球増加症は白血球増加，血小板増加，小球性低色素性赤血球の傾向を示すことから，今回の検討で，Hb19.0g/dL未満で白血球数，血小板数，赤血球指数が正常であれば，採血可能と判断した．

今回Hb測定の定量性を生かして，従来の採血基準の妥当性を検討した。まず，比重法とHb法の比較で，1.052以上はHb12.1g/dL以上を，1.053以上はHb12.6g/dL以上を示した。また，Hb値の低下に伴って赤血球指数が低下してくるが，平均値の低下開始に相当するHb値は，小球性低色素性赤血球に移行する点で，女性の成分採血の際の可否判定に用いられているところである。低下開始点は男性12.5g/dL，女性12.0g/dLで，男性が0.5g/dL高かった。また，12.5g/dL以下の男性献血申込者の比率は0.6%と少なく，あえて男性の採血基準を引き上げる必要はないと考えられる。以上および米国FDAの基準[11]を勘案して，私たちはHb法の判定に男女差を設けず，従来の採血基準を用いることで問題がないと考えた。

今回用いたヘモキュウによるHb測定法は，英国のNational Quality Assessment Schemeの精度管理で正確性の保証が得られている[11]。また，静脈血採血と耳朶あるいは指尖毛細血管穿刺との間に差異があるとの議論がある。これは，サンプリングが不適切な場合で，血流が十分保たれ，穿刺が正確に行われた場合は有意の差がないとの見解が一般的である[12]。また，指尖穿刺の方が，静脈穿刺より正確性を欠くとの報告もある[13]。

献血の可否を決定する検査は，大別して，血液学的検査，生化学検査，感染症関連検査が行われている。生化学，感染症関連検査は1953年血液事業が開始されて以来，次々と改良，改善が加えられ，NAT検査の導入によって世界的水準を保つにいたっている。一方，採血基準の根幹である貧血の有無判定については，当初の硫酸銅による比重法が現在にいたるも用いられ，一向に改良の気配がない。その間，比重不足による献血不適格者は増加の一途であり，女性の400mL献血で本社の調査で，1990年 9.9%，2000年 18.1%，2003年21.3%である[14,15]。輸血によるウイルス性肝炎が激減したのと極めて対照的である。いうまでもなく比重法は測定者の目視による定性的判定法であり，温度・湿度の影響，使用滴下回数や蒸発，観察者の主観を無視できない。臨床の場においても，かつては比重法や比色法(ザーリ法)が用いられたが，現在はHb,ヘマトクリットに統一され，比重，比色によっている医療機関は皆無である。したがって，血液センターと医療機関の間で貧血に関するかぎり整合した議論が全くできていない。国は献血者の確保の推進として，献血の検査結果を健康診査，人間ドック，職場検診で活用するとともに，地域の保健指導に用いるよう求めているが[16]，比重で表示される献血不適格者の成績は利用し得ない状況である。以上から，血液センターにおいてもHb法を早急に導入し，定量的な評価によって献血者の健康を守る配慮をすべきである。

結　論

1．献血の可否判定にHb法を導入した。従来の比重法に比して，不適格者率，副作用発症率とも差異はなかった。

2．Hbおよび赤血球指数の度数分布から，従来の採血基準(400mL：12.5g/dL以上，200mL：12.0mg/dL以上)を用いて差し支えないことが判明した。

3．Hb低値の献血申込者に対して，Hb値に応じた栄養指導，医療機関への受診指導を行うことができた。

4．Hb法は定量性，客観性において比重法に優っており，Hb法に統一すべきであることを提言した。

文　献

1) Boulton F.: Managing donors and iron deficiency. Vox Sanguinis, 87 (supple 2): 22-24, 2004.

2) Radtke H. *et al.*: Daily doses of 20mg of elemental iron compensate for iron loss in regular blood donors: a randomized, double-blind, placebo-controled study. Transfusion, 44: 1427-1432, 2004.

3) Cable R.G.: Hemoglobin determination in donors.

2002 AABB presentation session #307-TC. Oct. 28, 2002, Orland, USA.

4) Chanarin, I.: Laboratory Haematology. Churchill Livingstone. Edinburgh, 1989, pp 3-32.

5) 佐野秀明ほか：硫酸銅比重液用高温槽の検討．血液事業，10：156-158，1987.

6) 内田立身：赤血球沈降速度．臨床医，28：885-887，2002.

7) James V. *et al.*: Statistical analysis of inappropriate results from current Hb screening methods for blood donors. Transfusion 43: 400-404, 2003.

8) Shimoyama R. *et al.*: Donor selection in Japan: a trial of new criteria with predonation hemoglobin testing. Vox Sanguinis, 82: 72-75, 2002.

9) 中瀬俊枝ほか：ヘモグロビン事前検査にもとづく採血．血液事業，23：19-26，2000.

10) Bhaskaram, P. *et al.*: Varidation of hemoglobin estimation using Hemocue. Indian J. Pediatr. 70: 25-28, 2003.

11) Lewis, S. M.: Reliability of the HemoCue B-Hemoglobin system. HemoCue Technical Letter No 3, May 2003

12) Cable, R. G.: Hb screening of blood donors: how close is close enough? Transfusion, 43: 306-308, 2003.

13) Cable, R. H.: Hemoglobin determination in blood donors. Transfus. Med. Rev. 9: 131-144, 1995.

14) 日本赤十字社血液事業部編：血液事業の現状．平成15年度統計表：p. 73．2003

15) 内田立身ほか：日本人女性の貧血，最近の動向とその成因．臨床血液．45：1085-1089，2004.

16) 厚生労働省：輸血医療の安全性確保のための総合対策報告書，平成16年７月.

(12)

Statistical analysis of inappropriate results from current Hb screening methods for blood donors

Virge James, Keith F. Jones, Elizabeth M. Turner, and Robert J. Sokol

BACKGROUND: The objective was to apply statistical analysis to the false passes and fails that occur with the primary and secondary Hb-screening methods used at blood-donor sessions.

STUDY DESIGN AND METHODS: Venous samples from 1513 potential donors who had undergone primary $CuSO_4$ screening using capillary blood (Hb cut-offs: women, 125 g/L; men, 135 g/L) were tested at the session by a secondary method (HemoCue; cut-offs: women, 120 g/L; men, 130 g/L) and again at the base laboratory using another system (Beckman Coulter General S system), which generated the "true" Hb value.

RESULTS: False-pass and -fail rates for women and men, respectively, were 11.2 and 6.3 percent (women) and 5.2 and 1.8 percent (men) for $CuSO_4$; 1.9 and 3.7 percent (women) and 1.5 and 0.4 percent (men) for HemoCue; and 2.7 and 2.4 percent (women) and 1.8 and 0.2 percent (men) for a combined procedure that mimicked current practice of only testing $CuSO_4$ fails by HemoCue.

CONCLUSION: $CuSO_4$ Hb screening gives large numbers of false passes, particularly in women. Using venous samples, the majority correctly pass at the lower HemoCue cut-offs. The current dual-testing policy appears convenient for donor sessions, but because small percentages of false passes and fails represent large numbers of donors, every effort should be made to improve the accuracy of Hb screening.

Potential blood donors who attend donor sessions in the Trent Region (situated in the East Midlands, UK) initially undergo a health-screening survey. After passed this survey, they are subjected to primary Hb screening by the $CuSO_4$ gravimetric method carried out on finger-prick capillary blood, the cut-off levels for donation being set to correspond to Hb values of 125 g per L for women and 135 g per L for men.[1-3] To optimize blood-collection rates, UK regulations allow individuals who fail the primary $CuSO_4$ test to continue with the donation process if they pass the secondary Hb screening performed on a predonation venous sample using the HemoCue system.[2,4,5] With this method, donor acceptance or rejection is set at lower Hb levels: 120 g per L for women and 130 g per L for men.

We have recently become concerned that some donors are being bled inappropriately with these screening methods, whilst others with an acceptable Hb level are failing the tests. The purpose of this study is to determine whether this is the case and how to quantitate the problem by applying statistical analysis to the primary and secondary Hb-screening procedures used at our donor sessions, comparing them with a standard Hb measurement.

MATERIALS AND METHODS

Studies were carried out on potential volunteer blood donors attending routine donor sessions held throughout the Trent Region. All participants were fully informed of the purpose of the project and gave signed consent. The

From the National Blood Service, Trent Center; Sheffield Hallam University; and Northern General Hospital, Sheffield, United Kingdom.

Address reprint requests to: Virge James, MD, National Blood Service, Trent Center, Longley Lane, Sheffield S5 7JN, UK; e-mail: virge.james@nbs.nhs.uk.

Financial support was received from HemoCue Ltd., Viking Court, 31 Princess Road, Dronfield, S18 2lX, UK.

Received for publication July 9, 2002; revision received September 25, 2002, and accepted October 10, 2002.

TRANSFUSION 2003;43:400-404.

study had been formally approved by the Trent Multicentre Research Ethics Committee.

To avoid bias when selecting individual subjects for the study, a simple systematic sampling scheme was used at each donor session. Before screening, every n^{th} potential donor was approached for consent to enroll in the trial. If an individual declined, each subsequent person was approached until one consented. Subsequently, the next n^{th} individual was approached and so on. The value of n was controlled by the transfusion service staff at the screening station.

During quiet periods, n could be set at 1 so that every potential donor could be approached. During busier periods a larger value of n could be set, and at exceptionally busy times, sampling could be discontinued completely to avoid delaying the session.

Venous blood samples were collected from 730 women and 783 men who were potential donors who had undergone the primary $CuSO_4$ gravimetric Hb-screening test. All the venous samples, which included those from individuals who passed and failed $CuSO_4$ screening, were taken before any blood donation and tested at the donor session by the HemoCue method. These machines are calibrated to the International Council for Standardization in Haematology standard. The HemoCue results were used to construct a hypothetical screening test and were expressed as either a pass or fail in respect to cut-off Hb values of 120 g per L for women and 130 g per L for men.

A combined procedure that followed current practice was also applied. Thus, respondents were initially screened on the standard $CuSO_4$ test; those who passed were deemed to have passed the combined procedure. Those who failed the $CuSO_4$ test were considered to have passed the combined procedure if a subsequent HemoCue result was at least 120 g per L for women and 130 g per L for men.

The venous samples were tested again at the base laboratory with the Beckman Coulter General-S system (Beckman Coulter, High Wycombe, UK). These results were deemed to be the "true" Hb values against which the results of the $CuSO_4$, HemoCue and combined procedures could be compared.

Statistical methodology

In view of the known differences in Hb levels between men and women, data for the different sexes were analyzed separately. Because donor characteristics would be likely to vary considerably between individual donor sessions, any sampling biases with respect to donor age were adjusted by stratifying data for both men and women into quinquennial age bands and then testing to determine whether reweighting of the age-stratified data was necessary. This was achieved by chi-squared tests, comparing test and whole donor population data, and by a one-way ANOVA conducted for each of the women and men data sets with various Hb counts as the dependent variable and age category as the factor of interest.

The need to reweight was confirmed by both tests. A chi-squared value of 54.88 ($p < 0.0001$, $df = 10$) in respect to age distribution for women indicated that the test sample was severely under-represented in the 17 to 30 years age range, whereas for the age distribution for men, a chi-squared value of 18.60 ($p < 0.046$, $df = 10$) showed the test sample was under-represented in the 20-and-under ages. For the ANOVA, F values of 3.00 ($df = 10,724$, $p = 0.001$) for women and 2.23 ($df = 10,782$, $p = 0.015$) for men confirmed that in each case, Hb varied with age.

Reweighting to give reasonable donor population estimates was therefore carried out by calculating the stratified sample proportion of individuals possessing the appropriate attribute, together with its SE. This proportion is an unbiased estimator of the true population proportion possessing the desired attribute.[6,7] All values and standard errors were obtained using a statistical software package (SAS, SAS Institute, Cary, NC), and all proportions and standard errors were converted to percentages by multiplying them by 100.

The results of each screening test were compared to baseline Beckman Coulter Hb values of 125 g per L (women) and 135 g per L (men) for the $CuSO_4$ test and 120 g per L (women) and 130 g per L (men) for the HemoCue and combined procedures. The "false-pass" rates (i.e., the percentages of potential donors who would pass the relevant screening test but would fail the baseline Beckman Coulter test) were of particular interest.

RESULTS

Table 1 shows the results of the $CuSO_4$ Hb screening compared with the baseline Beckman Coulter values of 125 g per L (women) and 135 g per L (men). Table 2 (women)

TABLE 1. Results of $CuSO_4$ screening test compared with Beckman Coulter baseline at Hb levels of 125 and 135 g per L for women and men, respectively: population percentage estimates, stratum weighted by age

		Women		Men	
$CuSO_4$ result	Beckman Coulter result	Estimated percentage	SE	Estimated percentage	SE
Fail	Fail	12.4	1.3	3.9	0.7
Fail	Pass	6.3	0.9	1.8	0.5
Pass	Fail	11.2	1.3	5.2	0.8
Pass	Pass	70.1	1.8	89.0	1.1
Correct classification (%)		82.5		93.0	

TABLE 2. Results of screening tests for women compared with Beckman Coulter baseline Hb level of 120 g per L: population percentage estimates, stratum weighted by age

Screening test result	Beckman Coulter test result	$CuSO_4$ Estimated percentage	SE	HemoCue Estimated percentage	SE	Combined Estimated percentage	SE
Fail	Fail	6.0	1.0	6.0	0.9	5.3	0.9
Fail	Pass	12.7	1.3	3.7	0.7	2.4	0.6
Pass	Fail	1.9	0.6	1.9	0.6	2.7	0.7
Pass	Pass	79.4	1.6	88.4	1.3	89.6	1.2
Correct classification (%)		85.4		94.4		94.9	

TABLE 3. Results of screening tests for men compared with Beckman Coulter baseline Hb level of 130 g per L: population percentage estimates, stratum weighted by age

Screening test result	Beckman Coulter test result	$CuSO_4$ Estimated percentage	SE	HemoCue Estimated percentage	SE	Combined Estimated percentage	SE
Fail	Fail	2.2	0.5	2.0	0.5	1.7	0.5
Fail	Pass	3.6	0.6	0.4	0.2	0.2	0.2
Pass	Fail	1.3	0.4	1.5	0.4	1.8	0.5
Pass	Pass	93.0	0.9	96.2	0.7	96.3	0.7
Correct classification (%)		95.3		98.2		98.0	

and Table 3 (men) give the results of the individual $CuSO_4$ and HemoCue screening tests and of the combined procedures, comparing them with Beckman Coulter baseline values of 120 g per L for women and 130 g per L for men.

DISCUSSION

The UK requires a predonation Hb screening to be carried out on all potential donors, and only individuals with an Hb level at or greater than 120 g per L for women or 130 g per L for men proceed to donate.[8,9] However, accuracy of Hb-screening procedures at blood-donor sessions may be a problem, and our study, by quantitating this, provides data for informed debate (Tables 1-3). It also shows how such studies may be approached in the future. In the present case, statistical analysis without the need to reweight would have required an even larger sample size. This would have been impractical because the length of time it took to obtain the informed consent required by the Ethics Committee had a deleterious effect on the efficient running of many donor sessions, particularly busy ones. As a result, the test sample was not representative of the donor population as a whole. This, and because of clustering of sessions, made it important to reweight the data so that the test population truly reflected the whole donor population with regard to factors that affect screening outcomes, such as age and sex. Reweighting necessitated expressing the results in proportions (percentages) rather than as raw figures.

The primary purpose of Hb screening is donor protection, preventing an anemic individual from exacerbating their condition with potential ill effects. The secondary purpose is to ensure the patient receives a minimum infused Hb dose per RBC transfusion. Screening also acts as a nonspecific measure of the general health of the donor and may identify some conditions which could potentially be harmful to the recipient.[2]

Protocols with set cut-offs are not without problems: they cause administration and quality control costs, donor inconvenience, expense and anxiety as a result of medical follow-up of deferrals, as well as permanent loss of donors. Additionally, cut-offs need to be set to maximize donor safety but be balanced against the system's ability to collect an adequate blood supply, a particular concern when trying to exclude women with iron deficiency. Hb reference ranges vary with age, race, and sex, and are affected by altitude, smoking, and the site from which the sample is taken.[2,10] It has been suggested that, rather than having set cut-off values, a standard should be established whereby blood donations contain a "minimum Hb dose" of 50 g; this would allow individual blood centers to evaluate the appropriate safe Hb cut-off for their donors.[2]

The $CuSO_4$ gravimetric test has been the method of choice in the UK for primary Hb screening of potential blood donors for many years. It is fast, inexpensive, does not require a venous sample, and, although rigorous training and constant monitoring of session staff is necessary, does not need trained laboratory personnel. It does not, however, give a quantitative result, has a subjective endpoint, is difficult to quality control, and presents problems with the disposal of biohazardous material.[2] Although very anemic donors can, on occasion, pass the $CuSO_4$ test,[11] early reports suggested that the $CuSO_4$ method tended to give inappropriate failures, and thus significant numbers of such failed donors could be recovered with a revised Hb range or if an alternative screening method was applied.[2]

This is the rationale for the primary and secondary Hb-screening tests used in the UK. It is supported by several studies that show that many units of blood can be collected that would otherwise be lost. Figures of between 11 and approximately 50 percent recovery of donations with secondary screening are quoted.[2,12-14] The lowering of the cut-off Hb values for the secondary screening also helps. In one study, 29 percent of failed

donors passed the secondary test (HemoCue) at Hb cut-offs of 125 and 135 g per L (women and men, respectively); but with the cut-offs reduced to 120 and 130 g per L, this figure increased to over 44 percent.[14]

Initially there was concern that such a high proportion of donors, 11.2 percent of women and 5.2 percent of men in the present study, inappropriately pass the $CuSO_4$ screening test (Table 1); and, it should be noted that at these higher baselines, a HemoCue screening test would have considerably reduced the false-pass rates. Thus, the high false-pass rates in Table 1 do not mean that there is a similar proportion of donors being bled inappropriately. Examination of Tables 2 and 3 show that at baselines of 120 and 130 g per L, the $CuSO_4$ screening tests exhibit conservative false-pass rates similar in magnitude to the HemoCue procedure; only 1.9 percent of women and 1.3 percent of men who pass the $CuSO_4$ test have Hb levels less than 120 and 130 g per L, respectively, and should have been rejected as donors, indicating that, in practice, the current $CuSO_4$ cut-off levels can be tolerated. (The higher false-fail rates with the $CuSO_4$ test in Tables 2 and 3 are due to the higher cut-off settings.)

Tables 2 and 3 show that, had it been used in isolation, the HemoCue procedure would have classified 94.4 percent of women and 98.2 percent of men correctly at Hb levels of 120 and 130 g per L, respectively. Although this would appear to offer an improvement on the $CuSO_4$ test (set at 125 and 135 g/L for women and men, respectively), at present, the HemoCue procedure would be difficult to apply as a primary screening test on every potential donor because venous samples are preferred at our sessions. (HemoCue can be used on finger-prick blood, but capillary samples are known to give unreliable results[12,15] with all technologies and are thus unsuitable for secondary screening of blood donors.) Taking a venous sample from each person before donation could prove unacceptable to donors, slow down the donation process, as well as increase costs. Many studies have shown the excellent correlation between HemoCue and standard photometric methods in the laboratory,[14-18] and indeed we found the same in a prestudy evaluation of the analyzers used in this project. (In addition, HemoCue has a theoretic advantage over other photometric methods in that it incorporates a turbidity control, allowing more accurate results on lipemic samples.[2]) However, previous work has shown that accurate measurement of Hb level using the HemoCue system is difficult to achieve in the field.[19,20] There are several possible reasons for this; they include inadequate mixing of specimens,[19] sampling techniques, and operator performance,[20] rather than problems inherent to the methodology, and studies have shown that meticulous attention to sample mixing, mode of filling the cuvette, and continuous monitoring and training of staff can help to improve performance.[20]

Tables 1 through 3 show that the $CuSO_4$ and HemoCue screening tests are less accurate, compared with Beckman Coulter values, for women than men, with false-pass and -fail rates being higher for women than males. This has been recognized previously, and it was suggested that such differences in screening-test performance can be explained by the distribution of women and men donor Hb levels relative to the cut-off values for acceptance.[21] A comforting factor in our study, in spite of its relatively small sample size, is that the lowest false-pass levels were 109 g per L for women and 123 g per L for men. Although it was inappropriate to collect blood from such individuals by our current guidelines, these figures are not alarming; there were no clinical sequelae, as far as we are aware, in the donors, and the recipients would have obtained an adequate amount of Hb. The donors who had been inappropriately bled were contacted and informed.

The results of the "combined" screening procedures (Tables 2 and 3), which mimic current practice at donor sessions, respectively, show false-pass and false-fail rates of 2.7 and 2.4 percent, respectively, for women and 1.8 and 0.2 percent, respectively, for men. The false-pass rates for the combined procedure slightly exceed those for the HemoCue alone: 95-percent CIs for these differences in rate are approximately 1.6 and 0.8 percent for women and men, respectively. On the other hand, the false-fail rates on the combined procedures are slightly smaller than for HemoCue alone, with 95-percent CIs for these differences in rate of approximately 2.3 and 0.6 percent for women and men, respectively. It should be noted here that any false pass on HemoCue alone would also pass the combined procedure, regardless of the $CuSO_4$ test result. Consequently, the false-pass rate for the combined procedure must be at least as great as that for HemoCue alone.

In summary, compared with HemoCue alone, current practice trades off a slightly higher false-pass rate against a slightly lower false-fail rate, and so is still reasonable in spite of the error rates in the initial $CuSO_4$ screen, and they need not be changed until the problems of accurately measuring Hb in the field can be reduced or eliminated. Because approximately 2 million donations are collected annually in the UK, even small percentages of false passes and false fails at the Hb-screening stage represent a large number of individuals, and, consequently, any improvement in accuracy of Hb screening will be welcome.

ACKNOWLEDGMENTS

We thank HemoCue AB, HemoCue Ltd, and the staff at the Haematology Department, Northern General Hospital (Sheffield, UK) for their support; Mrs Diana Wood, Mrs Michele Titmuss, and Mrs Andrea Dixon for secretarial help; and all Trent Donor Session staff for making this study possible.

REFERENCES

1. van Slyke DD, Phillips RA, Dole VP, et al. Calculation of hemoglobin from blood specific gravities. J Biol Chem 1950;183:349-60.
2. Cable RG. Hemoglobin determination in blood donors. Transfusion Med Rev 1995;9:131-44.
3. Mollison PL, Engelfriet CP, Contreras M. Blood Transfusion in clinical medicine, 10th ed. Oxford: Blackwell Science, 1997:1-8.
4. von Schenck H, Falkensson M, Lundberg B. Evaluation of 'HemoCue', a new device for determining hemoglobin. Clin Chem 1986;32:526-9.
5. Zwart A, Buursma A, Kwant G, et al. Determination of total hemoglobin in whole blood: further tests of the 'HemoCue' method. Clin Chem 1987;33:2307-8.
6. Cochran WG. Sampling techniques, 3rd ed. Chichester: John Wiley and Sons, 1977:107-9.
7. Kish L. Survey sampling. Chichester: John Wiley and Sons, 1995:80-2.
8. Guidelines for the Blood Transfusion Services in the United Kingdom, 5th ed. London: The Stationary Office, 2001:26.
9. Boulton F, Collis D, Inskip H, et al. A study of the iron and HFE status of blood donors, including a group who failed the initial screen for anaemia. Br J Haematol 2000; 108:434-9.
10. Daae LN, Halvorsen S, Mathisen PM, Mironska K. A comparison between haematological parameters in 'capillary' and venous blood from healthy adults. Scand J Clin Lab Invest 1988;48:723-6.
11. Newman B. Very anemic donors may pass copper sulfate screening tests (Letter). Transfusion 1997;37:670-1.
12. Boulton FE, Nightingale MJ, Reynolds W. Improved strategy for screening prospective blood donors for anaemia. Transfus Med 1994;4:221-5.
13. Dhingra-Kumar N, Kela K. $CuSO_4$ gravimetric method for Hb screening of prospective donors—should it be discarded (Letter)? Transfus Med 1997;7:245-7.
14. Rushambuza FG, Martlew VJ, Innis M, et al. HemoCue haemoglobin estimation on venous blood samples of donors who fail the copper sulphate screening tests leads to the gain of many units which would otherwise have been lost (Abstract). Transfus Med 1998;8(Suppl 1):41.
15. Rushambuza FG, Martlew VJ, Innis M. Accuracy of HemoCue venous blood haemoglobin estimations at blood donor sessions (Abstract). Transfus Med 1998;8(Suppl 1):41.
16. Stivala JFA, Vickers MV, Dowuona-Hammond A, et al. A local quality assessment scheme for haemoglobin screening at donor sessions (Abstract). Transfus Med 1992;2(Suppl 1):54.
17. Prakash S, Kapil U, Singh G, et al. Utility of HemoCue in estimation of hemoglobin against standard blood cell counter method. J Assoc Physicians India 1999;47:995-7.
18. Rosenblit J, Abreu CR, Szterling LN, et al. Evaluation of three methods for hemoglobin measurement in a blood donor setting. Sao Paulo Med J 1999;117:108-12.
19. Neville RG. Evaluation of portable haemoglobinometer in general practice. Br Med J (Clin Res Eds) 1987;294:1263-5.
20. Boulton F, Purandare A, Cappleman J, et al. Hb determination by HemoCue at donor sessions—reliability of performance (Abstract). Transfus Med 2001;11(Suppl 1):45.
21. Ross DG, Gilfillan AC, Houston DE, et al. Evaluation of hemoglobin screening methods in prospective blood donors. Vox Sang 1986;50:78-80.

(13)

原　著

短期間の術前自己血貯血法の検討

北野　満・芦田　敦生・岡　藤博

はじめに

医療レベルの向上に伴いその質が問われる現在，手術における同種血輸血の回避は患者の当然の選択肢となりつつある。心大血管手術においては，早くから多くの施設が積極的に自己血輸血を導入することにより，無輸血達成へ向けて努力している。無輸血達成率は自己血貯血量および貯血期間に比例するのは周知の事実である。しかし心大血管手術においては，長期の待期期間を設けられる場合がそれほどなく，術前の長期入院や通院も患者の負担が大きい。そこで当科では可及的に貯血期間を短縮し，貯血量を最大限に準備できる方法として，術前8日からの貯血開始を基本的に施行してきた。今回この貯血法を施行した186例を貯血期間が9日以上であった群と7日以下であった群とで比較検証し，また同種血輸血に至った例と無輸血例とを要因別に比較し，その成績と限界について検討した。

対象・方法

当科で1996年9月から2003年2月までに人工心肺を使用した心大血管手術例は427例であった。そのうち自己血貯血を施行したのは258例で，すべての人工心肺使用例中60.4％，全待期手術中73.5％あった。対象手術は冠動脈バイパス術，弁膜症手術，胸部大動脈瘤手術，先天性心疾患手術，その他であった。自己血貯血の適応は，原則として年齢が80歳以下で入院時Hbが10.0 g/dl以上の待期手術としており，非適応は感染性心内膜炎患者，透析患者，高度心不全患者，左主幹部病変を伴う不安定狭心症患者としている。貯血は全例入院中としている。自己血採血のプロトコールは，毎回採血前にHb値を測定し，10.0 g/dl以上であれば1週間ごとに400 ml採血している。保険適応内であればエリスロポエチン製剤（EPO）を6,000単位静脈投与を隔日投与，もしくは24,000単位の皮下注投与を隔週に投与した。また，鉄剤としてフマル酸第一鉄305 mgを毎日内服投与した。ここで論ずる貯血期間とは，初回自己血貯血開始日より手術前日までの日数とした。待期手術の患者は8日前に入院し，入院日に400 mlの貯血を行い，1週間後の手術前日にも400 ml貯血する（EPO投与は皮下注の場合は初回の1回のみ，静注の場合は計3回投与となる）という貯血法を186例に施行した（M群）。準緊急手術症例や心房中隔欠損症などの軽症例では貯血期間が7日以下で，400 mlのみの貯血で手術に臨み，これらは44例であった（S群）。術前の精査などで術前8日以前より入院可能であった患者においては，手術が決定した時点から貯血を開始した。このような症例で9日以上の貯血期間が得られたのは28例であった（L群）。これらの3群の無輸血率を比較するとともにM群において同種血輸血に至った例と無輸血例を性差，年齢，体重，EPO使用量，入院時Hb値，手術直前Hb値，人工心肺時間，手術時間，術式についておのおの要因別に比較した。検討において，

市立長浜病院心臓血管外科

術後から退院まで同種血輸血を施行しなかったものを無輸血例とした。手術時は全例回収洗浄式自己血輸血装置を用い，術後約12時間はドレーン排液も回収した。人工心肺は無血体外循環で手術終了時回路内血液を返血した。各群の数値は平均値±標準偏差で表し，統計学的検定はstudent-t，χ^2，分散分析を用い，p値＜0.05を有意差ありとした。

結果

各群の手術術式の内訳，およびその無輸血率は表1に示した。冠動脈バイパス術に貯血期間が短い傾向がみられたが，手術を急ぐ必要のある例が多かったためと思われた。おのおの3群間に有意差は認めなかったが，冠動脈バイパス術の無輸血率が低く，貯血期間の短い群にその傾向が強かった。各群の性差，年齢，体重，貯血期間，総貯血量，EPO使用量，入院時Hb値，手術直前Hb値，人工心肺時間，手術時間，無輸血率を表2，表3に示した。S群の貯血期間は1～7日，平均5.5±1.6日で，L群が9～28日，平均15.8±5.6日であった。総貯血量はM群で400～800 ml，平均770±103 ml，S群がすべて400 ml，L群が800～1,600 ml，平均1,029±249 mlであった。性差，

表1　対象手術と無輸血率

術式	例数			無輸血率		
	M群	S群	L群	M群	S群	L群
CABG	72 (63.7%)	29 (25.7%)	12 (10.6%)	72.2%	55.2%	91.7%
VD	76 (78.4%)	8 (8.2%)	13 (13.4%)	90.8%	87.5%	92.3%
TAA	14 (87.5%)		2 (12.5%)	78.6%		100 %
CHD	12 (63.2%)	7 (36.8%)		100 %	100 %	
その他	12 (92.3%)		1 (7.7%)	66.7%		100 %

CABG:冠動脈バイパス術，VD:弁膜症手術，TAA:胸部大動脈瘤手術
CHD:先天性心疾患手術

表2　対象群の比較1

	例数	性差 (M/F)	年齢 (years)	体重 (Kg)	貯血期間 (days)	総貯血量 (ml)	EPO投与量 (×1000 IU)
M群	186	119/67	63.1 ± 12.9	56.3 ± 9.1	8.0 ±0.0	770 ±103	20.9 ± 5.9
S群	44	28/16	62.7 ± 10.4	57.3 ±10.9	5.5 ±1.6	400 ± 0	3.8 ± 7.4
L群	28	18/10	61.6 ± 9.1	59.6 ± 9.6	15.8 ±5.6	1029 ±249	29.4 ±15.3

表3　対象群の比較2

	入院時Hb (g/dl)	手術直前Hb (g/dl)	人工心肺時間 (min.)	手術時間 (min.)	無輸血率	p value
M群	13.0± 1.4	11.0± 1.4	114 ± 70	246 ± 124	81.7%	0.047*
S群	12.9± 1.7	11.4± 1.4	99 ± 49	242 ± 155	68.2%	
L群	13.5± 1.3	11.2± 1.4	109 ± 35	223 ± 53	92.9%	0.231

年齢，体重，入院時Hb値，手術直前Hb値，人工心肺時間，手術時間において3群間に有意差は認めなかった。M群の無輸血率は81.7%で，S群の68.2%と比べ有意に高く（p=0.047），L群の92.9%と比べ低いものの有意差はなかった。M群において同種血輸血例と無輸血例を，性差，年齢，体重，貯血量，EPO使用量，入院時Hb値，手術直前Hb値，人工心肺時間，手術時間の各要因で比較したところ（表4），年齢，体重，入院時Hb値，手術直前Hb値，人工心肺時間，手術時間において有意差を認めた。M群の内で，2回目の採血前にHb値が10.0 g/dl以下，もしくは全身状態不良，採取困難な例で800 ml貯血できなかった例は15例（8.1%）あり，その無輸血率は66.7%と低い傾向にあったが，800 ml貯血例の無輸血率と有意差は認めなかった。また，術後出血再開胸や再手術を施行した例は9例あり，その無輸血率は44.4%と有意に低かった。術式では冠動脈バイパス術と弁膜症手術を比較すると前者で無輸血率が有意に低値であった（表5）。なお，全例において自己血廃棄例はなかった。

考察

心臓血管外科領域においては，他の領域に先がけて早くより同種血輸血回避に対する努力が試みられ，年々手術成績が向上するに伴い無輸血手術に対する関心は広がりつつある。無輸血達成へのもっとも効果的な方法として，術前貯血式自己血輸血が施行されるようになり[1]，人工心肺を使用する心大血管手術においては，現在ほぼ一般的な手法とされている[2]。しかしその適応や貯血期間

表4　M群における輸血例と無輸血例の要因別比較

要因		輸血例	無輸血例	P値
男女比	(M/F)	17/17	102/50	0.060
年齢	(years)	69.4 ± 8.2	61.7 ± 13.3	0.002 *
体重	(Kg)	51.7 ± 8.5	57.3 ± 9	0.001 *
貯血量	(ml)	741 ± 144	777 ± 91	0.067
EPO使用量	(×1000IU)	21.9 ± 4.6	20.6 ± 6.1	0.269
入院時Hb	(g/dl)	12.5 ± 1.5	13.1 ± 1.4	0.032 *
手術直前Hb	(g/dl)	10.0 ± 1.1	11.2 ± 1.4	<0.001 *
人工心肺時間	(min.)	173 ± 123	101 ± 42	<0.001 *
手術時間	(min.)	381 ± 211	216 ± 64	<0.001 *

表5　M群における無輸血率に影響する因子

	例数	輸血例	無輸血率	p value
800ml未完遂	15 (8.1%)	5	66.7%	
800ml完遂	171 (91.9%)	29	83.0%	0.221
再開胸(+)	9 (4.8%)	5	44.4%	
再開胸(-)	177 (95.2%)	29	83.6%	0.012 *
冠動脈バイパス術	72 (38.7%)	20	72.2%	
弁疾患手術	76 (40.9%)	7	90.8%	0.003 *