血行動（献血回数、献血場所、最近1年間の献血回数など）、献血に対する態度・イメージなど29項目である。

解析はSPSS 12.0J for Windowsを用いて行い、有意水準は0.05とした。

（倫理面への配慮）

本研究は、個人を特定することなく献血に伴う副作用情報を分析するとともに、献血者の貧血情況を測定するものであり、貧血検査については献血の際の同意事項であるため倫理上の問題は生じない。また、データの取り扱いについては「疫学研究に関する倫理指針(文部科学省・厚生労働省平成17年6月29日)」を遵守している。

C．結果

C－1．献血者の年令基準見直しに関する基礎的検討

17歳献血者への400ml全血採血の導入した場合の全血献血者の採血不適格者は、17歳男性の献血受付者数34,816名中、献血不適格者数は5,050名（14.5%）であり、17歳女性も献血受付者数53,188名中、献血不適格者数は20,728名（39.0%）と他の年代と比較して高い傾向が認められた。項目別に見ても、Hb不足（Hb値が基準値未満）、血圧、服薬、問診項目1（献血の永久不適項目に該当）、問診項目2（今回の献血は不可と判断される項目に該当）、事前検査、その他の全ての項目での不適格者数が他の年代と比較して高かった。

200ml全血献血者の年齢階層別副作用発生状況では、17歳男性の副作用発生率は1.19%であり、18～29歳の2.39%と比較して低い値であった。（18 19歳男性の副作用発生率は1.95%、2.79%）17歳女性の副作用発生率は1.75%であり、18～29歳の1.37%と比較すると高かったが、18歳、19歳の1.75%、1.81%との比較ではほぼ同等の値であった。

17歳に400m全血献血を導入した場合の献血人数(量)の増加の見込みであるが、平成18年度に200ml全血献血者を行なった17歳献血者のうち、どの程度が400ml全血献血の基準（体重、Hb値）を満たすかを調べた。17歳男性では29,765名中、400ml全血の献血基準（体重50Kg以上、Hb量12.5g/dl以上）を満たすのは28,961名（97.3%）であり、17歳女性では32,460名中、17,723名（54.6%）が体重・Hb量の両方の基準を満たすと推定された。

上記の献血者が全て400ml献血を行った場合には、年間に200ml献血換算で46,684名分（男性28,961名、女性17,723名）の献血量の増が見込まれるが、これは平成18年度の全血（200ml）換算総献血量6,378,490名の0.73%（男性0.45%、女性0.28%）に相当した。

全血献血の上限年令の見直しについては全血献血の献血不適格状況を見ると、男性におけるHb不足の比率は50代が0.19%、60～64歳は0.42%、65～69歳は0.69%と年令が増すとともに上昇する傾向があり、特に68歳・69歳のHb不足の率は0.93%、1.25%と高い値を示している。他の不適格項目の率は50代、60代で特に高い傾向はなかった。また、女性の50代、60代献血者の献血不適格者数は他の年代と比較して同等以下であった。200ml献血時の副作用発生状況、及び400ml献血時の副作用発生状況を見ると、男性では50代、60代献血者の発生率は他の年代と比較して低く、女性でも同様に50代、60代献血者の副作用発生率は他の年代と比較して低くかった。

全血の献血者数、献血率とも60歳から減少傾向を示している。そこで献血率と（男女計）と年齢についての回帰直線を求めたところ、200ml献血では、$Y=-0.04X+2.93$（$R^2=0.96$）、400ml献血では、$Y=-0.15X+10.61$（$R^2=0.97$）の式で表される負の相関関係が認められた。この回帰直線を用いて、全血献血の年齢基準の上限を74歳まで引き上げた場合の献血率についてシミュレーションを行なった。200ml献血では70歳で0.13%の献血率が73歳までに0.01%まで減少し、400ml献血では70歳は0.10%であるが

71歳で0.01%まで減少すると予測された。

血小板成分献血の上限年令の見直しについては、成分献血の受付者における献血不適格者状況を見ると、男性ではHb不足の率は、50～54歳で0.84%、54～59歳で1.12%、60～64歳で1.59%、64～69歳で1.69%と年齢を増すごと不適格の率も増加する傾向が認められたが、女性では50代・60代のHb不足の率は他の年代と比較して高くはなかった。

血小板成分献血（PC）を行なっている献血者の副作用の発生率は50～54歳の副作用発生率は男女とも他の年代と比較して同等以下であった。また、血漿成分献血（PPP）を行なっている献血者の副作用発生率を見ても男女とも50～69歳の副作用発生率は他の年代と比較して同等以下であった。

血小板成分献血の上限年令を現行の54歳から59歳迄延長した場合に献血者がどの程度増加するかをシミュレーションしてみた。年齢階層別の血小板成分献血者数は男女とも年齢を増すごとに献血者数が減少する傾向が認められている。45歳から54歳の間で、血小板献血者数（男女計の延べ人数）と年齢の関係について見てみると、$Y=-992.69X+65090.20$（$R^2=0.98$）で示す負の相関関係が認められた。

この回帰直線を用いて、血小板献血の上限年齢を現行の54歳から59歳まで引き上げた時に増加する献血者数を推定してみると、年間に45,534名の献血者の増加が見込まれ、これは18年度の総血小板成分献血者数775,148名の5.49%に相当人数であった。

また、全国7地域の血液センターで、現在血小板成分献血に協力をしている50歳～54歳の献血者を対象として血小板献血の上限年齢の見直しに関するアンケート調査を行なった。施設別の調査例数は　北海道188名、宮城県73名、東京都182名、愛知県123名、大阪府219名、岡山県177名、福岡県158名であり、合計は1130名であった（男性739名、女性391名）。年齢分布は50歳260名、51歳197名、52歳205名、53歳231名、54歳237名であった。

満54歳を越えてからの血小板献血については、男性で682名（92.3%）、女性で358名（91.6%）から今後も協力したいとの回答があった。血小板献血の上限年齢は54歳迄です。献血年齢の上限を引き上げについては、男性で661名（89.4%）、女性で337名（86.2%）から賛成の回答が得られたが、わからないとの回答も男性で68名（9.2%）、女性で47名（12.0%）あった。さらに賛成の場合、何歳までが適当と考えるかについては、男性では65歳未満との回答が225名（30.5%）最も多く、次いで60歳未満が207名（28.0%）であり、上限なしの回答は113名（15.3%）あった。女性では60歳未満との回答が153名（39.2%）と最も多く、次いで65歳未満が74名（18.9%）、上限なし41名（10.5%）の順であった。献血基準の見直しに関する意見は、「年齢に関係なく健康ならば献血可能」、「個人差があるので一律の年齢基準の設定は難しい」などの意見が多かった。献血基準の見直しに反対の意見は、3件あり、2件では（女性）血小板献血を行なった際に調子が悪くなったことを理由としていた。

C－2．血液比重による採血適否判定とHb簡易測定値との関係について

比重測定1.052以上1.053未満を示し、400mLから200mLに変更した献血者の簡易Hb平均値と標準偏差値は、男性12.6±0.8 g/dL、女性12.4±0.6g/dLで、現行の200mL採血基準のHb12 g/dL以上とほぼ合致する範囲であった。

簡易測定Hb値と検査課測定Hb値との関係については、愛知Cでは、検査課での血球計算測定はXE-2100を使用し、4℃保存で採血翌日（約24～32時間後）に測定している。簡易測定法と同時に測定したものではないため、検査課測定値は参考データにとどまるが、簡易Hb値は検査課機器と比較して、平均値で男性0.4、女性0.3 g/dLそれぞれ低い値を示していた。相関係数は、男性は0.923と「非常に強い相関」を示したが、女性で

は0.877と「やや強い相関」の結果であった。

献血申込者の簡易Hb値分布は、平均と標準偏差値は、男性14.9±1.1g/dL、女性12.7±1.1 g/dLであった。男性で13.0 g/dL未満は3.6%、女性でHb12.5g/dL未満は37.9%であった。

血液比重判定による男性献血者の簡易Hb値分布を求めたが、男性の200mL献血者数は582人（5.3%）で、10代の占める比率が高い。400mL献血は採血基準により、男女ともに比重測定法で1.053（Hb測定法で12.5g/dL）以上と定められている。　400mL男性献血者では、Hb簡易測定値で13.0g/dL未満は241人、逆に比重測定法で1.053未満と判定しHb13.0g/dL以上は139人存在した。Hb簡易検査法に切り替え、判定基準値を13.0g/dL以上に設定すると、1.04%の減少が予測された。一方、血液比重判定による女性献血者の簡易Hb値分布であるが、400mL女性献血者では、比重測定にて1.053以上で、Hb簡易測定値12.5 g/dL未満は10.2%（310人）含まれていた。逆に比重測定では1.053未満で、Hb12.5g/dL以上を示した400mL献血希望者は269人であった。Hb簡易測定法に切り替え、判定基準値（Hb12.5g/dL以上）現行継続とした場合、41人（1.44%）の減少が予測された。

男性≧13.0、女性≧12.5g/dL設定時の年代別採血不適率は、男性400mL献血希望者ではHb≧13.0g/dLとした場合、年代とともに不適率が上昇し、50代（6%）、60代（11.2%）で高く、全体では3.5%が不適となった。200・400mL同一判定基準を設定すると、200mL希望男性の6.7%が不適となった。女性に対し、200・400mL同一判定基準（Hb≧12.5g/dL）を設定すると、10代～40代の不適率が高く、女性全体として400mL希望者で35%、200mL希望者で42.6%が不適となった。

献血申込者の簡易Hb値最高値は男性20.0 g/dL、女性18.7 g/dLであった。Hb上限値の設定について、臨床的に精査が必要とされる数値*を参考として男性19 g/dL以上、女性17 g/dL以上を設定した場合、不適率は男女ともに0.08%であった。

総蛋白量については、今回の検討対象者では、血中蛋白量が血液比重による適否判定に影響したと考えられる例は認めなかった。

C－3．医学生の献血に対する意識調査

299名から回答を得た。内訳は1・2年96名（男72名、女24名）、3・4年113名（男65名、女48名）、5・6年90名（男59名、女30名、不明1名）であった。

現在までの献血回数が1回以上であると回答したものは105名（35%、n=299）であった。また、最近1年間に1回以上献血したと回答したものは45名（15%、n=296）であった。

将来の献血状況予測であるが、今後献血に協力する意向については、1年以内に絶対献血すると回答したものが31名（11%、n=289）であった。

回帰分析によって献血経験者ならびに未経験者の献血行動に関連する要因のモデルを作成したところ、経験者では「ここ1年間で何回献血しましたか」、「献血を続けることを止めようと考えたことがありますか」、「仮に献血する気持ちになった場合、確実に実行できると思いますか」の3項目、未経験者では「あなたにとって、献血は義務の1つですか」、「呼びかけられても献血しなかったとき、そのことを後悔することが多いですか」、「仮に献血する気持ちになった場合、確実に実行できると思いますか」、「問27. 近年、献血者数は増加していると思いますか、減少していると思いますか」の4項目で「今後献血に協力する気持ちはありますか」との間に有意に相関が見られた。

D．考察

若年者の献血基準であるが、欧米ではGoldmanらの報告によると16歳または17歳が下限と見受けられる。そこで、現在は200ml全血献血に限定されている17歳に400ml全血採血の導入をした場合に見込まれる増加率を調べたところ、全血総献血人数の0.75%（男性0.45%、女性0.28%）に相当する増加が見込まれている。なお、0.75%の増加は、平成18年度17歳の献血率4.7%に基づき試算したものであり、17歳の献血率が平成18年度の18・19歳の献血率の9.2%、9.9%により近づくならば、17歳献血者の占める比率は更に高くなることが考えられる。17歳の献血率が4.7%に留まっている要因の一つは、輸血用血液製剤の医療機関における需要の多くが400ml全血由来の製剤に移行し、200ml全血由来の血液製剤の需要が低下していることが考えられる。今後、若年者の献血推進（特に17歳）を進めて行くには、需要と供給のアンバランスが発生させない為にも17歳献血者に400ml全血献血を導入していくことが必要と考える。献血不適格者数は16歳、17歳が他の年代と比較して全ての項目で高値であったのは、初回献血者がこの年齢で多いことに起因すると考える。副作用の発生は若年者で高いといわれているが[1]、200ml献血時のVVR軽症例の発生頻度は17歳男性では1.05%であり、18歳～29歳の2.14%よりは低く、30代の1.01%とほぼ同等であった(18歳1.76%、19歳2.23%)。また、17歳女性の200ml献血時のVVR軽症例の発生頻度1.35%は、18歳～29歳の1.09%および他の年代と比較するとやや高い値であったが、18歳、19歳の1.39%、1.47%と違いはなった。

次に、全血献血の年齢の上限基準の見直しであるが、欧米では国により基準は異なり64歳から上限設定無しまで様々である。もし、本邦で74歳まで献血の上限年齢を引き上げた場合に見込まれる献血者数は年間6,573名で、全血総献血数の0.11%に限られることがわかった。これはカナダが2004年に献血の上限基準を見直した時に0.27%献血者が増加したとのGoldman報告[2]と比較しても低い値である。男性の68歳、69歳の献血者のHb不足の率が高値を示していることは、70歳以上の献血者が継続して全血採血を行なえるかの重要なポイントと考える。阿部らの報告では、赤血球系は70歳以降より急速に造血機能が低下し、骨髄有核細胞数が減少、脂肪髄の増加が認められるが、これらの年齢では日常生活活動能（ADL）の違いによりHb値は大きく異なるとしている。献血者は基本的にADLが高い母集団と考えられるが、現行採血基準で全血献血を行なっている65歳以上群のHb分布を調査し、他の年代と比較することも必要と考える。

血小板献血の上限年齢は54歳であるが、欧米では血小板成分献血の年令基準は全血献血の上限年齢を準用しており、採血の可否判定は検診医の判断に委ねられ、わが国より上限が高く設定されている。

そこで、現行の54歳の上限年齢を59歳に引き上げた場合に増加する献血者数を推定してみると、5.49%の血小板成分献血者数の増加に繋がる事がわかった。また、現在50歳～54の血小板成分献血者を対象として実施したアンケート調査では、90%以上の方は今後も血小板成分献血に協力すると回答し、85%以上の方が血小板献血の上限年齢は見直に賛成との回答が得られている。なお、血小板献血者数を年代別に見ると、男女とも年齢を増すごとに献血者数は減少しており、50～54歳の献血者は比較的献血に理解のある方が多く、そのことがアンケート結果に反映されているとも考えられる。今後は30代、40代の血小板献血者を対象としたアンケートも実施し、広い年代の意見をとりまとめることも必要と思われる。　50代以上の成分献血者のHb不足の率が高い点であるが、愛知県赤十字血液センター古田らは[4]、頻回の成分献血者で比重落ちの率が高いと報告している。成分献血時の事前採血の検体量や成分献血に用いるデスポーザブルキット内の残血などが要因の一つと考えられるが、成分献血を行なっている献血者の年代別のHb分布を調査し、年齢の要因が関与しているか否かを明確にすることは必要であろう。また、今回の集計結果ではVVRを含め、50代以上の献血者副作用の発生頻度は血小板・血漿献血ともは他の年代と比較して同等以下の率であったが、埼玉県赤十字血液センター溝口らは中年女性が血漿献血でVVRを発生した場合は回復が遷延する例を多く認めると報告している。高齢者の血小板献血におけるVVR回復時

間を調査し、回復時間の遷延の有無を確認しておくことも必要であろう。

血液比重による採血適否判定とHb簡易測定値との関係についてであるが、血液比重測定法と簡易Hb測定法はともに、手技を正しく行えば採血基準に従った適否判定に有用な手法と言える。H17年に実施された簡易Hb測定機器評価試験で、検査課自動血球計数装置の測定値と比較して平均値がやや低いことが確認されている。今回の検討は、同一検体を24～32時間後に検査課機器**で測定したHb値であるが、簡易Hb値は平均値で男性0.4、女性0.3 g/dLそれぞれ低い値を示していた。簡易Hb測定機器の誤差は±0.3 g/dLとされており、採血基準を下回る献血者からの採血が防止できる設定である。

Hb測定法への切り替えに伴い、現行基準値は健常男性のHb値と比較して低いことから、基準値を12.5から13.0 g/dLにひき上げた場合の採血予測を行ったところ、比重測定値1.053以上の判定時に比べ1.04%の減少が予測された。女性ではHbを現行基準と同じ12.5 g/dLと設定し、比重測定による判定と比較すると1.44%の減少が予測された。女性において、簡易Hb測定機器導入で献血者予測が減少する理由として、測定機器が本来のHb値よりやや低めに表示するよう設定されていることも影響していると思われる。

200mL採血数は減少傾向（H18年：200mL 26%、400mL 74%）にある。受血者にとり供血者数は少ないほうが望ましく、200mL採血は小児の輸血用に限定して採血している施設もある。200mLの採血基準を400mLと同一基準にひきあげた場合、200mL採血比率の低い九州地区ではほとんど影響がないと思われる。しかし、400mL確保に苦慮している地域では、冬季の献血者減少時期など採血計画の変更が必要となる可能性がある。Hb基準値の引き上げについては、今後予期しない感染症の流行や、供血者選択に新たな制限が加わる事態発生時などの血液確保も考慮して、検討されるべきであろう。

血液比重測定法は、基準値を満たすかどうかに限定した判定であるが、簡易Hb測定法では基準をはずれた献血申し込み者に対し、個々の状態に応じた健康指導が可能となる。Hb簡易測定機器導入後は、この利点を生かした健康指導体制も望まれる。

医学生の献血に対する意識調査であるが、今回の調査では35.1%（95%信頼区間29.9～40.7%）が献血をしたことがあるという結果となった。過去に行われた調査によると、19～29歳で献血経験のある人の割合は42.8%であり、この数値と比較すると本学医学生の献血経験者率は有意に低いことがわかる（$p<0.05$）。年齢が上がるにつれて献血経験の機会が増えると考えると、本学医学生の献血経験者率の低さは、回答者の平均年齢が22.3歳と若いことによるものだと推測できる。

一方、1年間の献血率（最近1年間に献血した人数を母集団の人数で除した数値）は15.2%（95%信頼区間11.6～19.7%）であった。日本赤十字社によると平成18年度の20～29歳の献血率は7.6%であり[1]、平成19年度もこの数値が維持されると仮定すると、医学生の献血率は一般の献血率に対して有意に高いと言える（$p<0.05$）。

また、今後の献血状況に関しては、「1年に以内に絶対献血する」と回答した10.7%（95%信頼区間7.6～14.8%）の人が必ず献血すると仮定し、平成18年度の20～29歳の献血率が平成20年度も維持されると仮定すると、平成20年度も本学医学生の献血率は一般よりも有意に高くなると考えられる（$p<0.05$）。

では、本学医学生の献血率が高い理由は何なのであろうか。調査票の分析の結果、最近1年間に献血した45名のうち19名（42%）が初めて献血をしており、この19名のうち14名（73.7%）が主な献血場所として「大学の献血バス」と回答していることや、最近1年間に献血した45名のうち17名（37.8%）が「1年以内に絶対献血する」、16名（35.5%）が「1年以内に献血するつもりでいる」と回答していることが分かった。これらのことから、本学医学生の献血率の高さは、献血経験者が継続的に献血することに加え、毎年10月に開催される大学祭での献血バスの活動による初回献血者確保によって維持されていると推測することができる。

これまでの考察から、本学医学生は「献血経験者率は低いが献血意志は高く、1度献血すると継続する可能性

が高い」という特徴を持つ集団であり、新規の献血者確保のための重要なターゲットとなり得ると結論づけることができる。

今後実際に医学生に対して献血のプロモーションを行う場合には、今回の調査結果で作成した献血意志関連モデルを参考にすると良い。未経験者のモデルでは、「あなたにとって、献血は義務の1つですか」、「近年、献血者数は増加していると思いますか、減少していると思いますか」が「規範意識」、「呼びかけられても献血しなかったとき、そのことを後悔することが多いですか」が「献血に対する態度」、「問25. 仮に献血する気持ちになった場合、確実に実行できると思いますか」が「統制感」とそれぞれのカテゴリーに入っており、TRAあるいはTPBの理論が当てはまることがわかる。一方、経験者のモデルはTRAやTPBの理論とは一致せず、「継続的に献血をしており、前回の献血でネガティブなイメージを持たず、特に阻害要因がなければ献血経験者は継続的に献血を行う」という構造になっていることがわかる。

よって、未経験者に対してはTRAおよびTPBの理論に基づいた戦略を、経験者に対しては「毎回の献血で悪いイメージを持たせないこと」を念頭においた戦略を採ると良い結果が得られると考えられる。また、初回献血者の確保に関しては献血バスが大きな効果を持っていることも考慮すべきである。

E．まとめ

年齢基準の見直しで多くの献血者の増加が見込まれることから、血小板成分献血の上限年令(現行54歳)の見直しを第一優先のテーマとして検討を進めるべきである。次に17歳女性400ml全血献血でのデータ収集が今後の課題となる。全血献血の上限年令の見直しについては、増加が見込まれる献血者数は少なく、60歳以上で比重落ち率が増加していることを考慮すると、研究の優先順位は低いと考えられる。

献血経験や意識に関する医学生調査では、献血経験者率は低いものの、献血率・献血意志は高い集団であり、献血プロモーションによる効果は十分得られることが示唆された。また、プロモーションの際には献血経験の有無によって異なる戦略を採ることが望ましいことも明らかにされた。

F．健康危険情報

特になし

G．研究発表

1. 論文発表

予定あり

2. 学会発表

予定あり

H．知的財産権の出願・登録状況

(予定を含む)

1. 特許取得

特になし

2. 実用新案登録

特になし

3. その他

特になし

Vasovagal reactions in high school students: findings relative to race, risk factor synergism, female sex, and non-high school particpants

B.H. Newman

BACKGROUND: High school (HS) students have a high incidence of vasovagal reactions and are a good population for the study of vasovagal reactions.
STUDY DESIGN AND METHODS: Data from 1076 Caucasian students, 226 African-American students, and 157 nonstudents from HS blood drives in 2001 were entered into a database. Race, high-risk-factor synergism, the phenomenon of "survivorship," and female sex were evaluated. In addition, non-HS student participants were described.
RESULTS: Vasovagal reactions were 84 percent lower in African-American HS students than in Caucasian HS students (3 of 226 vs. 88 of 1076; 1.3 vs. 8.2 percent; $p = 0.0001$; relative risk, 6.2). In Caucasian HS students, first-time donor status increased the vasovagal reaction rate to 9.4 percent (vs. 3.6% in repeat donors, $p < 0.004$). Low weight ($\leq$ 130 lb) increased the reaction rate to 13.6 percent (vs. 3.3% in weight > 81.2 kg, $p < 0.001$). Together they increased the reaction rate to 16.0 percent (vs. 3.2%, $p < 0.0001$). Females had more reactions than males (11.3 vs. 4.8%, $p < 0.001$), but the reaction rates equalized when donors under 150 lb were excluded (5.7 vs. 4.6%, $p = 0.66$).
CONCLUSION: African-American HS students had a significantly lower vasovagal reaction rate than Caucasian HS students. There was synergy among high-risk factors in Caucasian HS students. Female and male vasovagal reaction rates were similar when low-weight donors were excluded.

High school (HS) blood donors are young, frequently donate for the first time, and have a high incidence of vasovagal reactions. The high vasovagal reaction rate, which ranges from 8 percent to 11 percent,[1] makes them a unique population in which to study vasovagal reactions.

The following issues or questions were addressed in the present study. 1) Past studies have alluded to the possibility that African-American blood donors have fewer vasovagal reactions than Caucasians.[2,3] This study quantified the risk of a vasovagal reaction in Caucasian and African-American HS students. 2) Several measurable risk factors such as youth, low weight, and first-time donation status are associated with an increase in vasovagal reactions.[4-7] This study measured these risks and evaluated the degree to which they are additive. 3) Two recent studies reached different conclusions as to whether female sex increased the vasovagal reaction rate. One study found that confounding factors such as lower weight explained the higher vasovagal reaction rate in females,[7] while another study, although unpublished, found that female sex by itself was a risk factor (N.R. Haley, written communication, September 2000). This study addressed this question by evaluating female and male vasovagal reactions in four weight groups, which in a stepwise fashion eliminated lower weight donors. In addition to addressing these issues or questions, the study also evaluated non-HS participants to determine the extent of their participation, their demographics, and their vasovagal reaction rate.

ABBREVIATIONS: HS = high school; RR(s) = relative risk(s).

From the American Red Cross Blood Services, SE Michigan Region, Detroit, Michigan.

Address reprint requests to: Bruce H. Newman, MD, Medical Director, American Red Cross Blood Services, SE Michigan Region, 100 Mack, Detroit, MI 48201; e-mail: newmanb@usa.redcross.org.

Received for publication May 22, 2002; revision received July 9, 2002, and accepted July 10, 2002.

TRANSFUSION 2002;42:1557-1560.

MATERIALS AND METHODS

Phlebotomy

HS blood donations were collected on-site at Detroit metropolitan high schools. The donors were screened using a 40-question questionnaire, a mini-physical exam consisting mainly of vital signs, and a Hb-screening test. Accepted blood donors were subjected to a whole blood phlebotomy and collection of additional blood samples, which together did not exceed 535 mL. Blood donors rested on the donor bed after donation and were advised to spend 10 minutes at the refreshment site. All vasovagal reactions were recorded on the blood donor record, and an additional report was submitted if syncope occurred.

Data collection

Data from 1076 Caucasian HS students, 226 African-American HS students, and 157 nonstudent participants taken from randomly chosen Caucasian and African-American HS blood drives in 2001 were entered into a database (Excel 1997; Microsoft Corporation, Seattle, WA). The data entered consisted of the donor's age, race, sex, self-reported weight, blood donation status (first-time or repeat donation), a unique unit whole blood number, and the donor's reaction status. In addition, blood pressure results from 100 randomly selected Caucasian students were compared with 100 randomly selected African-American students.

Statistical analysis

Two-by-two contingency tables and a two-tailed Fisher Exact test were used to determine p values and relative risks (RRs) with 95 percent CIs. $p < 0.05$ was considered to be significant.

RESULTS

Demographics

Table 1 identifies the demographics of Caucasian and African-American HS students and nonstudent participants. Caucasian and African-American HS students were similar for mean donor age, percentage of females, percentage of first-time donors, and percentage of donors who weighed no more than 130 lb, but African-American HS students weighed slightly more (166 vs. 157 lb).

Nonstudent participants were 10.8 percent of the total number of participants. In comparison to HS students, they were significantly older (mean age, 44 vs. 17 years), had a lower first-time donor rate (9 vs. 79%-82%), weighed significantly more (180 vs. 157-166 lb), and had a lower percentage of donors under who weighed no more than 130 lb (10 vs. 22%–24%).

Comparison of vasovagal reaction rates

The vasovagal reaction rate was 8.2 percent (88 of 1076) in Caucasian HS students versus 1.3 percent (3 of 226) in African-American HS students ($p = 0.0001$; RR, 6.2; 95 percent CI, 2.0-19.3) versus 1.3 percent (2 of 157) in nonstudent participants ($p < 0.0004$). Eight syncopal reactions occurred in the Caucasian HS students, and none occurred in the other two groups ($p = 0.34$ with African-American students). Blood pressure results in Caucasian and African-American HS students were compared as a potential cause for the vasovagal reaction rate difference between the two groups. Table 2 shows a comparison of blood pressures in 100 randomly selected Caucasian HS students and 100 randomly selected African-American HS students. The differences were not significant.

Additive effects of high-risk factors in Caucasian HS students

The additive effects of risk factors could only be evaluated in the Caucasian HS students because the other two groups had very few reactions. Table 3 shows the effect of different risk factors. A first-time donor had a vasovagal reaction rate of 9.4 versus 3.8 percent in a repeat donor ($p < 0.002$; RR, 2.6). A low-weight donor ($\leq$ 130 lb) had a 13.6 percent vasovagal reaction rate versus 3.3 percent in a high-weight donor ($\geq$ 180 lb) ($p < 0.0001$; RR, 4.0). Adding both risk factors together increased the reaction rate to 16.0 versus 3.2 percent in donors who lacked these factors ($p < 0.004$; RR, 5.0). Since 45 percent of the Caucasian females weighed no more than 130 lb and only 5 percent of the males weighed no more than 130 lb, female sex was added last because of the confounding factor of low weight. The four factors increased the reaction percentage to 16.4 versus 3.8 percent in those who lacked these factors ($p < 0.01$; RR, 5.0).

TABLE 1. Blood donor demographics in Caucasian, African-American, and nonstudent participants

Population	Number	Mean age (years)	Females percentage	First-time donor percentage	Mean weight (lb)*	Percentage weighing no more than 130 lb
Caucasian HS students	1076	17	49	79	157 (150)	24
African-American HS students	226	17	47	83	166 (160)	22
Nonstudent participants	157	44	52	9	180 (180)	10

* Number in parentheses is median.

Repeat Caucasian donations (the "survival" phenomenon)

Repeat donors weighed more than first-time donors (163 vs. 155 lb), but the percentage of males and the percentage of females weighing no more than 59.0 kg in the two groups were statistically the same. Eighty-four percent of the repeat donors donated their second lifetime unit and 16 percent donated their third lifetime unit, based on a random sample of 50 HS blood donors. Repeat donors had a 60 percent reduction (3.8 vs. 9.4%) in their vasovagal reaction rate, but there was no synergistic benefit when additional factors such as "high weight" (weight ≥ 81.7 kg) or "male sex" or "both" were added to repeat donor status.

Vasovagal reactions in females

Table 4 shows the vasovagal reaction rate in Caucasian girls and boys at four different weight scenarios. Vasovagal reactions were higher in females than males when all donors were included (11.3 vs. 4.8%, p = 0.002) or when donors under 130 lb were excluded (9.4 vs. 5.0%, p = 0.018). Vasovagal reactions in females and males were similar when donors under 150 lb were excluded (5.7 vs. 4.6%, p = 0.66).

DISCUSSION

Caucasian HS students have a high predisposition toward blood donation-related vasovagal reactions because of their youth, high percentage of first-time donations, and lower weight.[4-7] Other studies have also shown that history of syncope and psychological factors can also increase vasovagal syncopal reaction rates.[8] The percentage of vasovagal reactions in first-time, mainly Caucasian HS donors has been reported to be as high as 8.7 times greater than in experienced blood donors.[1] Thus, Caucasian HS students represent an excellent population in which to study vasovagal reactions.

Two studies provided some evidence that African-Americans might have a lower predisposition for blood donation-related vasovagal reactions than Caucasians.[2,3] The present study is the first to quantify and compare the risk in two relatively equal groups of Caucasian and African-American HS students. African-American HS students have a vasovagal donor reaction that is 84 percent lower than Caucasian HS students (1.3 vs. 8.2%, p < 0.0001), and none of the eight syncopal vasovagal reactions occurred in the African-American group (0 vs. 0.74%, p = 0.34), although the differences in syncope between the two groups did not reach significance. Several studies have shown that elevated systolic blood pressure is protective against vasovagal reactions.[5-7] This potential explanation was studied but did not account for the differences between African-American and Caucasian vasovagal reaction rates (see Table 2).

Several studies have also demonstrated synergy among risk factors.[2,5,7] Graham[2] studied 352 Caucasian blood donors in 1957 (published 1961) in a hospital setting. The risk of a vasovagal reaction in his setting was

TABLE 2. Comparison of blood pressures in randomly selected Caucasian and African-American HS students

	Caucasian students	African-American students	p value*
Number	100	100	NA
Male percentage	61	52	0.2538
First-time percentage	73	85	0.0554
Mean BP†	115.6/71.3	117.4/71.6	0.36/0.84
Median BP	114/70	117/70	NA
Systolic BP ≤100 (%)	16	15	1.000
Systolic BP ≥140 (%)	7	13	0.2381
Diastolic BP ≤60 (%)	16	15	1.000
Diastolic BP ≥80 (%)	24	28	0.6289
Mean BP (females)	111.2/69.5	115/71.2	0.24/0.46
Mean BP (males)	118.4/72.5	119.6/72.5	0.62/0.71

* p < 0.05 is clinically significant.
† BP = blood pressure.

TABLE 3. Additive effects of risk factors in Caucasian HS students

Risk factor(s)	Vasovagal reaction rate (%)	p value*	RR (95% CI)
HS student	88/1076 (8.2)		
HS student; FT† donor (A1)	80/853 (9.4)	0.002	2.6 (1.3-5.3)
HS student; weight ≤130 lb (B1)	36/264 (13.6)	<0.0001	4.1 (1.9-8.6)
HS student; FT donor; weight ≤130 lb (C1)	35/219 (16.0)	<0.004	5.0 (1.2-20.4)
HS student; FT donor; weight ≤130 lb; female (D1)	32/195 (16.4)	<0.01	4.3 (1.1-17.6)
HS student; repeat donor (A2)	8/223 (3.6)		
HS student, weight ≥180 lb (B2)	8/239 (3.3)		
HS student; repeat donor; weight ≥180 lb (C2)	2/63 (3.2)		
HS student; repeat donor; weight ≥180 lb, male (D2)	2/53 (3.8)		

* Comparisons were made between A1 and A2, B1 and B2, etc.
† FT = first-time.

TABLE 4. Comparison of vasovagal reaction rates for females and males for four different weight groups

	Females*	Males*	p value†
≥110 lb			
All	51/523 (11.3)	27/553 (4.8)	0.002
First-time	55/422 (13.0)	25/433 (5.8)	0.0004
Repeat	4/101 (4.0)	2/120 (1.7)	1.000
≥130 lb			
All	32/341 (9.4)	27/537 (5.0)	0.018
First-time	29/266 (10.9)	23/417 (5.5)	0.011
Repeat	3/75 (4.0)	4/120 (3.3)	1.000
≥150 lb			
All	8/141 (5.7)	19/415 (4.6)	0.660
First-time	7/109 (6.4)	16/323 (5.0)	0.633
Repeat	1/32 (3.1)	3/92 (1.6)	1.000
≥180 lb			
All	1/44 (2.3)	7/191 (3.7)	1.0
First-time	1/34 (2.9)	5/138 (3.6)	1.0
Repeat	0/10 (0)	2/53 (3.8)	1.000

* Data presented as n (%).
† $p < 0.05$ is different.

quite high (15%), and a combination of factors increased the risk to 35 percent to 71 percent in some scenarios. Tomasulo et al.[5] and Kasprisin et al.[6] in blood center studies showed much lower risks. The risks in those two studies did not exceed 6.4 percent, even when risks were combined. The present study evaluated low-weight (≤ 59.0 kg) and first-time donation status in Caucasian HS students and found that low weight was a more significant factor than first-time donation status based on RRs (4.0 vs. 2.6) (see Table 3). Trouern-Trend et al.[7] found the same pattern in a study of vasovagal syncopal reactions. When low-weight and first-time donation status were combined, the risk was even greater (RR, 5.0). However, female sex barely affected the risk, when it was added as a fourth "risk" factor (RR, 4.3) because most of the "low-weight" individuals (< 130 lb) had already been excluded.

Repeat blood donors had a 60 percent decrease in vasovagal reactions (3.8 vs. 9.5%, $p < 0.004$) and adding other positive factors such as "high weight," "male," or "both" did not provide any additional benefit. Thus, repeat blood donation status alone is a good predictor for a low vasovagal reaction rate in HS students.

Female sex as a risk factor was evaluated by observing the vasovagal reaction rate in a stepwise fashion as lower weight donors were removed. The pattern clearly showed that lower weight (≤ 130 lb), which is much more common in females than in males (45 vs. 5%), was a major factor for increased vasovagal reactions in females. However, when donors under 150 lb were excluded, there were no differences between female and male vasovagal reaction rates. Thus, low weight is the main factor that causes a high reaction rate in females.

One limitation in this study was the low number of repeat donors. This influenced the RR ratios by increasing variability and decreasing precision. A second limitation was the size of the African-American population studied. It was too small to evaluate the causes of vasovagal reactions in the population.

In summary, this study showed that African-American HS students have a significantly lower vasovagal reaction rate than Caucasian HS students. There is synergy among high-risk factors and low weight is a more significant risk factor than first-time donor status. Although females have more vasovagal reactions than males, this is mainly due to lower weight, and the differences disappeared when donors under 150 lb were excluded. Repeat HS blood donors have 60 percent fewer vasovagal reactions, and a successful first-time donation is a good predictor of future success.

ACKNOWLEDGMENTS

The author thanks Monique Gamblin and Torrance Hucks for data entry and Edward Notari for help with the statistics.

REFERENCES

1. Khan W, Newman B. Comparison of donor reaction rates in high school, college, and general blood drives (abstract). Transfusion 1999;39:31S.
2. Graham DT. Prediction of fainting in blood donors. Circulation 1961;23:901-6.
3. Khan W, Newman B. Vasovagal donor reactions at high school blood drives (abstract). Transfusion 1999;39:32S.
4. Poles FC, Boycott M. Syncope in blood donors. Lancet 1942;2:531-5.
5. Tomasulo PA, Anderson AJ, Paluso MB, et al. A study of criteria for blood donor deferral. Transfusion 1980;20: 511-8.
6. Kasprisin DO, Glynn SH, Taylor F, et al. Moderate and severe reactions in blood donors. Transfusion 1992;32: 23-6.
7. Trouern-Trend J, Cable R, Badon S, Newman B, Popovsky M. A case-controlled multicenter study of vasovagal reactions in blood donors: Influence of gender, age, donation status, weight, blood pressure, and pulse. Transfusion 1999;39:316-20.
8. Newman B. Donor reactions and injuries from whole blood donations (review). Transfus Med Rev 1997;11: 64-75.

Donor reactions in high-school donors: the effects of sex, weight, and collection volume

B.H. Newman, S.L. Satz, N.M. Janowicz, and B.A. Siegfried

BACKGROUND: The high incidence of donor reactions in first-time, 17-year-old Caucasian whole-blood donors makes this group ideal for the study of donor reactions.
STUDY DESIGN AND METHODS: Donor reaction rates were retrospectively evaluated in 7274 first-time, 17-year-old Caucasian whole-blood donors based on observations recorded at the collection sites. The effect of sex and weight on donor reactions was determined. In addition, a model was developed to estimate how different blood collection volumes would affect donor reaction rates.
RESULTS: The donor reaction rate was 12.0 percent (870/7274). Female donors overall had a higher donor reaction rate than male donors (16.7% vs. 7.3%) and also had a higher donor reaction rate than male donors at each 20-lb weight interval in the range from 110 to 189 lb. A model suggested that a change in the blood-unit volume from 450 to 500 mL would increase donor reaction rates by 18 percent in either female or male donors, whereas a reduction in the blood-unit volume from 500 to 400 mL would decrease donor reaction rates by 29 and 27 percent in female and male donors, respectively.
CONCLUSION: First-time, 17-year-old Caucasian female donors had a higher donor reaction rate than male donors overall and at equivalent donor weights. In the range of present US blood-unit volumes, a change in collection of as little as 50 mL could have a significant impact on blood donor reaction rates in high-school students.

From the American Red Cross Blood Services, Southeastern Michigan Region, Detroit, Michigan; and the Wayne State University School of Medicine, Detroit, Michigan.

Address reprint requests to: Bruce H. Newman, MD, Medical Director, American Red Cross Blood Services, SE Michigan Region, 100 Mack Avenue, Detroit, MI 48201; e-mail: newmanb@usa.redcross.org.

Received for publication May 18, 2005; revision received June 24, 2005, and accepted June 27, 2005.

doi: 10.1111/j.1537-2995.2006.00713.x

TRANSFUSION 2006;46:284-288.

Clinical studies have evaluated the incidence of blood donor reactions[1] and have studied the correlation of donor characteristics such as weight,[2-6] age,[3-6] first-time or repeat donor status,[3-6] race,[6-8] and sex[3,4,6] to donor reaction rates. This study evaluated first-time, 17-year-old, Caucasian high-school students because these donors have a very high donor reaction rate of approximately 9 to 11 percent,[6,9] which is seven to nine times higher than the donor reaction rate in an experienced, general donor population.[2] We evaluated two nonfixed variables (sex, weight), but three variables (donor status, age, race) were fixed. We also developed a model for donor reaction rates as a function of sex and the ratio of whole-blood collection volume per donor weight, which allowed us to estimate the effects of various whole-blood collection volumes.

MATERIALS AND METHODS

Blood donor suitability and phlebotomy

High-school blood donors met acceptability criteria before being subjected to phlebotomy. The donors then lay in a supine position, and a 525-mL phlebotomy was performed in the antecubital fossa of the arm with a 16-gauge needle. The blood collection volume included 481 mL in a whole-blood unit, 33 mL in tubes for post-donation tests, and 11 mL trapped in the plastic tubing. Blood donor reactions observed at the collection site were recorded. A "donor reaction" was defined as the presence of any of the following symptoms or signs during or shortly after whole-blood donation: dizziness, diaphoresis (sweating), sudden weakness, hypotension, bradycardia, and syncope (faint). Approximately 97 percent of the reactions were nonsyncopal reactions.

Blood donor selection and data analysis

All high-school blood drive donor history records from 77 blood drives between October 1, 2003, and March 23, 2004, were reviewed. Donor selection was limited to 17-year-old, first-time, Caucasian donors who successfully donated a whole-blood unit. Studies have shown that African-American donors have a considerably lower donor

rate than Caucasian donors, so African-American donors were excluded from the study.[6,7] The decision to use successful donations and exclude unsuccessful donations was an arbitrary one. A total of 7274 donor history records were deemed suitable for evaluation.

Statistical analysis

Confidence intervals (CIs) for reaction rates were calculated as minimum-length intervals by integration of the Bayesian posterior with diffuse priors[10] with the assistance of computer software (the Solver tool in Microsoft Excel 2002, Microsoft Corp., Redmond, WA). Logistic regression was performed with Epi Info.[11] Proportion comparisons were done with the Fisher Exact test.

RESULTS

Donor weight distribution

Figure 1 shows a bell-shaped curve for male donors, with some skewing toward higher weights. In contrast, the curve for female donors appears truncated, suggesting that many Caucasian high-school female donors weighed less than 110 lb and could not donate blood.

Donor reaction rates in 17-year-old, first-time Caucasian blood donors

Table 1 shows the donor reaction rate for the total population and for each sex in 20-lb incremental weight groups. The donor reaction rate for the total population was 12.0 percent. Female donors had a 2.3-fold higher donor reaction rate than male donors, 16.7 percent versus 7.3 percent, and female donors had higher donor reaction rates within equivalent weight groups. Female donor reaction rates were 61 to 149 percent greater than male donor reaction rates, depending on the weight group. Figure 2 shows the donor reaction rates versus weight for female and male donors. Donor reaction rates appeared to decrease asymptotically as donor weights increased. Thus, logistic regression of reaction rate against a linear function of coded sex, reciprocal weight, and the product of coded sex and reciprocal weight—representing an interaction between sex and weight—was performed. The model was

$$\ln\left(\frac{r}{1-r}\right)=a+bs+\frac{c}{w}+\frac{ds}{w}, \quad (1)$$

where r is proportion of donors of coded sex s and weight w having a reaction; s = 0 if donor is male or 1 if donor is female; w is donor weight (lb); and a, b, c, and d are constants.

The coefficient d of the term representing sex–weight interaction was not significantly different from zero ($p = 0.09$ by a two-tailed test), so this term was omitted from the model. The remaining constants were found to have the following values: $a = -4.2941$, $b = 0.6120$, and $c = 284.1776$. All were significantly different from zero ($p < 0.0001$ by a two-tailed test). These constants yield the following formulas, which are plotted in Fig. 2.

$$\ln\left(\frac{r}{1-r}\right)=-4.2941+\frac{284.1776}{w} \text{ for male donors} \quad (2)$$

$$\ln\left(\frac{r}{1-r}\right)=-3.6821+\frac{284.1776}{w} \text{ for female donors.} \quad (3)$$

These formulas were used to give estimates of donor reaction rates at infinite weight, which were 2.5 percent for female donors and 1.3 percent for male donors. In a more practical context, the estimated donor reaction rates at 300 lb were 6.1 percent for female donors and 3.4 percent for male donors.

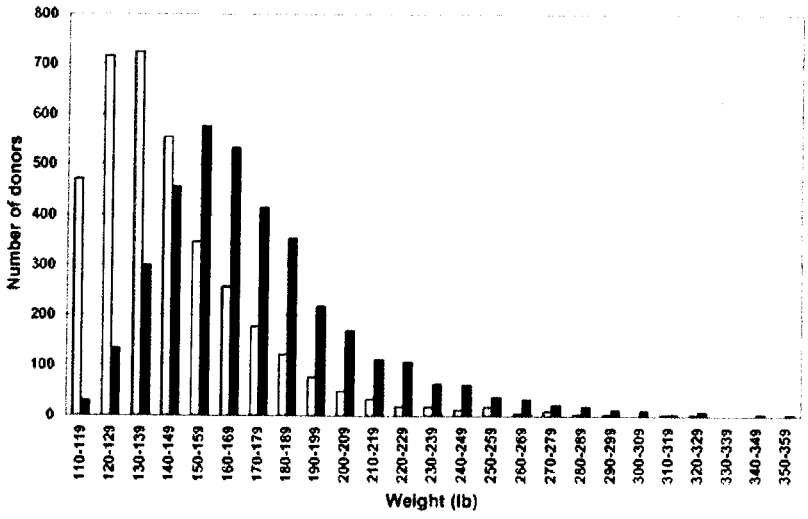

Fig. 1. Weights of first-time Caucasian high-school donors. (□) Female donors; (■) male donors.

Model for the effect of different blood-unit volumes on blood donor reaction rates

There is evidence that lower blood collection volumes are associated with lower reaction rates (see Discussion). We propose a unifying hypothesis that, for 17-year-old, first-time Caucasian donors, the donor reaction rate is a function of sex and the ratio of whole-blood collection volume to donor weight. Using the fact that Equations 2 and 3 were based on data obtained using a collection volume of 525 mL,

TABLE 1. Donor reaction rates in first-time, Caucasian high-school students

Donor sex	Weight (lb) 110-129	130-149	150-169	170-189	190-209	210+	Total
Female							
Number of reactions/number of donations	248/1187	206/1278	90/602	36/298	12/124	10/116	602/3605
Percent reactions	20.9	16.1	15.0	12.1	9.7	8.6	16.7
Male							
Number of reactions/number of donations	19/164	73/754	103/1108	39/768	15/386	19/489	268/3669
Percent reactions	11.6	9.7	9.3	5.1	3.9	3.9	7.3
Total							
Number of reactions/number of donations	267/1351	279/2032	193/1710	75/1066	27/510	29/605	870/7274
Percent reactions	19.8	13.7	11.3	7.0	5.3	4.8	12.0

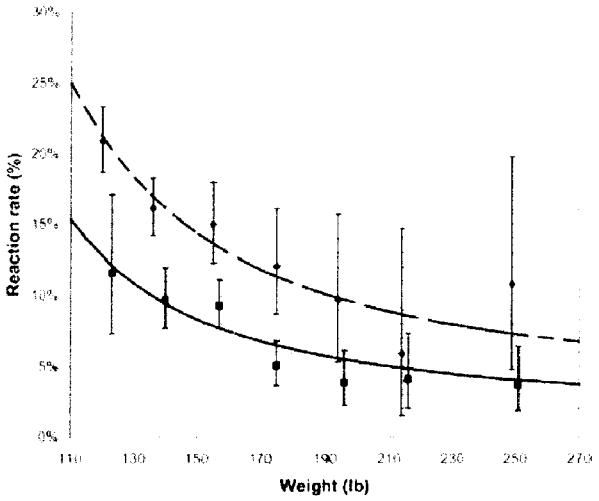

Fig. 2. Donor reaction rates in first-time Caucasian high-school students. Collections for each sex were grouped into 20-lb weight intervals for donor weights from 110 through 229 lb and a single interval for weights of 230 lb or more. The x coordinate of each group is the median weight, and the y coordinate is the reaction rate and its 95 percent CI. Curves were derived by logistic regression, as described under Materials and Methods. (◆) 95 percent CI, female donors; (■) 95 percent, male donors; (--) model, female donors; (—) model, male donors.

these equations were generalized to be consistent with the hypothesis

$$\ln\left(\frac{r}{1-r}\right) = -4.2941 + 0.5412907\frac{V}{W} \text{ for male donors} \quad (4)$$

$$\ln\left(\frac{r}{1-r}\right) = -3.6821 + 0.5412907\frac{V}{W} \text{ for female donors,} \quad (5)$$

where v is the blood collection volume in mL. When v = 525, Equations 4 and 5 are simplified to Equations 2 and 3, respectively.

The collection volume is the blood-unit volume plus the volume of blood in collection-set tubing and samples for testing. As previously stated, the latter is estimated to be 44 mL. Table 2 uses this estimate, the above model, and this study's donor weight distribution to give expected donor reaction rates at various blood-unit volumes. Table 3 compares the expected rates at different blood-unit volumes. The model suggests that an increase in the whole-blood unit volume from 450 to 500 mL would cause a 1.2-2.7 percent absolute increase in the donor reaction rate and a 17.9 to 18.2 percent relative increase in the donor reaction rate in first-time, Caucasian, high-school donors. Female donors had a greater absolute increase in the donor reaction rate (2.7 reactions per 100 collections vs. 1.2), but both sexes had similar relative increases of approximately 18 percent. A decrease in the whole-blood collection volume from 500 to 400 mL would decrease the donor reaction rate by 27 to 29 percent. Female donors would have a greater absolute decrease in the donor reaction rate (5.1% vs. 2.1%), but female and male donors would have a similar relative decrease (29% vs. 27%).

TABLE 2. Expected donor reaction rates at other collection volumes (reactions per 100 collections)

Sex	Blood-unit volume (mL) 500	481	450	400	350	300	250
Female	17.8	16.7	15.1	12.7	10.7	8.9	7.4
Male	7.8	7.3	6.6	5.7	4.8	4.1	3.5

TABLE 3. Expected effects of blood-unit volume changes on donor reaction rates*

Sex	Blood-unit volume change (mL) 450 to 500	500 to 400	500 to 250
Female	+2.7 (+17.9%)	−5.1 (−28.7%)	−10.4 (−58.4%)
Male	+1.2 (+18.2%)	−2.1 (−26.9%)	−4.3 (−55.1%)

* Absolute change in reactions per 100 collections (relative change).

DISCUSSION

Donor reactions are common. In a recent study, 7.0 percent of 1000 randomly selected interviewed whole-

blood donors had a donor reaction.[2] The rate was 2.5 percent based on observation at the collection site, but an additional 4.5 percent were found after a donor interview 3 weeks later. Approximately 97 percent of the donors had mild reactions, meaning that the donors had symptoms and signs such as dizziness, diaphoresis, pallor, and sudden weakness but did not faint. A 1-year follow-up showed that donors who had a reaction were 34 percent less likely than asymptomatic donors to return and donate again within a 1-year period.[12] Studies show that the blood donation return rates are even lower when donors had syncope.[13-15] Therefore, it is clear that a non-syncopal donor reaction decreases a donor's return rate, and syncope further decreases the return rate. Donor reactions are also a donor safety issue. One study showed a 14 percent injury rate in donors who progressed to syncope.[16] These injuries were often to the head and were generally minor, but lacerations and fractures occasionally occur. Serious injuries such as a closed-head injury are very rare but possible.

Three key factors associated with the probability of a donor reaction are weight,[2-6] age,[3-6] and first-time or repeat donor status.[3-6] Weight and age are the most important factors, and first-time or repeat donor status has marginal importance.[17] High weight, high age, and repeat status all protect donors against donor reactions. Caucasian donors have more risk for a donor reaction than African-American donors have.[6-8] Several studies have shown that female donors have more donor reactions than male donors,[3,4,6] but this was thought to be due to the female donor's smaller size because when female and male high-school donors over 149 lb were compared, the donor reaction rates were the same.[6] In addition, in 850 first-time, Caucasian donors from the same study, there were no differences in donor reaction rates when female and male donors in equivalent 20-lb weight groups were compared.[6] This study evaluated 8.6-fold more donors (7274 vs. 850) and detected large differences between reaction rates of female and male first-time Caucasian donors of similar weight.

Based on safety data for a 500 mL collection volume from a large blood center[18] and from the American Red Cross, most blood centers increased their whole-blood unit volume from 450 mL to a higher value. The American Red Cross collects 481 mL in each unit but 525 mL in total volume. This volume can be collected in any donor—even a donor with the lowest allowable weight, 110 lb (50 kg)—because it meets the AABB standard for a maximum whole-blood collection volume of 10.5 mL per kg of body weight.[19] Other blood centers collect two different whole-blood units—a 450-mL unit for low-weight donors and a 500-mL unit for donors weighing over approximately 120 lb.

A large blood center compared donor reaction rates in 282,000 donors who donated 450-mL whole-blood units and 547,000 donors who donated 500-mL whole-blood units.[18] The center did not detect a difference in donor reaction rates, which were 1.36 and 1.28 percent, respectively. But the subjects were from the general donor population, approximately 80 percent of whom were repeat donors and were much older and heavier than high-school students. A more sensitive study would have compared equivalent groups of very-high-risk donors such as the lower-weight female donors in this study, but this would have required entry of donor weight into the blood center's database, which is often not done.

In the donors studied here, the effect of two variables, sex and weight, on the reaction risk were determined. Three other variables, age, race, and first-time donor status, were fixed. It is probable but unproven that the bulk of the reactions in this group were caused by these five risk factors. Future studies could measure other factors that are thought to be associated with reactions such as a history of a donor reaction or being in the environment of a "group reaction." One could determine if there was an independent contribution from each variable by use of a logistics regression analysis, and such analysis could also quantify the contribution.

The model in this study, which relates the donor reaction rate in first-time, Caucasian high-school students to sex and the ratio of blood collection volume to donor weight, suggests that a 50-mL increase in whole-blood collection volume increased donor reaction rates by 18 percent. The model also suggests that a decrease in the blood-unit volume from 500 to 400 mL would decrease donor reaction rates by 29 percent in female donors and 27 percent in male donors, which is a very significant improvement. These lower rates are supported by Japanese data. The Japanese collect 400-mL (70% of collections) and 200-mL (30% of collections) units. They report a donor reaction rate of 0.6 to 0.7 percent based on 3.3 million whole-blood donations (H. Ikeda, Japanese Red Cross Society Central Blood Center, Japan; and M. Satake, Tokyo Red Cross Blood Center, Japan; written communications, 2003). Our data and model indicate that collecting 400-mL whole-blood units might be particularly effective in reducing donor reaction rates in young, low-weight, and first-time donors.

One limitation in this study was the lack of high-weight female donors. This made it difficult to show sex-related differences at high weights. A second limitation was that the data were based solely on observation of donors. In another study, a postdonation interview increased the number of reactions detected in a general donor population 2.3-fold, from 2.5 to 7.0 percent.[2] We do not believe that limiting the study to successful donations had an effect. The rate of unsuccessful donations in 4340 high-school students in the fall and winter of 2004 in our center was 5.0 percent (219/4340). It was 4.0 percent (21/525) in donors with a reaction and 5.2 percent (198/3815)

in donors with no reaction ($p = 0.21$). These data also challenge the perception that donor reactions are associated with more unsuccessful donations.

In conclusion, first-time, female Caucasian high-school students have a much higher donor reaction rate than male donors of equivalent weight. A model suggested that a change in the blood-unit volume from 450 to 500 mL would increase the donor reaction rate in this group by approximately 18 percent, and a decrease in the blood-unit volume from 500 to 400 mL would decrease the donor reaction rate by 27 to 29 percent. This kind of decrease in donor reaction rates would have a significant positive impact on safety and blood donor retention rates—particularly in first-time, lower-weight, high-school donors and other donors at high risk.

REFERENCES

1. Newman BH. Donor reactions and injuries from whole-blood donation. Transfus Med Rev 1997;11:64-75.
2. Newman BH, Pichette S, Pichette D, Dzaka E. Adverse effects in blood donors after whole-blood donation: a study of 1,000 blood donors interviewed 3 weeks after whole-blood donation. Transfusion 2003;43:598-603.
3. Trouern Trend JJ, Cable RG, Badon SJ, et al. A case-controlled study of donor reactions in blood donors: influence of sex, age, donation status, weight, blood pressure, and pulse. A case-controlled multicenter study. Transfusion 1999;39:316-20.
4. Tomasulo P, Anderson AJ, Paluso MB, et al. A study of criteria for blood donor deferral. Transfusion 1980;20:511-8.
5. Kasprisin DO, Glynn SH, Taylor Miller KA. Moderate and severe reactions in blood donors. Transfusion 1992;32:23-6.
6. Newman BH. Donor reactions in high school students: findings relative to race, risk factor synergism, female sex, and non-high school participants. Transfusion 2002;42: 1557-60.
7. Newman B, Siegfried B, Buchanan L. The effect of ethnicity on the incidence of donor reactions in first-time whole-blood donors [letter]. Transfusion 2005;45:1398-9.
8. Graham DT. Prediction of fainting in blood donors. Circulation 1961;23:901-6.
9. Khan W, Newman B. Comparison of donor reaction rates in high school, college, and general blood drives [abstract]. Transfusion 1999;39(Suppl):31S.
10. Ross TD. Accurate confidence intervals for binomial proportion and Poisson rate estimation. Comput Biol Med 2003;33:509-31.
11. Dean AG, Arner TG, Sunki GG, et al. Epi Info, a database and statistics program for public health professionals. Atlanta (GA): Center for Disease Control and Prevention; 2002.
12. Newman B, Newman D. The effect of the blood donor's physical experience on blood donor return rates. Transfusion 2003;43(Suppl):140A.
13. Cable R, Trouern-Trend JJ, Badon SJ. The effect of blood donor syncopal reactions on subsequent blood donation [abstract]. Transfusion 1999;39(Suppl):114.
14. Gorlin JB, Petersen J. Reactions in first-time high school blood donors. Transfusion 2004;44:463.
15. Siegfried B, Newman B. Effect of reaction in allogeneic whole-blood donors on intervals from donation to next presentation [abstract]. Transfusion 2004;44(Suppl):78A.
16. Newman BH, Graves S. A study of 178 consecutive vasovagal syncopal reactions from the perspective of safety. Transfusion 2001;41:1475-9.
17. Newman BH, Roth AJ. Estimating the probability of a blood donation adverse event based on 1000 interviewed whole-blood donors. Transfusion 2005;45:1715-21.
18. Bianco C, Robins JL. Whole blood collection volumes and donor safety: equivalence between 450 mL and 500 mL collections [abstract]. Transfusion 1994;34(Suppl):15S.
19. Fridey JL, editor. Standards for blood banks and transfusion services. 22nd ed., Reference Standard 5.4.1A. Bethesda: American Association of Blood Banks; 2003. p. 69-73.