Automated Exchange Transfusion and Exchange Rate

Masahisa Funato, M.D., Seiichi Shimada, M.D., Hiroshi Tamai, M.D., Hideo Taki, M.D. and Yasushi Yoshioka, M.D.

Department of Pediatrics, Yodogawa Christian Hospital, Osaka

An automated blood exchange transfusion (BET) with a two-site technique has been devised by Goldmann et al and by us, using an infusion pump. With this method, we successfully performed exchange transfusions 189 times in the past four years on 110 infants with birth weights ranging from 530 g to 4,000 g. The exchange rate by the automated method was compared with the rate by Diamond's method. Serum bilirubin (SB) levels before and after BET and the maximal SB rebound within 24 hours after BET were: 21.6 ± 2.4, 11.5 ± 2.2, and 15.0 ± 1.5 mg/dl in the automated method, and 22.0 ± 2.9, 11.2 ± 2.5, and 17.7 ± 3.2 mg/dl in Diamond's method, respectively. The result showed that the maximal rebound of the SB level within 24 hours after BET was significantly lower in the automated method than in Diamond's method ($p<0.01$), though SB levels before and after BET were not significantly different between the two methods. The exchange rate was also measured by means of staining the fetal red cells (F cells) both in the automated method and in Diamond's method, and comparing them. The exchange rate of F cells in Diamond's method went down along the theoretical exchange curve proposed by Diamond, while the rate in the automated method was significantly better than in Diamond's, especially in the early stage of BET ($p<0.01$). We believe that the use of this automated method may give better results than Diamond's method in the rate of exchange, because this method is performed with a two-site technique using a peripheral artery and vein.

(*Acta Paediatr Jpn 1989;* 31: 572 ~ 577)

Key Words
Blood exchange transfusion, Bilirubin, Fetal red cell

Introduction

In the past several methods for automated blood exchange transfusion (BET) have been proposed, using a peristaltic pump or a micro-infusion rolling pump; however, these methods have not been commonly used throughout the world because of technical difficulties [1–4].

Recently, a new modification for automated BET using an infusion pump was proposed by Goldmann et al [5] and by us [6, 7]. We devised an automated apparatus for BET from an Atom infusion pump, and in 1982 we began to use this apparatus for automated BET instead of the Diamond's method. With this method, we successfully performed exchange transfusions 189 times in 110 cases with birth weights ranging from 530 g to 4,000 g, over a period of four years (1982–1986).

Received February 7, 1989
Revised May 8, 1989
Accepted June 2, 1989

Correspondence address: Masahisa Funato, M.D., Department of Pediatrics, Yodogawa Christian Hospital, 2-9-26, Awaji, Higashi-Yodogawa-ku, Osaka 533

So far, there are not enough data on the efficacy of automated BET compared with that of several traditional methods, except for the data reported by Goldmann et al [5] on the exchange rate of serum bilirubin (SB) before and after BET. We examined the exchange rate in the automated method by means of measurement of SB before and after BET and of the maximal SB rebound within 24 hours after BET, and also by means of staining and counting the ratio of fetal red cells (F cells) to adult cells (A cells) before, during, and after BET, comparing them with the ratio in Diamond's method.

Materials and Methods

Table 1 shows cases which had automated BET in our hospital from 1982 to 1986. Thirty-three of 110 cases (30%) were very small prematures weighing less than 1,500 g. The indication in these cases was not only hyperbilirubinemia, but also other disorders such as sepsis, disseminated intravascular coagulopathy, renal failure, and hyperammonemia. Partial BET for polycythemia was also carried out using this automated method. From these cases, a selection was made under uniform conditions for measurement of exchange rate of SB and also at random for measurement of exchange rate of F cells. As a control group, a selection was made the same way from 118 cases which had BET by Diamond's method from 1978 to 1982.

Automated BET was performed with an exchange apparatus which was supplied by Atom (Fig. 1). Two 50 ml syringes were set, one for exsanguination and the other for transfusion. For the two-site technique, a peripheral artery and vein were chosen, such as the radial or brachial artery for exsanguination and the cephalic or basilic vein for transfusion. A twenty-four gauge cannula (Terumo) was used to obtain an arterial or venous route.

To obtain a peripheral arterial route, the transillumination method of Pearse [8] was successfully applied. The total volume for BET was determined to be about 160–180 ml/kg. BET speed was adjusted to 100–150 ml/kg/hr (maximal speed up to 399 ml/hr).

Table 1. Cases having automated BET

Birth weight (g)	Cases	Number of BET
999	21	41
1,000 – 1,499	13	29
1,500 – 2,499	33	54
2,500	43	65
Total	110	189
		(1982.10.–1986.6)

(Causes)
Hyperbilirubinemia : 42
Sepsis : 21
D.I.C. : 18
Renal Failure : 6
Hyperammonemia : 1
Polycythemia : 22 (Partial BET)

In Diamond's method, BET is performed in the classical fashion by umbilical venous catheterization (8 or 5 French size) with push-and-pull technique [9]. The stroke volume of push-and-pull for BET was determined as 7 ml/kg and the total volume was also determined as about 160–180 ml/kg. BET by Diamond's method took about 1–2 hours.

Informed consent was obtained from the parents in all cases and for both methods.

1. Exchange Rate of Serum Bilirubin (SB)

SB levels were measured before and after BET, and were also serially measured within 24 hours after BET, in 18 cases by the automated method and in 23 cases by Diamond's method. Though the indication for BET in all these cases was hyperbilirubinemia, cases were strictly selected according to the criteria of birth weight >2,000 g, SB level before BET >18 mg/dl, no major problems such as blood-type incompatibility, and only one BET performed. The mean and standard deviation (SD) of birth weight and gestational age were 3,083 ± 455 g and 38.7 ± 1.6 weeks in the automated method, and 2,840 ± 409 g and 37.3 ± 3.0 weeks in Diamond's method, respectively (unpaired T; p: ns). The mean age at which BET was performed, exchange volume used, and exchange time taken were, respectively: 4.1 ± 1.3 days of life, 175 ± 20 ml/kg, and 117 ± 48 minutes in the automated method

and 4.7 ± 1.7 days of life, 180 ± 12 ml/kg, and 104 ± 23 minutes in the Diamond method. There were no significant differences between the automated and the Diamond's methods (unpaired T; p: ns).

SB levels before and after BET were measured by means of the alkali-azo-bilirubin (AAB) method (Wako) and the serial measurement of rebound SB within 24 hours after BET was performed by means of the bilirubinometer (Erma), as routine laboratory examinations.

2. Exchange Rate of Fetal Red Cells (F Cells)

In 10 cases of the automated method and in 14 cases of Diamond's method which were selected at random, the ratio of fetal red cells (F cells) to adult cells (A cells) was determined before (0 ml/kg of blood exchanged), during (14, 35, 70, 105, and 140 ml/kg exchanged) and after BET (175 ml/kg exchanged). The mean and SD of birth weight and gestational age were, respectively: 2,596 ± 817 g and 37.2 ± 2.7 weeks in the automated method, and 2,631 ± 489 g and 36.9 ± 3.2 weeks in Diamond's method (unpaired T; p: ns). The age at which BET was performed, exchange volume used, and exchange time taken were, respectively: 3.5 ± 4.0 days of life, 183 ± 31 ml/kg, and 131 ± 31 minutes in the automated method, and 4 ± 2.0 days of life, 184 ± 13 ml/kg, and 111 ± 35 minutes in Diamond's method. Between the 2 methods there were no significant differences in these factors (unpaired T; p: ns).

The indications for BET were hyperbilirubinemia in 20, sepsis in 2, and disseminated intravascular coagulopathy in 2.

F cells were stained by means of an acid elution method [10] using a staining solution supplied by Boeringer Mannheim GMBH (14.8 mM $FeCl_3$: 16.5 mM hematoxylin and 0.1 g erythrosin/100 ml). Figure 1 shows stained F cells and ghosted A cells. The counting of the F cells and A cells was performed under a microscope (×400) by a laboratory technician who did not know which method of BET has been used.

Statistic analysis was performed by unpaired T test.

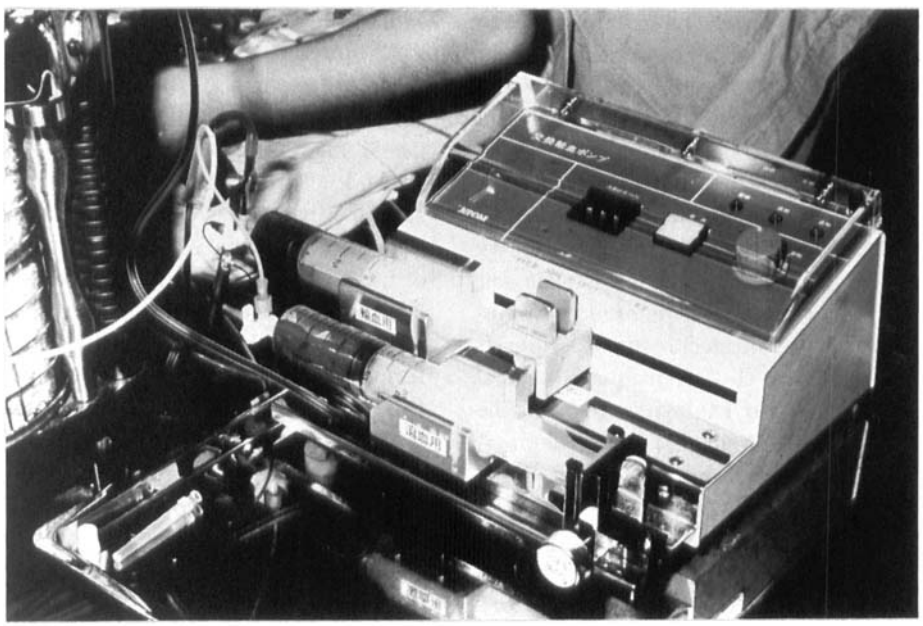

Fig. 1: Automated apparatus for exchange transfusion.

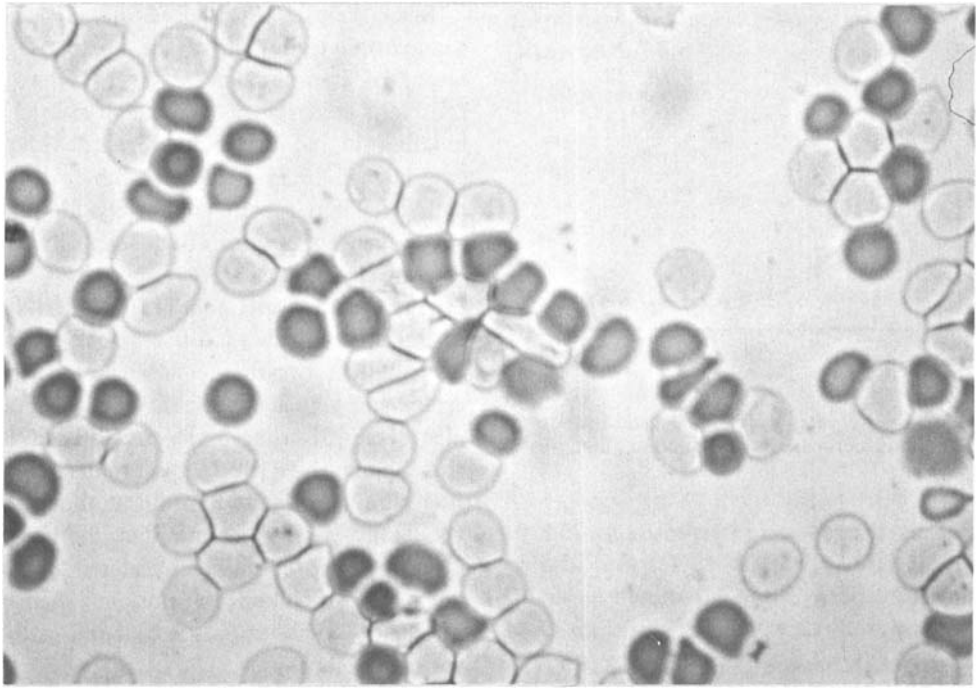

Fig. 2: Fetal red cells stained by means of acid elution method. Stained fetal cells and ghosted adult cells seen under microscope (×400).

Results

1. Exchange Rate of Serum Bilirubin (SB)

Figure 3 shows serum bilirubin (SB) levels before and after BET and the maximal rebound of SB within 24 hours after BET by the automated method and by Diamond's method. SB levels before and after BET and the maximal SB rebound within 24 hours after BET were, respectively: 21.6 ± 2.4, 11.5 ± 2.2, and 15.0 ± 1.5 mg/dl in the automated method, while they were 22.0 ± 2.9, 11.2 ± 2.5, and 17.7 ± 3.2 mg/dl in Diamond's method (Mean ± SD). Though SB levels before and after BET were not significantly different between the two methods, maximal rebound of the SB level within 24 hours after BET was significantly lower in the automated method than in Diamond's method (unpaired T; p: <0.01).

2. Exchange Rate of Fetal Red Cells (F cells)

Figure 4 shows the ratio of fetal red cells (F cells) to adult red cells (A cells) in the automated method, in comparison with Diamond's method. The percentage of F cells to A cells before BET (0 ml/kg of blood exchanged) was calculated and corrected to 100% in all samples. The corrected percentage of F cells at the points of 14, 35, 70, 105, 140, and 175 ml/kg

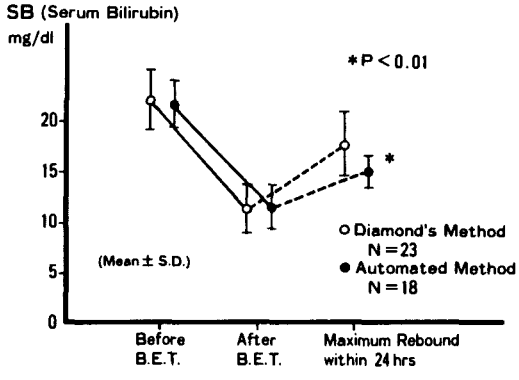

Fig. 3: Serum bilirubin (SB) levels before and after blood exchange transfusion (BET) and maximal rebound of SB within 24 hours after BET in automated method, compared with Diamond's method

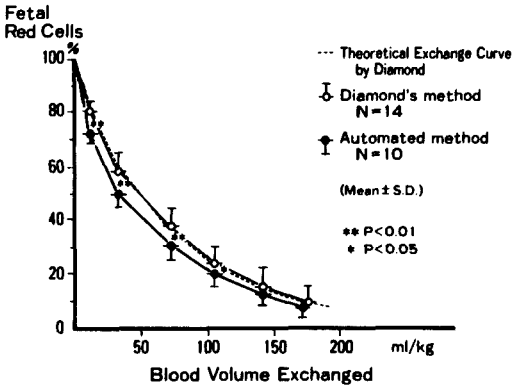

Fig. 4: Exchange rate of fetal red cells in automated method, compared with Diamond's method.

of blood exchanged were, respectively: 73.8 ± 4.6, 51.2 ± 5.5, 31.3 ± 4.8, 20.4 ± 4.5, 13.5 ± 4.7, and 8.7 ± 5.1% in the automated method, while they were 80.9 ± 5.2, 59.7 ± 7.5, 39.3 ± 7.1, 25.7 ± 7.0, 17.1 ± 6.1, and 10.9 ± 5.5% in Diamond's method (Mean ± SD). Though the exchange rate in Diamond's method went down along the theoretical exchange curve proposed by Diamond [9], the rates were significantly lower in the automated method at the points of 14, 35, 70 ml/kg exchanged (unpaired T; $p < 0.01$) and 105 ml/kg exchanged (unpaired T; $p < 0.05$) as compared with Diamond's method.

Discussion

A trial for automated BET was first proposed by Valentine (1966) [1], who inserted two catheters into the umbilical vein; one was placed at a shallow point for exsanguination and the other deep for transfusion, and an automated BET was performed using a peristaltic pump. Later several other automated methods for BET were proposed by Cavalieri et al (1967)[2], Garofaro et al (1971) [3], and Philpott & Banerjee (1972) [4], taking a peripheral vein or the umbilical vein and/or umbilical artery and using a peristaltic pump or a Holter microinfusion rolling pump. But these methods have not been commonly used throughout the world, because of technical difficulties.

Since Pearse [8] successfully reported a cannulation technique of the radial artery by means of transillumination in 1978, we have routinely undertaken peripheral arterial cannulation to monitor blood pressure or blood gas, instead of inserting an umbilical arterial catheter. Using a peripheral artery and vein, we also began to perform BET manually with a two-site technique, as described by Campbell et al [11] and Morita et al [12].

Recently, a new modification of automated BET with a two-site technique of peripheral artery and vein has been introduced by Goldman et al [5] using a Harvard infusion pump and by ourselves [6, 7], using an Atom infusion pump. We found that this method for BET was easily performed and that the use of an infusion pump could be considered a common technique of blood transfusion. There were no major complications associated with this automated technique.

Goldman et al [5] theoretically pointed out two merits of this method, compared with traditional methods such as that of Diamond. First, there might be little hemodynamic change during BET with this method, since the technique was isovolemic. In our previous paper we have already reported no significant variation in blood pressure before, during and after automated BET and no occurrence or exacerbation of intraventricular hemorrhage with this method [13].

Secondly, Goldman et al also pointed out the possibility of a greater efficacy of exchange by an automated method, compared with the Diamond's method, because it was a two-site technique. In their paper they gave a preliminary report of a better exchange rate of SB before and after BET by the automated method than by Diamond's method, but enough data were not given on the exchange rate of the automated method [5].

We therefore carefully studied the exchange rate by the automated method in two ways: by means of SB measurement before and after BET and the maximal rebound of SB within 24 hours after BET, and additionally, by means of staining and counting the F cells and A cells before, during, and after BET, and comparing

these data with those in Diamond's method.

Though the SB levels before and after BET were not significantly different in the Automated method and in the Diamond method, maximal rebound of the SB level within 24 hours after BET was significantly lower in the automated method than in Diamond's method ($p < 0.01$). This means that more shunt bilirubin might be removed by the automated method, because of a greater efficacy of the exchange due to the two-site technique. Our result was a little different from Goldman's. They did not mention rebound bilirubin levels in either method in their paper [5]. Our data were the result of a matched study in which there were no significant differences between the two methods in birth weight gestational week, age at which BET was performed, exchange volume used, or exchange time taken.

The exchange rate of F cells to A cells was also significantly better in the automated method than in Diamond's, especially in the early stage of BET. ($p < 0.01 - < 0.05$) This efficacy might be derived from the two-site technique, because there was 1 ml or 0.25 ml of dead space in the 8 French or 5 French sized umbilical catheter, which must partly bear responsibility for the lower efficacy of Diamond's method with its push-and-pull technique. These data were also the result of a randomized matched study in which there were no significant differences between the two methods in birth weight, gestational week, age at which BET was performed, exchange volume used, or exchange time taken.

Our data showed that there was definitely a greater efficacy of exchange in the automated method than in Diamond's method, because this method was performed with a two-site technique using a peripheral artery and vein. We believe this automated method may be an easier, safer, and more effective modification of traditional techniques for exchange transfusion, which can be used safely even for extremely premature infants.

Acknowledgement

We are grateful to Miss Yukie Takemura, Chief of the Laboratory of Yodogawa Christian Hospital, for her assistance.

References

1. Valentine GH. Exchange-transfusion apparatus. Lancet 1966; 2: 1466.
2. Cavalieri S, Mastella G, Battaglino GC. Exsanguino transfusione nel neonato a goccia fluente con micropompa. Comunicazione $XXXII_0$ Congr Ital Pediat Como 1967.
3. Garofalo E, Minerva A, Baltieri G: Exchange-transfusion by means of microinfusion rolling pump. Helv Pediatr Acta 1971; 26: 461.
4. Philpott MG, Banerjee A. Automated method for exchange transfusion. Arch Dis Child 1972; 47: 815.
5. Goldman SL, Tu HC. Automated method for exchange transfusion; A new modification. J Pediatr 1983; 102: 119.
6. Funato M, Tamai H, Shimada S et al. Automated apparatus for exchange transfusion. Editorial correspondence. J Pediatr 1984; 104: 160.
7. Funato M, Tamai H, Shimada S et al. Trial of an automated method for exchange transfusion. Acta Neonatologica Japonica 1984; 20: 217 (in Jpn).
8. Pearce RG. Percutaneous catheterization of the radial artery in newborn babies using transillumination. Arch Dis Child 1978; 53: 549.
9. Diamond LK. Erythroblastosis fetalis or hemolytic disease of the newborn. Proc R Soc Med 1947; 40: 546.
10. Kleihauer E. Feststellung des Zeitpunktes von Intra-Kraniellen Blutung bei Neugeborenen, 5 Deutscher Kongress für perinatale Medizin. Perinatale Medizin 1973; 4: 429.
11. Campbell N, Stewart I. Exchange transfusion in ill newborn infants using peripheral arteries and veins. J Pediatr 1979; 94: 820.
12. Morita T, Fujiwara T, Maeta H et al. Exchange transfusion in sick neonates using peripheral veno-artery lines. Igakunoayumi 1980; 115: 461 (in Jpn).
13. Funato M, Shimada S, Tamai H et al. Automated BET, blood pressure, and IVH. Acta Paedaitr Jpn 1988; 30: 588.