.5	*	234.6±107.5
+RBC(% d RBC)	100±20	*	69±25	93±25	*	63±29

PABD=pre-operative autologous blood donation; Hct=haematocrit; T1-S=time interval between first PABD and surgery; T1-T2=time interval between first and second PABD; T2-S=time interval between second PABD and surgery; +RBC=increase (regeneration) of RBC mass in response to PABD. +RBC(% d RBC)=increase in RBC mass calculated as a percentage of RBC mass deposited. Data are given as mean±SD. * P<0.01 between anaemic and non-anaemic female or male patients who made one or two PABD. ns: non statistically significant. Calculations were based on systemic Hct (systemic Hct=venous Hc tx 0.914). Data drawn from Singbartl *et al.* (2007)[21].

short period of time to an individually accepted level of anaemia, in order to stimulate erythropoieis as intensely as possible; and (ii) there should be a long time-interval between the (last) PABD and scheduled surgery in order to allow sufficient RBC regeneration.

An inverse, non-linear relation between Hct level and endogeneous erythropoietin levels has been demonstrated in non-uraemic, anaemic patients with various disorders, with a steep and large increase of this hormone when the Hct falls below 30%[30,31]. Clinical data on endogenous erythropoietin titres in patients undergoing a conventional PABD programme with one predeposit donation per week showed a biphasic change of the levels of this hormone: an initial

small peak was followed by a decline to a plateau level[32]. These findings indicate that erythropoiesis is insufficiently stimulated by a conventional PABD programme.

A clinical comparison of PABD and intra-operative blood salvage showed no statistically significant difference between these ABC measures with respect to transfusion of allogeneic blood in orthopaedic patients[33]. However, using mathematical modelling of the original PABD data to compare the efficacy of PABD and intra-operative blood salvage demonstrated that PABD was superior to intra-operative blood salvage only when the PABD was associated with regeneration of a RBC mass of approximately 400 mL[23]. Overall, and depending on the number of PABD units/RBC mass deposited, intra-operative blood salvage was by far the superior ABC alternative[23]. The differences between the results of the mathematical model and the clinical findings can be explained by methodological differences. While in the mathematical model transfusion criteria were stringently followed, in the clinical study transfusion parameters partly differed between patients undergoing PABD and those in whom intra-operative blood salvage was used.

Due to physiology of erythropoiesis and its critical determinants, an intensified PABD programme should stimulate erythropoiesis strongly. Compared to a conventional PABD programme with the predeposit of one unit per week, depositing a variable number of PABD units within a short period of time would decrease a patient's Hct more rapidly and to a greater degree, stimulate erythropoiesis more efficaciously and enable a longer period of time until scheduled surgery, despite an identical number of PABD units deposited. For example, withdrawing three PABD units within 10 days caused erythropoietin levels to rise to a higher level than in a conventional PABD programme[34]. The "ideal" PABD programme does, however, still await configuration and routine application.

Going yet one step further with respect to planning an "ideal" PABD programme would involve exploiting both critical determinants of RBC regeneration in response to PABD within one PABD session[22]; i.e. withdrawing (for example) two RBC units in a single PABD session. Comparing a conventional programme of two single-unit deposit by apheresis (2SUD) to a double-unit deposit programme (DUD), we showed that DUD was much more efficacious than 2SUD, both in patients with osteoarthritis and in those with rheumatoid arthritis[22] (Table V). Eyrthropoiesis was stimulated more strongly following DUD than following SUD, as demonstrated by the smaller ΔHct (pre-operative Hct - initial Hct) in patients undergoing DUD than in those undergoing 2SUD; this was the case for both patients with osteoarthritis and those with rheumatoid arthritis. Differences in +RBC between the groups of patients undergoing 2SUD and DUD were statistically significant and also clinically relevant (approximately 90 mL or 60%) both in osteoarthritis and rheumatoid arthritis patients (Table V). However, when the two PABD programmes (DUD or SUD) were used in patients with osteoarthritis and rheumatoid arthritis, the clinical efficacy did not differ between these two groups of patients. Data in the literature demonstrated comparable results for +RBC with respect to RBC mass deposited during the DUD PABD programme[35,36].

Based on these findings on RBC regeneration, the DUD strategy is close to an "ideal" PABD programme as far as concerns efficacy. In clinical practice, the RBC mass that can be deposited during a DUD PABD programme is limited only by the patient's individual physical condition, the initial Hct level/initial RBC mass and the minimal Hct level/minimal RBC mass acceptable.

The choice of whether to use PABD or not is the culmination of a decision-making process concerning an individual patient's supposed needs for a peri-operative blood supply. Besides the physiological bases of erythropoiesis, this depends on a variety of additional factors, related to the characteristics of the individual's elective surgery in a given case, the special circumstances of the patient to be operated on, and the PABD itself (Table VI). Since PABD is not without potential risks to the donor, i.e. patient, 'the supposed benefit of PABD has to be weighed against the risks of donation and retransfusion of autologous blood on one hand and against the risk of allogeneic transfusion on the other hand"[37].

A skilled coordination of the various, and in part diverging, aspects of applying an efficacious PABD programme is essential between surgeons, anaesthesiologists and transfusion specialists. Besides the importance of a rational indication for PABD, a

Table V - Comparison of relevant baseline, time, donation, and efficacy data in patients with osteoarthritis and rheumatoid arthritis with respect to different PABD programmes used.

Parameter	Patients with osteoarthritis			Patients with rheumatoid arthritis		
	Two single-unit deposit (2SUD) (n=60)		One double-unit deposit (DUD) (n=100)	Two single-unit deposit (2SUD) (n=24)		One double-unit deposit (DUD) (n=50)
EBV (L)	4.7±0.8	ns	4.6±0.7	4.3±0.6	ns	4.2±0.7
Initial Hct (%)	41.4±4 [a]	ns	39.9±4 [b, e]	40.5±4 [c]	*	37.4±4 [d, e]
Initial RBC mass (L)	1.8±0.4	ns	1.7±0.4	1.6±0.3	*	1.4±0.3
Total blood volume deposited (mL)	430 each (860)	* ns	860 860	430 each (860)	* ns	860 860
Total d RBC mass (mL)	347±30	ns	343±36	336±30	ns	322±32
T1-S (days)	26.9±2.5	ns	25.9±2.9	27.4±1.2	ns	27.0±2.9
T1-T2 (days)	14.0±1.0	-	-	14.0±0.6	-	-
T2-S (days)	13.0±2.4	-	-	13.1±2.4	-	-
Hct at 2nd PABD	39.3±3.6	-	-	37.6±3.5	-	-
Pre-operative Hct (%)	37.2±4 [a]	ns	37.9±4 [b, f]	35.8±5 [c]	ns	35.3±4 [d, f]
ΔHct (%) (pre-op Hct –initial Hct)	-4.2±3.2	*	-2.0±3.0	-4.7±3.9	*	-2.2±2.8
Pre-operative RBC mass (L)	1.6±0.4	ns	1.6±0.4	1.4±0.3	ns	1.3±0.3
+RBC to 1st PABD (mL)	89±119	*	261±114	60±77	*	238±112
+RBC to 2nd PABD (mL)	79±119	-	-	89±120	-	-
+RBC total (mL)	168±133	*	261±114	149±152	*	238±112
+RBC (% d RBC)	48.4	na	76.1	44.3	na	73.9

PABD=pre-operative autologous blood donation; EBV=patient's estimated blood volume (calculated); Hct=haematocrit; Total d RBC-mass=total RBC mass deposited by PABD; T1-S=time-interval between first PABD and surgery; T1-T2=time interval between first and second PABD; T2-S=time interval between second PABD and surgery; +RBC=increase (regeneration) of RBC mass in response to PABD; +RBC(% d RBC)=increase in RBC mass calculated as a percentage of RBC mass deposited. data are given with mean±SD; [a, b, c, d, e, f, *] P<0.05.; ns=not statistically significant; na=not analysed; calculations were based on systemic Hct (systemic Hct = venous Hct x 0.914). Data drawn from Singbartl *et al.* (2007)[22].

rational PABD programme must be based on the physiological principles of erythropoiesis. If, however, these principles are not followed, for whatever reason, PABD will be hardly more than the transfer of RBC from a patient into a plastic bag with little or no benefit for the patient: poorly efficacious, poorly effective, and highly inefficient. It is the physician in charge of an individual patient who must design a personalised, rational (autologous) transfusion programme according to the individual patient's needs and the basics of erythropoiesis: PABD is just one autologous alternative among others. In various institutions, anaesthesiologists and transfusion specialists have co-operated successfully to maximise the efficacy of PABD, meet the individual patient's needs and, finally, satisfy the surgeons as well.

Table VI - Factors to be considered when deciding whether to use a PABD programme in an individual patient.

Type of elective surgery
- aseptic
- infectious
- tumour
- time interval to scheduled surgery
- expected surgical blood loss
Patient's individual situation
- age
- co-existing diseases
- co-medication
- initial Hct/initial RBC mass
- minimal Hct/minimal RBC mass acceptable
- allowable blood loss calculated from initial Hct/initial RBC-mass to minimal Hct/minimal RBC-mass versus expected blood loss; including an individual margin of safety (appropriate formulae have been published elsewhere[18-23])
- need for blood transfusion expected from the calculation
- rare blood group/special constellation of erythroid allo-antibodies
- physical fitness to deposit autologous units pre-operatively
- autologous alternatives possible/reasonable
- pharmacological alternatives possible/reasonable
Specific preliminaries for pre-operative autologous blood donation versus (autologous) transfusion alternatives in order to apply pre-operative autologous blood donation safely, efficaciously, effectively and efficiently
- decision on pros/cons of pre-operative autologous blood donation

Key words: pre-operative autologous blood donation; efficacy; decisive clinical parameters.

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