A snapshot of ABO, RH, and JK blood group systems in modern Ireland

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Funding information
Irish Blood Transfusion Service; ADG Department

Abstract

Objectives: This study aimed to capture a snapshot of the Irish population to determine if there had been any changes in the ABO and RH blood group system (BGS) distribution from previous Irish studies and to establish an Irish JK BGS frequency, providing real time donor information to the Irish Blood Transfusion Service (IBTS).

Background: Ireland’s population is constantly increasing and becoming more diverse, this has potential implications for the IBTS to provide blood with extended phenotypes for certain cohorts of patients.

Materials and methods: All first time blood donors had relevant testing performed in the Automated Donor Grouping (ADG) laboratory using the Beckman Coulter PK7300 analyzer with appropriate antisera by validated methods. All pertinent information and test results were categorized and analyzed.

Results: The number of donors tested was 3427. ABO phenotype: A: 29.82%, B: 12.02%, O: 54.95% and A,B: 3.21%. RHD: 82.26%. RHCE: R1R1: 17.62%, R2R2: 2.89%, R1R2: 13.95%, R1r: 33.35%, R2r: 13.07%, Ror: 1.25%, R1RZ: 0.06%, R2RZ: 0.06%, r0r: 0.55%, r00r: 0.53%, rr: 16.66%. Kidd phenotype: Jk(a+b+): 49.63%, Jk(a-b+): 23.34%, Jk(a+b-): 27.02%.

Conclusion: The observed frequencies for the relevant BGSs remained relatively unchanged to the prevalence values expected; however, statistically significant differences between the 2015 study and some of the previous studies were found for ABO distribution. 14.24% of the first time donors were born outside Ireland and statistically significant differences (P-value < 0.001) were noted for aspects of the ABO and Rh phenotype distribution for the Irish born donors (BiI) vs those born outside Ireland (BoI).

KEYWORDS
ABO, Ireland, JK Irish, Kidd, RH

1 | INTRODUCTION

The Irish Blood Transfusion Service (IBTS) is a blood establishment whose functions are set out in Statutory Instruments and European directives. The Automated Donor Grouping Laboratory (ADG) tests all blood donations in the Irish Republic. An ABO, RHD, RHCE, K antigen, antibody and a high titer antibody screen are determined for each donation. Extended antigen typing is undertaken to meet the
requirements of patients with alloantibodies or transfusion dependent patients. Rare and complex extended phenotypes can be difficult to provide.

Worldwide, blood group system (BGS) distribution varies among populations.\textsuperscript{1,2} Generally, Group A has the greatest frequency in North-western Europe and Group B in parts of Southeast Asia.\textsuperscript{1,2} Up to 77% of Group A frequencies are found in Aboriginal people in South Australia.\textsuperscript{2} Populations with Group O greater than 60% are found in native people in the Americas and some parts of Africa and Australia.\textsuperscript{1,2} Native people in South and Central America were almost 100% Group O before European arrival.\textsuperscript{2}

BGS distribution in Ireland was first examined in 1937 and 1940 where the authors found that Group O frequency was higher in Dublin than in other parts of Europe.\textsuperscript{3,4} In 1947, it was found that Group O along the western seaboard of Ireland reached 60% whereas the east coast had a higher frequency of Group A and less Group O.\textsuperscript{5} One assumption was that successive invasions had pushed the native Irish populations further west.\textsuperscript{5}

Ireland’s population has been influenced by invasions, migration and settlement.\textsuperscript{5,6} From 1846 to 1848, the population fell from eight million to six million during the potato famine.\textsuperscript{6} This decline continued; in the 1950’s, Ireland’s population was 2 898 264\textsuperscript{7} which, is the approximate period of time when the previous studies were undertaken. Ireland’s population is constantly increasing; census data indicates a population increase to 4 761 865 million in 2016\textsuperscript{8} from 4 588 252 million in 2011.\textsuperscript{9}

According to the 2016 census, 535 475 of people registered in Ireland were non-Irish nationals\textsuperscript{10} who came from over 200 nations, 12 of these nations accounted for 73.6% of Ireland’s non-Irish population.\textsuperscript{11} The proportion of the population that identified as “white Irish” was 82.2%.\textsuperscript{12} This increasingly ethnically diverse society has potential implications for the IBTS in its requirements to provide blood products. To provide Jk(a-b-) blood to a patient with anti-Jk3 is extremely difficult, if not impossible to obtain from an ethnically Irish donor population.\textsuperscript{13}

The expected prevalence values determined for the Irish population for this study were Group A: 31%, Group B: 11%, Group O: 56% and Group AB: 3%.\textsuperscript{14,15} with RhD antigen positive: 83%.\textsuperscript{14-16} A previous Irish Rh phenotype profile, indicated higher R1r’s (DcE/dce) and R2r’s (DcE/dce) with lower r’s (dce/dce) in western Ireland.\textsuperscript{17} The expected JK BGS phenotype prevalence for a Caucasian population were: Jk(a-b+) 50.3%, Jk(a-b-) 23.4%, Jk(a-b+) 26.3%.\textsuperscript{13}

The objectives of this cross sectional study were to test and categorize first time donors during a specific time period, to determine if there had been any statistically significant changes in the Irish population’s ABO BGS and RhD antigen frequency relevant to the previous studies and in relation to the distribution of these BGS’s within Ireland; to determine an RHCE and JK frequency; to assess if there were differences of the BGS’s distribution within the two resultant populations, that is, born in Ireland (BiI) vs born outside Ireland (BoI) donors. A corollary was the participation of donors from different countries in blood donation in Ireland compared with their proportions in the Irish population. The outcome would be a snapshot of ABO (001), RHD (004), RHCE (004), and JK (009) BGS prevalence in Ireland.

2 | MATERIAL AND METHODS

2.1 | Subjects studied

Donors donating for the first time to the IBTS were included in this study as this avoided any bias that would occur if using known donors from clinic call-ups. Donors from all 26 counties were represented. Clinic locations were dependent on IBTS clinic rosters. Testing was performed over a 14 week period from August to December 2015. Venous blood was collected in Vacuette K3 EDTA anticoagulant, refrigerated overnight and on arrival to the laboratory centrifuged prior to testing at 3500 rpm (2739 g) for 5 minutes. All procedures were undertaken according to ADG standard operating procedures (SOP’s). The final sample size was 3427 with 2939 donors BiI and 488 donors BoI. The Kidd profile had 3423 donors, (2935 BiI/488 BoI) with a loss of four donors (BiI) due to positive infectious disease markers. Both ABO profiles and Rh phenotype testing had been completed prior to this notification.

2.2 | Ethical considerations

Ethical approval was obtained from the IBTS in accordance with research ethics and governance policy and procedures, including code of practice for professional integrity in the conduct of research and the Ulster of University Ethics Filter Committee. Informed consent was included with the Health and Lifestyle Questionnaire (HLQ) completed by all donors. The donors were informed that parts of, or the entire donation may be used for purposes other than direct transfusion to a patient; uses such as research and development were given. A project number was assigned to each donor to fulfill all ethical requirements in relation to confidentiality of the donor.

2.3 | Instrument 1

The Beckman Coulter PK 7300 automated system was the platform used, which when combined with appropriate reagents facilitated hemagglutination reactions in Beckman Coulter microtiter plates.\textsuperscript{18} The PK system interfaced to the laboratory information management system (LIMS) ePROGESA via electronic document management system (eDMS).\textsuperscript{19}

2.4 | Instrument 2

Hook, Tucker, and Zenyz (HTZ) Qasar IV\textsuperscript{20} facilitated serological testing using BioRad gel card techniques. Confirmation of some ABO weaker reverse groups using BioRad ID-card Diaclon ABO/D+ reverse grouping was performed with BioRad ID-DiaCell A\textsubscript{2} and B.
2.5 | Test

Blood groups were determined by the presence or absence of agglutination when the test red blood cells (RBCs) were reacted against specific antisera. The ABO/RHD determination for each donation was performed on two separate ABO profiles. An RHCE and JK phenotype were determined, each with its own profile on the PK7300’s.

2.6 | Antisera

The antisera for the PK7300 microplate technique had been validated in ADG to ensure potency and specificity without a compromise in sensitivity.21

The first ABO profile (ABOa) used the following clones; anti-A [Bioscot-millipore; Birma-1], anti- B [Bioscot-millipore; LB-2], anti-A,B [Bioscot-millipore; ES-15/ES-4], anti- D 1 [Diagast -Totem; p3x61 + p3x21223B10 + p3x290 + p3x35], and anti- D 2 [Immucor -Novacon; D415/D175].

The second ABO profile (ABOb) used anti-A [Immucor-Novacon; A98], anti- B [Immucor- Novacon; BV84 + B97], anti-A,B [Immucor- Novacon; A98 + B84 + B97 + AB125], anti-D 1 [Bioscot-millipore; Rum-1], and anti-D 2 [Bioscot-millipore; MS-201].

The two anti-D antisera on ABOa detected DVI positive RBCs; whereas the two anti-D antisera on ABOb did not detect DVI positive RBCs.

The Rh phenotype profile used the following antisera clones; anti-C 1 [Bioscot-millipore; MS 24] & anti-C 2 [Imumed- antitoxin; MS273], anti-c 1 [Bioscot-millipore; MS33] & anti-c 2 [Imumed- antitoxin; MS35], anti-E 1 [Bioscot-millipore; MS80/MS258] & anti-E 2 [Imumed antitoxin; MS258/906], anti-e 1 [Bioscot-millipore; MS16/21/63] & anti-e 2 [Imumed- antitoxin; MS16/21/63]. A further anti-D antisera [Imumed- antitoxin; MS26/TH28] was necessary for the interpretation of the Rh phenotype (most probable Rh genotype).

The JK phenotype profile used anti-Jk\(^a\) 1 [Bioscot-millipore; MS15] & anti-Jk\(^b\) 2 [Imumed-antitoxin; MS15], anti-Jk\(^a\) 1 [Bioscot-millipore; MS 8] & anti-Jk\(^b\) 2 [Imumed-antitoxin; MS 8].

2.7 | Reagents

2.7.1 | Diluents

Phosphate buffered serology saline (PBSS) pH 7.0 [Biosciences] was used for dilution to improve reaction patterns.22 RBC typing and antibody screening was performed by an enzyme technique22 using Bromelain [Sigma-Aldrich], a proteolytic enzyme used daily at a 0.1% working solution.

2.7.2 | Reagent RBCs

The five reagent RBCs (rRBCs) required were prepared from RBC packs with known phenotypes on a daily basis. RBCs were washed and prepared in saline suspension at concentrations of 1.25%-1.45%, depending on the validated RBC concentration required for the relevant profile on the PK7300’s.

An O R1R1 K+/-K- and an O R2R2 K+/-K- rRBC were used for antibody screening and an A1B rRBC was used to detect anti-A,B high titer positive donors on the ABOoa profile.

The testing of the donor plasma for its hypothetical ABO antibody/ies (reverse group) was performed using A1 RhD- and B RhD-rRBCs on the ABOb profile.

2.8 | Controls

An inert monoclonal control [Bioscot- Millipore] was the negative antisera control used with each set of antisera prepared.

Each profile was controlled with the relevant controls placed throughout each run.21

ABOa RBC controls were: A2B, A1, B, weak RhD+, and DVI+ which were prepared from RBC packs daily, washed and resuspended in saline. An R1r K+ RBC (a previous donation with historical phenotype) was also necessary.

Anti D [Quotient-Albachek; 0.3 IU/mL] was the sensitivity control for antibody screening. An anti-A,B [Bioscot-millipore; ES-15/ES-4] prepared at 1:16 dilution was used as a control for donor anti-A,B high titer detection.

ABOb used the same controls as ABOa except no requirement for a K+ cell; ABOb profile also had a group A, B, and O (RBC controls selected from a previous ABOb run where strong reverse group reactions were observed) to control the reverse ABO.

The Rh phenotype profile had the following controls: R1R2, R1R2, R1r, R2r, R1r, r’r, r’r and rr, where using Fisher-Race terminology; R1 = DcE, R2 = DcE, Rc = Dce, R2 = Dce, r’ = dCe, r” = dcE, and r = dce.13

The JK profile was controlled with: two Jk(a-b+), two Jk(a+b-), and two Jk(a+b+) controls. RBC controls for the Rh phenotype and Kidd profiles were selected from previous testing / historical donor phenotypes.

2.9 | Quantitative variables

Once testing was complete, the ABO, RhD, Rh phenotype, and JK phenotype results were recorded, together with relevant donor demographic data. The BGS’s by donor were further categorized by Bir/Bol and county/country. The Bol donors were classified using United Nations country and area codes.23

The outcome measure was the blood group antigen presence or not on the donor RBCs. The result was Group A, B, O or A,B and depending on D antigen presence or not, each donors blood group was further defined to A RhD positive, A RhD negative, B RhD positive, B RhD negative, O RhD positive, O RhD negative, AB RhD positive, or AB RhD negative. The Rh phenotype frequency outcomes (most probable genotype) were \(R_1R_1, R_2R_2, R_1R_2, R_3r, R_3r, R_3R_2.\)
26.3%. The difference (d) that would be clinically relevant for this study was: A RhD positive: 2.63%, and AB RhD negative: 0.58%. O RhD positive: 2.25%, O RhD negative: 9.40%, AB RhD positive: 9.78%, AB RhD negative: 26.3%. The difference (d) that would be clinically relevant for this study was: A RhD positive: 2.63%, and AB RhD negative: 0.58%. O RhD positive: 2.25%, O RhD negative: 9.40%, AB RhD positive: 9.78%, AB RhD negative: 26.3%.

2.10 | Statistics

The expected prevalence (p) of each BGS was determined from previous Irish studies for A, B, O, A,B\textsuperscript{14,15} and the D antigen\textsuperscript{16-16} and from that expected for a Caucasian population for the Jk antigens (Jka and Jkb).\textsuperscript{13} These expected prevalence values (p) were: A: 31%, B: 11%, A,B: 3%, O: 56%,\textsuperscript{14,15} D: 83%;\textsuperscript{14-16} and the expected JK phenotype prevalence’s were: Jk(a+b+): 50.3%, Jk(a−b+): 23.4%, Jk(a+b−): 26.3%.\textsuperscript{13} The difference (d) that would be clinically relevant for this study\textsuperscript{24} was determined to be 5.0% for all groups except 3.0% for Group B and 1.0% for group A,B. Power calculations were performed at 80% and 90% power.\textsuperscript{24,25} Formula for 80% power was: (n = \( \frac{s^2}{d^2} \)) and 90% power: (n = \( \frac{21s^2/d^2}{} \))\textsuperscript{26} where: s\(^2\) = (p (1−p]). Confidence limits at 95% were estimated, assuming the binomial distribution conformed to a normal distribution using (p + / − 1.96 * SE) where 1.96 was the Z value\textsuperscript{25} and SE calculated as (\( \sqrt{p \cdot (1−p) / n} \))\textsuperscript{24-26} where n was the sample size determined from the power calculations.

Further assessment for associations between the relevant categorical variables was done using contingency tables and a chi square test with P-values calculated.\textsuperscript{25} A P-value less than 0.05 was considered statistically significant for this study as this indicated evidence of a difference between the variables been analyzed.\textsuperscript{25} This analysis was performed using SPSS 22\textsuperscript{27} and Stata software.\textsuperscript{28}

Allele frequency calculations were performed\textsuperscript{29-34} assuming Hardy Weinberg Equilibrium (HWE) rules\textsuperscript{34} applied to the population. The Rh phenotype haplotype frequency was estimated from the Rh phenotype frequencies.

3 | RESULTS

3.1 | Total Irish donor population (n = 3427)

The ABO phenotype distribution in modern Ireland was Group A: 29.82%, Group B: 12.02%, Group O: 54.95%, and Group A,B: 3.21%. RhD positive phenotype distribution was 82.26% and RhD negative: 17.74% (r, r, and r). This was further refined to: A RhD positive: 24.31%, A RhD negative: 5.52%, B RhD positive: 9.78%, B RhD negative: 22.25%, O RhD positive: 45.55%, O RhD negative: 9.40%, AB RhD positive: 2.63%, and AB RhD negative: 0.58%.

The Rh phenotype frequency for Ireland was: R\textsubscript{1}R\textsubscript{2}: 17.62%, R\textsubscript{1}R\textsubscript{2}: 2.89%, R\textsubscript{2}R\textsubscript{2}: 13.95%, R\textsubscript{1}r: 33.35%, R\textsubscript{2}r: 13.07%, R\textsubscript{1}r: 1.25%, R\textsubscript{1}R\textsubscript{2}: 0.06%, R\textsubscript{2}R\textsubscript{2}: 0.06%, r,r: 0.55%, r,r: 0.53%, and r,r: 16.66%.

Estimated Rh phenotype haplotype frequency: R\textsubscript{1}: 41.30%, R\textsubscript{2}: 16.43%, R\textsubscript{1}: 0.63%, R\textsubscript{2}: 0.06%, r,r: 0.28%, r,r: 0.26%, r,r: 41.05%.

The JK phenotype distribution of modern Ireland (n = 3423) was: Jk(a+b+): 49.63%, Jk(a−b+): 23.34%, Jk(a+b−): 27.02%.

3.2 | Irish born donors (n = 2939)

The ABO phenotype distribution for Bil donors was: Group A: 28.92%, Group B: 11.13%, Group O: 57.43% and Group A,B: 2.52%. RhD positive: 82.34% and RhD negative: 17.66%. Refer to Table 1 for the totals for the eight ABO groups for the Bil donors for each county and province. The Rh phenotype for the Bil donors can be found in Table 2 with county/provincial totals.

The estimated Rh phenotype haplotype was: (n = 2939): R\textsubscript{1}: 40.68%, R\textsubscript{2}: 16.81%, R\textsubscript{1}: 0.61%, R\textsubscript{2}: 0.05%, r,r: 0.19%, r,r: 0.31%, r,r: 41.36%.

The JK phenotype was: Jk(a + b−): 49.64%, Jk(a+b−): 23.10% and Jk(a + b−): 27.26%. Refer to Table 3 for the Bil JK distribution for counties / provinces.

The Bil donors comprised 85.76% of the first time donors. These donors came from Leinster (48.38%), Munster (33.65%), Connacht (11.91%), and Ulster (6.06%). The percentage of Bil donors recorded from each province, broadly reflected Ireland’s population distribution where Leinster comprised 55.3% of the population, followed by Munster 26.9%, Connacht 11.6%, and Ulster at 6.2%.\textsuperscript{35}

3.3 | Non Irish born donors (n = 488)

The ABO phenotype distribution for the Bol donors was: Group A: 35.25%, Group B: 17.42%, Group O: 39.96% and Group A,B: 7.38%. RhD positive: 81.76% and RhD negative: 18.24%. Refer to Table 4 for the totals for the eight ABO blood group frequencies and Table 5 for the Rh phenotype of the Bol donors by geographical region.\textsuperscript{23}

Estimated Rh phenotype haplotype (n = 488): R\textsubscript{1}: 45.09%, R\textsubscript{2}: 14.14%, R\textsubscript{1}: 0.72%, R\textsubscript{2}: 10.0%, r,r: 0.82%, r,r: 0.00%, r: 39.15%.

The JK phenotype was: Jk(a+b+): 49.59%, Jk(a+b−): 24.80% and Jk(a+b−): 25.61%. The JK BGS distribution by each geographical region can be found in Table 6.

The four largest groups of Bol donors were found in Europe split into four regions\textsuperscript{23}: Northern: 27.5%, Eastern: 26.43%, Southern: 11.48%, and Western: 12.30%. The other 110 donors came from various parts of the World. Asian donors accounted for 9.22%, Oceania 3.07%, Africa 1.64%, and North American donors comprised 8.61% of the Bol donors.

3.4 | Bol donor participation in the study relative to their proportion in the population

Refer to Table 7 for the estimated proportions in the Irish population of each geographical area where the Bol donors from this
study indicated origin. The populations of these geographical regions where the BoI donors indicated origin comprised an estimated 10% of Ireland's total resident population, with the European regions comprising almost 9% of this figure. However, with a sample size of 488 BoI donors, less than 0.10% of the BoI donor's resident in Ireland participated.

### 3.5 Analysis

The data was assessed using an urban/rural analysis format to determine if there were differences of the relevant distributions within Ireland. Further analysis established if there were
differences in the resultant two populations. Analysis of the observed vs calculated expected values from the allele frequencies was performed. An analysis with that expected from previous studies\textsuperscript{a,6,15-17} to the observed values obtained in this 2015 snapshot was undertaken for ABO and RhD distributions.

| TABLE 2 | Rh phenotype distribution for BiI donors |
|---------|-----------------------------------------|
|         | R1R1 | R1R2 | R2R2 | R1r  | R2r  | Ror  | r’r  | r’r  | rr   | Other | Total |
| Leinster|       |      |      |      |      |      |      |      |      |      |       |
| Carlow  | 7     | 6    | 1    | 10   | 3    | 0    | 0    | 0    | 3    | 0    | 30    |
| Dublin  | 73    | 56   | 15   | 144  | 63   | 7    | 1    | 5    | 74   | 0    | 436   |
| Kildare | 19    | 14   | 7    | 36   | 17   | 0    | 0    | 0    | 26   | 0    | 113   |
| Kilkenny| 11    | 8    | 4    | 39   | 6    | 0    | 0    | 1    | 17   | 0    | 86    |
| Laois   | 14    | 4    | 0    | 17   | 9    | 0    | 0    | 0    | 4    | 0    | 48    |
| Longford| 2     | 0    | 0    | 2    | 1    | 1    | 0    | 0    | 3    | 0    | 9     |
| Louth   | 8     | 14   | 1    | 22   | 7    | 0    | 0    | 1    | 11   | 0    | 64    |
| Meath   | 16    | 17   | 1    | 30   | 17   | 2    | 1    | 0    | 18   | 0    | 102   |
| Offaly  | 5     | 6    | 0    | 20   | 12   | 0    | 0    | 0    | 11   | 0    | 54    |
| Westmeath| 12   | 9    | 1    | 20   | 5    | 2    | 0    | 0    | 7    | 0    | 56    |
| Wexford | 15    | 19   | 4    | 40   | 21   | 1    | 0    | 0    | 25   | 0    | 125   |
| Wicklow | 14    | 7    | 3    | 24   | 8    | 3    | 0    | 0    | 18   | 0    | 77    |
| Sub-Total| 237 | 187  | 42   | 483  | 190  | 17   | 2    | 6    | 258  | 0    | 1422  |
| %       | 16.67 | 13.15 | 2.95 | 33.97 | 13.36 | 1.20 | 0.14 | 0.42 | 18.14 | 0.00 | 100   |
| Munster |       |      |      |      |      |      |      |      |      |      |       |
| Clare   | 10    | 15   | 3    | 17   | 12   | 1    | 0    | 0    | 13   | 0    | 71    |
| Cork    | 78    | 61   | 13   | 150  | 59   | 4    | 6    | 4    | 75   | 2\textsuperscript{a} | 452   |
| Kerry   | 20    | 12   | 1    | 38   | 19   | 2    | 1    | 2    | 11   | 0    | 106   |
| Limerick| 22    | 12   | 4    | 37   | 16   | 3    | 0    | 1    | 13   | 1\textsuperscript{b} | 109   |
| Tipperary| 15   | 27   | 7    | 42   | 18   | 3    | 0    | 2    | 18   | 0    | 132   |
| Waterford| 12   | 19   | 5    | 42   | 16   | 1    | 2    | 0    | 22   | 0    | 119   |
| Sub-Total| 157 | 146  | 33   | 326  | 140  | 14   | 9    | 9    | 152  | 3    | 989   |
| %       | 15.87 | 14.76 | 3.34 | 32.96 | 14.16 | 1.42 | 0.91 | 0.91 | 15.37 | 0.30 | 100   |
| Connacht|       |      |      |      |      |      |      |      |      |      |       |
| Galway  | 26    | 22   | 4    | 55   | 20   | 2    | 0    | 2    | 21   | 0    | 152   |
| Leitrim | 4     | 5    | 0    | 8    | 2    | 1    | 0    | 0    | 4    | 0    | 24    |
| Mayo    | 13    | 14   | 4    | 32   | 12   | 0    | 0    | 0    | 14   | 0    | 89    |
| Roscommon| 5    | 13   | 1    | 9    | 5    | 0    | 0    | 0    | 6    | 0    | 39    |
| Sligo   | 6     | 7    | 2    | 15   | 6    | 0    | 0    | 0    | 10   | 0    | 46    |
| Sub-Total| 54   | 61   | 11   | 119  | 45   | 3    | 0    | 2    | 55   | 0    | 350   |
| %       | 15.43 | 17.43 | 3.14 | 34.00 | 12.86 | 0.86 | 0.00 | 0.57 | 15.71 | 0.00 | 100   |
| Ulster (part of)|       |      |      |      |      |      |      |      |      |      |       |
| Cavan   | 11    | 5    | 0    | 21   | 5    | 1    | 0    | 0    | 9    | 0    | 52    |
| Donegal | 21    | 11   | 0    | 35   | 9    | 1    | 0    | 0    | 39   | 0    | 86    |
| Monaghan| 9     | 8    | 2    | 9    | 4    | 0    | 0    | 1    | 7    | 0    | 40    |
| Sub Total| 41  | 24   | 2    | 65   | 18   | 2    | 0    | 1    | 25   | 0    | 178   |
| %       | 23.03 | 13.48 | 1.12 | 36.52 | 10.11 | 1.12 | 0.00 | 0.56 | 14.04 | 0.00 | 100   |
| Total   | 489   | 418  | 88   | 993  | 393  | 36   | 11   | 18   | 490  | 3    | 2939  |
| %       | 16.64 | 14.22 | 2.99 | 33.79 | 13.37 | 1.22 | 0.37 | 0.61 | 16.67 | 0.10 | 100   |

\textsuperscript{a}R1Rz by one and R2Rz by one.

\textsuperscript{b}R1Rz by one.
3.5.1 Irish born donors data analysis

The Irish ABO distribution was analyzed using chi square for urban / rural association. Using a 7 x 2 contingency table (Supplementary Table: S1) for Dublin, Leinster, Cork, Munster, Galway, Connacht, and Ulster and the eight blood group totals, no statistically significant differences were found between the ABO distribution and geographical areas within Ireland. $\chi^2 = 40.58, 42\text{df}, P\text{-value} = 0.534$.

The same regions (Dublin, Leinster, Cork, Munster, Galway, Connacht, and Ulster) were analyzed for RhD positive vs RhD negative association using a 7 x 2 contingency table (S2). No statistically significant association was found between the urban and rural areas with regards to D antigen distribution. $\chi^2 = 4.63, 6\text{df}, P\text{-value} = 0.592$.

A rural/urban analysis using a 7 x 3 (Dublin, Leinster, Cork, Munster, Galway, Connacht, and Ulster) contingency table (S3) was used to examine the JK distribution within Ireland. No statistically significant difference was found in this distribution within the geographical areas of Ireland. $\chi^2 = 18.45, 12\text{df}, P\text{-value} = 0.103$.

Another rural/urban analysis was used to examine the Rh phenotype distribution throughout Ireland using a 7 x 10 (Dublin, Leinster, Cork, Munster, Galway, Connacht, and Ulster) contingency table. (S4). No evidence of any statistically significant differences in Rh phenotype distribution within Ireland was found. $\chi^2 = 57.78, 54\text{df}, P\text{-value} = 0.338$.

3.5.2 Irish born vs non-Irish born donor data analysis

The BiI vs BoI donor population was analyzed for the eight ABO blood groups, using a 2 x 8 contingency table (S5). On analysis, a highly statistically significant difference: ($\chi^2 = 78.42, 7\text{df}, P\text{-value} < 0.001$), was found which indicated a strong difference between the two populations in regard to the ABO blood group distribution, the result being a relative decrease in Group O and a relative increase in Group A, B and Group A,B in the BoI donor population.

Both populations were analyzed for RhD positive vs RhD negative associations, using a 2 x 2 contingency table (S6). No statistically significant difference was found. $\chi^2 = 0.10, 1\text{df}, P\text{-value} = 0.757$.

The Rh phenotype distribution between the two populations was analysed in a 2 x 10 contingency table (S7); a highly statistically significant difference ($\chi^2 = 31.48, 9\text{df}, P\text{-value} < 0.001$) was noted for the populations in regard to RHCE distributions; the two largest single degree of freedom components were: R1R1 for BiI donors (16.64%) vs BoI donors (23.57%) where $\chi^2 = 13.83, 1\text{df}, P\text{-value} < 0.001$ and for r’r for BiI donors (0.37%) vs BoI donors (1.64%) where $\chi^2 = 12.08, 1\text{df}, P\text{-value} = 0.001$.

The JK distribution of both populations was analyzed using a 2 x 3 contingency table (S8); $\chi^2 = 0.93, 2\text{df}, P\text{-value} = 0.627$; therefore, no evidence of a statistically significant difference between the two populations was found.

3.5.3 Expected Allele frequency calculations (HWE) and analysis

For the allele frequencies for the relevant BGS’s refer to Table 8. The observed and estimated expected allele values$^{29-34}$ are found in Table 9.
Chi square analysis for the ABO BGS frequency for the observed vs expected values were consistent with the population been in Hardy Weinberg equilibrium for the total, BiI and BoI populations as the P-value was greater than .10 for each analysis, which indicated no statistically significant difference between the observed and the expected ABO groups calculated for each population.

The RhD phenotype was determined serologically as RhD positive and RhD negative, however, the expected values for RhD+ hemizygous vs homozygous expression were calculated from the observed allele frequencies (Table 9) for each population. Expected JK allele estimates were also calculated from the observed allele frequencies for each population. Chi square analyses between the observed and expected D values and JK values (Table 9) indicated agreement for each donor population.

### 3.5.4 | Expected BGS prevalence vs observed BGS prevalence

The observed prevalence (total and BiI) with that expected can be found in Table 10. The differences considered clinically relevant for this study were 5.0% for all groups except, 3.0% for Group B and 1.0% for Group A.B. All observed values were within 95% confidence limits of the expected values, calculated at 80% and 90% power. 80% power was achieved for Group O and Jk(a+b+) phenotypes and 90% power was achieved for RhD antigen sample size for this study. The difference between the observed and expected (Table 10) was not considered clinically relevant.

### 3.5.5 | Analysis of observed values with previous studies

Previous study frequencies, plus the author’s data for total (n = 3427), BiI (n = 2939), and BoI (n = 488) are in Table 11. It can be observed that there is variability in regard to ABO frequencies between the previous studies and between the current study and the previous studies. Contingency tables for two previous studies were prepared; these were the only two studies with total numbers that could be tabulated for the eight ABO groups in the same format as current study. On analysis in a 3 × 8 contingency table (S9), statistical significant differences were found: \( \chi^2 = 30.69, 14 \text{ df}, P \text{-value} = 0.006 \). However, when the current study was compared to the 1956 study; \( \chi^2 = 15.84, 7 \text{ df}, P \text{-value} = 0.027 \) but not for the 1964 study; \( \chi^2 = 6.27, 7 \text{ df}, P \text{-value} = 0.517 \).

An earlier (1940) study and later (1977) study was analyzed, with the current study, using 2 × 4 contingency tables (S12 and S13). A

| TABLE 4 | ABO BGS distribution for BoI donors |
|----------|-----------------------------------|
|          | A+ | A- | B+ | B- | O+ | O- | AB+ | AB- | Total |
| Northern Europe |     |    |    |    |    |    |     |     |       |
| Total       | 36  | 6  | 15 | 4  | 56 | 12 | 2   | 2   | 133   |
| %          | 27.07 | 4.51 | 11.28 | 3.01 | 42.11 | 9.02 | 1.50 | 1.50 | 100   |
| Eastern Europe |     |    |    |    |    |    |     |     |       |
| Total       | 33  | 19 | 18 | 8  | 28 | 5  | 15  | 3   | 129   |
| %          | 25.58 | 14.73 | 13.95 | 6.20 | 21.71 | 3.88 | 11.63 | 2.33 | 100   |
| Southern Europe |     |    |    |    |    |    |     |     |       |
| Total       | 14  | 5  | 5  | 2  | 24 | 2  | 4   | 0   | 56    |
| %          | 25.00 | 8.93 | 8.93 | 3.57 | 42.86 | 3.57 | 7.14 | 0.00 | 100   |
| Western Europe |     |    |    |    |    |    |     |     |       |
| Total       | 21  | 7  | 8  | 0  | 16 | 4  | 4   | 0   | 60    |
| Total %     | 35.00 | 11.67 | 13.33 | 0.00 | 26.67 | 6.67 | 6.67 | 0.00 | 100   |
| Eastern Asia |     |    |    |    |    |    |     |     |       |
| Total       | 2   | 0  | 3  | 0  | 3  | 0  | 1   | 0   | 9     |
| Central Asia |     |    |    |    |    |    |     |     |       |
| Total       | 1   | 0  | 0  | 0  | 0  | 0  | 0   | 0   | 1     |
| Southern Asia |     |    |    |    |    |    |     |     |       |
| Total       | 1   | 0  | 0  | 0  | 1  | 0  | 0   | 0   | 2     |
| South East Asia |     |    |    |    |    |    |     |     |       |
| Total       | 3   | 0  | 3  | 0  | 7  | 0  | 1   | 0   | 14    |
| Western Asia |     |    |    |    |    |    |     |     |       |
| Total       | 4   | 0  | 7  | 0  | 6  | 1  | 1   | 0   | 19    |
| Northern America |     |    |    |    |    |    |     |     |       |
| Total       | 11  | 2  | 6  | 2  | 16 | 3  | 2   | 0   | 42    |
| Oceania     |     |    |    |    |    |    |     |     |       |
| Total       | 5   | 0  | 2  | 0  | 6  | 1  | 1   | 0   | 15    |
| Africa      |     |    |    |    |    |    |     |     |       |
| Total       | 2   | 0  | 1  | 1  | 4  | 0  | 0   | 0   | 8     |
| Overall Total | 133 | 39 | 68 | 17 | 167 | 28 | 31  | 5   | 488   |
| Overall %   | 27.25 | 7.99 | 13.93 | 3.48 | 34.22 | 5.74 | 6.35 | 1.02 | 100   |
A statistically significant difference was found for the 1940\(^4\) study; \(\chi^2 = 8.76, 3\text{ df}, P\text{-value} = 0.033\), but not for the 1977\(^1\) study; \(\chi^2 = 0.53, 3\text{ df}, P\text{-value} = 0.912\).

An assessment of RhD frequency change over time was performed using two contingency tables in 2 \(
\chi^2\) formats (S14 and S15) for the 1948\(^1\) study; \(\chi^2 = 2.45, 2\text{ df}, P\text{-value} = 0.117\) and 1964 study\(^5\) \(\chi^2 = 1.15, 2\text{ df}, P\text{-value} = 0.283\). These were the only two studies with total numbers for tabulations. No statistical significance was found for the RhD antigen distribution from analysis of these previous studies.

### 4 | DISCUSSION

The observed phenotype frequencies have remained relatively unchanged from the prevalence values expected\(^1\)-\(^3\)-\(^6\)-\(^1\) for the study (Table 10), however, variability was observed between the previous studies\(^5\)-\(^8\)-\(^1\) and between this study and the past studies (Table 11). From the available evidence, statistical significance was found for the ABO distribution between this study and some of the previous studies but not for the RhD antigen distribution.

The Bol donor population was statistically significantly different to the Bil population in relation to aspects of the ABO and Rh phenotype distribution. This has service implications for the IBTS; in terms of patient requirements, as there is a cohort of sickle cell anemia patients of African ancestry on transfusion programs for primary prophylaxis of cerebrovascular disease where Group B frequency at greater than 20% are found.\(^1\) Group O is often substituted for Group B for this cohort of patients leading to pressures on the Universal group.

Low numbers of donors came from the African continent (1.64%). Increased recruitment of these donors would broaden the choice of blood groups available to ensure matching of groups to patients and might help to avoid overuse of O negative units (rr substituted for R\(r\) or R\(r\) or R\(rr\)). O negatives accounted for 9.40% of the Irish blood supply according to this study. This is of concern and the IBTS has a business objective that the BAME community (Black, Asian, and Minority Ethnic populations) will be targeted for blood donation, post introduction of malaria testing at the IBTS.

Most haemoglobinopathy and thalassemia patients require extended phenotyping due to regular transfusions and exchanges.\(^2\) Many of these patients require four to eight units twice a month, with an exchange transfusion requiring 10 units. With increased recruitment of African born donors an increase in R\(r\) blood products would be expected. R\(r\) prevalence for these donors is 45.8% whereas for Caucasians the R\(r\) prevalence is 2.1%.\(^1\) From this study, R\(r\) phenotypes comprised 1.22% of Bil donors and 1.43% of Bol donors. The provision of R\(r\) blood cell products presents a significant challenge.

**TABLE 5** Rh phenotype BGS distribution for Bol donors

|          | R1R1 | R1R2 | R2R2 | R1r  | R2r  | Ror  | r’r   | r’r   | rr   | Other | Total |
|----------|------|------|------|------|------|------|-------|-------|------|-------|-------|
| Northern Europe | 25   | 23   | 5    | 36   | 18   | 2    | 4     | 0     | 20   | 0     | 133   |
| %        | 18.80| 17.29| 3.76 | 27.07| 13.53| 1.50 | 3.01  | 0.00  | 15.04| 0.00  | 100   |
| Eastern Europe | 32   | 8    | 3    | 39   | 11   | 0    | 4     | 0     | 31   | 1\(^a\) | 129   |
| %        | 24.81| 6.20 | 2.33 | 30.23| 8.53 | 0.00 | 3.10  | 0.00  | 24.03| 0.78  | 100   |
| Southern Europe | 15   | 3    | 0    | 25   | 4    | 0    | 0     | 0     | 9    | 0     | 56    |
| %        | 26.79| 5.36 | 0.00 | 44.64| 7.14 | 0.00 | 0.00  | 0.00  | 16.07| 0.00  | 100   |
| Western Europe | 15   | 5    | 0    | 20   | 8    | 1    | 0     | 0     | 11   | 0     | 60    |
| Total %  | 25.00| 8.33 | 0.00 | 33.33| 13.33| 1.67 | 0.00  | 0.00  | 18.33| 0.00  | 100   |
| Eastern Asia | 4    | 2    | 1    | 0    | 2    | 0    | 0     | 0     | 0    | 0     | 9     |
| Central Asia | 0    | 0    | 0    | 1    | 0    | 0    | 0     | 0     | 0    | 0     | 1     |
| Southern Asia | 0    | 1    | 0    | 1    | 0    | 0    | 0     | 0     | 0    | 0     | 2     |
| South East Asia | 9    | 4    | 0    | 1    | 0    | 0    | 0     | 0     | 0    | 0     | 14    |
| Western Asia | 5    | 3    | 0    | 5    | 2    | 3    | 0     | 0     | 1    | 0     | 19    |
| Northern America | 8    | 7    | 2    | 12   | 6    | 0    | 0     | 0     | 7    | 0     | 42    |
| Oceania | 0    | 2    | 0    | 8    | 4    | 0    | 0     | 0     | 1    | 0     | 15    |
| Africa | 2    | 2    | 0    | 2    | 0    | 1    | 0     | 0     | 1    | 0     | 8     |
| Overall Total | 115  | 60   | 11   | 150  | 55   | 7    | 8     | 0     | 81   | 1     | 488   |
| Overall %  | 23.57| 12.30| 2.25 | 30.74| 11.27| 1.43 | 1.64  | 0.00  | 16.60| 0.20  | 100   |

\(^a\)R\(_2\)R\(_2\) by one.

\(\chi^2\) distribution for Bol donors.
for blood stock management. The frequency of 45% Ror prevalence in populations of African ethnicity does not impact on the Irish supply because of low participation of this group in blood donation. The 2016 census reported 64 639 citizens of African ethnicity resident in Ireland.

The ABO BGS of the Bol donors had increased Group A, Group B, and Group A,B and less Group O than the Bi donor group. This fact was particularly noticeable for the Eastern European donors who comprised 26.43% of the Bol donors (Table 4). A limitation of this data was n = 129, however, increased recruitment of these donors might assist in the provision of ABO matched blood groups. Poland, a country in the eastern European geographical area, accounted for the largest non-Irish national group in Ireland with a population of 122 515.

The first time donor’s Bol comprised 14.24% of the donor population in this study, which is positive for the IBTS in terms of donor geographical diversity to enable provision of units for those patients with complex transfusion requirements. However, it was demonstrated that the European cohort (378 donors: 77.46%) had compensated for the Non-European cohort (110 donors: 22.54%). This was reflective of the non-Irish population living in Ireland corresponding to the geographical location of the Bol donor population (Table 7).

Based on the number of Bol donors who donated during this study, an estimated 1800 Bol donors could be expected to donate to the IBTS in a year; this might be increased substantially with a proposed targeted advertising campaign aimed to recruit more donors from all World regions, in particular, to encourage the non-European cohort.

The Jk(a-b-) phenotype can be found at highest frequencies in Polynesian donors where frequency occurs at 0.9%. With few donors from this World region, this rare Jk(a+/b-) phenotype was not observed in this 2015 snapshot of 3423 donors. No evidence of Jk(a++b++) phenotype was observed. A small number of donors (0.38%) were at the threshold of detection with a weakened Jkb antigen expression, all had heterozygous antigen expression.

**Table 6** Kidd BGS distribution for Bol donors

| Geographical Origin | Jk(a+b+) | Jk(a-b+) | Jk(a+b-) | Total |
|---------------------|----------|----------|----------|-------|
| Northern Europe     | 69       | 34       | 30       | 133   |
| %                   | 51.88    | 25.56    | 22.56    | 100   |
| Eastern Europe      | 65       | 33       | 31       | 129   |
| %                   | 50.39    | 25.58    | 24.03    | 100   |
| Southern Europe     | 27       | 13       | 16       | 56    |
| %                   | 48.21    | 23.21    | 28.57    | 100   |
| Western Europe      | 31       | 12       | 17       | 60    |
| %                   | 51.67    | 20.00    | 28.33    | 100   |
| Central Asia        | 4        | 1        | 4        | 9     |
| Southern Asia       | 2        | 0        | 0        | 1     |
| South Eastern Asia  | 3        | 5        | 6        | 14    |
| Western Asia        | 9        | 5        | 5        | 19    |
| Northern America    | 20       | 10       | 12       | 42    |
| Oceania             | 7        | 5        | 3        | 15    |
| Africa              | 4        | 3        | 1        | 8     |
| Overall Total       | 242      | 121      | 125      | 488   |
| Overall %           | 49.59    | 24.80    | 25.61    | 100   |

**Table 7** Bol donor participation relative to their proportion in the Irish population

| Geographical origin of the Bol donors | Non-Irish Donors | % Bol population resident in Ireland from each Geographical Origin | % resident in Ireland from each geographical area as % of the total Irish population | % participation of Bol donors in study as % of each geographical area resident in Ireland |
|--------------------------------------|-----------------|---------------------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| N                                    | 2011a 2016b     | 2011a 2016a                                                    | 2011 2016                                                                         | 2011 2016                                                                         |
| N Europe                             | 133              | 174 676 164 295                                               | 3.86 3.50                                                                        | 0.08 0.08                                                                        |
| E Europe                             | 129              | 173 173 182 754                                               | 3.83 3.90                                                                        | 0.07 0.07                                                                        |
| S Europe                             | 56               | 19 160 35 461                                                 | 0.42 0.76                                                                        | 0.29 0.16                                                                        |
| W Europe                             | 60               | 27 823 30 680                                                 | 0.61 0.65                                                                        | 0.22 0.20                                                                        |
| E Asia                               | 9                | 12 616 11 702                                                 | 0.28 0.25                                                                        | 0.07 0.08                                                                        |
| C Asia                               | 1                | 125                                                          | 0.00 0.00                                                                        | 0.80 0.80                                                                        |
| S Asia                               | 2                | 3218 1958                                                    | 0.07 0.04                                                                        | 0.44 0.72                                                                        |
| SE Asia                              | 14               | 7213 16 086                                                  | 0.16 0.34                                                                        | 0.03 0.01                                                                        |
| W Asia                               | 19               | 2918 4545                                                   | 0.06 0.10                                                                        | 0.65 0.42                                                                        |
| N America                            | 42               | 13 404 12 985                                                | 0.30 0.28                                                                        | 0.31 0.32                                                                        |
| Oceania                              | 15               | 4243 3524                                                   | 0.09 0.08                                                                        | 0.35 0.43                                                                        |
| Africa                               | 8                | 9342 6442                                                   | 0.21 0.14                                                                        | 0.09 0.12                                                                        |
| Total                                | 488              | 447 911 470 557                                              | 9.90 10.03                                                                       | 0.11 0.10                                                                        |

aPopulation usually resident in Ireland 2011: 4 525 281. bPopulation usually resident in Ireland 2016: 4 689 921.
Previous Irish studies and this current study agree that Group O had a higher frequency in the west of Ireland (greater than 60% in Connacht). For example, clinics in the west of Ireland would yield more Group O donors. A higher percentage of Group A in Ulster, relative to the other provinces (Table 1) agreed with previous observations. Previous studies noted higher rates of Group B, in particular in relation to Roscommon and Longford. There was insufficient data from these counties to assess this, however, the Ulster province (n = 178) recorded highest Group B (12.92%). Rh phenotype data from a previous Irish study agreed with this 2015 study (Table 2) which showed higher R1R2 complexes in Connacht (17.43%) and also indicated a higher prevalence of rr donors in Leinster (18.14%).

| Allele | Total (n=3427) | Observed | Expected |
|--------|----------------|----------|----------|
| A      | 1022           | 1022     | 172      |
| B      | 412            | 424      | 85       |
| O      | 1883           | 1883     | 195      |
| AB     | 110            | 98       | 36       |
| RhD+ (homozygous) | 1185     | 1148     | 187      |
| RhD+ (hemizygous)  | 1634     | 1671     | 212      |
| RhD-   | 608            | 608      | 89       |
| JK'A   | 925            | 920      | 125      |
| JK'B   | 799            | 794      | 121      |
| JK'AJK'B | 1699    | 1709     | 242      |

Individual data from counties in Ireland for the Bil donors was insufficient to analyze differences between the counties and provinces in more detail so one would need a larger study with more data from all counties to observe these trends. A larger study on the Bol donors would give stronger evidence of an overall difference of this population to the Irish population, with larger sample sizes from all the geographical areas.

A significant limitation of this study was that the ethnic background of the donor could not be captured on the Health and Lifestyle questionnaire (HLQ), therefore Bil donors who were not of white Irish ethnicity were not identified; the same applied to Bol donors who may in fact have been of Irish ethnicity but Bol. Many people may be born in for example, Africa, but state that their nationality is Irish and vice versa. Dual nationalities have increased from 55,905 in 2011 to 104,784 in 2016. However, in the absence of ethnicity data the Bol measure is used as the best surrogate available. The IBTS have plans to capture donor ethnicity on the HLQ’s to enable selection of donors for extended phenotyping and to identify rare donors for specific screening.

| Blood group phenotypes | Expected prevalence % | Observed % | Observed% |
|------------------------|------------------------|------------|-----------|
| O                      | 5<sup>14,15</sup>      | 55         | 57        |
| A                      | 31<sup>14,15</sup>     | 30         | 29        |
| B                      | 11<sup>14,15</sup>     | 12         | 11        |
| AB                     | 3<sup>14,15</sup>      | 3          | 3         |
| D                      | 8<sup>34,16</sup>      | 82         | 82        |
| Jk(a-b-)               | 23<sup>13</sup>        | 23         | 23        |
| Jk(a+b-)               | 26<sup>13</sup>        | 27         | 27        |
| Jk(a+b+)               | 50<sup>13</sup>        | 50         | 50        |

### Table 8

| Allele | A<sup>29</sup> | B<sup>29</sup> | O<sup>29</sup> | RhD+<sup>30,31</sup> | RhD-<sup>30,31</sup> | JK'A<sup>32-34</sup> | JK'B<sup>32-34</sup> |
|--------|----------------|----------------|---------------|----------------------|----------------------|----------------------|----------------------|
| All Ireland | 0.1796 | 0.0772 | 0.7432 | 0.5788 | 0.4212 | 0.5184 | 0.4816 |
| Bil     | 0.1715 | 0.0702 | 0.7584 | 0.5798 | 0.4202 | 0.5208 | 0.4792 |
| Bol     | 0.2360 | 0.1258 | 0.6382 | 0.5729 | 0.4271 | 0.5041 | 0.4959 |

### Table 9

| Allele | Total (n=3427) | Observed | Expected |
|--------|----------------|----------|----------|
| A      | 1022           | 1022     | 172      |
| B      | 412            | 424      | 85       |
| O      | 1883           | 1883     | 195      |
| AB     | 110            | 98       | 36       |
| RhD+ (homozygous)<sup>a</sup> | 1185 | 1148 | 187 |
| RhD+ (hemizygous)<sup>a</sup> | 1634 | 1671 | 212 |
| RhD-   | 608            | 608      | 89       |
| JK'A   | 925            | 920      | 125      |
| JK'B   | 799            | 794      | 121      |
| JK'AJK'B | 1699    | 1709     | 242      |

### Table 10

| Blood group phenotypes | Expected prevalence % | Observed % | Observed% |
|------------------------|------------------------|------------|-----------|
| O                      | 5<sup>14,15</sup>      | 55         | 57        |
| A                      | 31<sup>14,15</sup>     | 30         | 29        |
| B                      | 11<sup>14,15</sup>     | 12         | 11        |
| AB                     | 3<sup>14,15</sup>      | 3          | 3         |
| D                      | 8<sup>34,16</sup>      | 82         | 82        |
| Jk(a-b-)               | 23<sup>13</sup>        | 23         | 23        |
| Jk(a+b-)               | 26<sup>13</sup>        | 27         | 27        |
| Jk(a+b+)               | 50<sup>13</sup>        | 50         | 50        |

5 | Conclusion

3427 donors with a full Rh phenotype and 3423 donors with a Kidd type were added to the IBTS donor database; these donors were available for further extended phenotyping on re-donation. The observed phenotype frequencies for the relevant BGS’s remained relatively unchanged from the prevalence values expected for the study, however, statistical significance was found between this study and
some of the previous studies for ABO distribution. The ABO and Rh phenotype distribution between the BiI and BoI donors was found to be statistically significantly different in aspects of their frequencies; it is these BoI donors that the IBTS hopes to encourage to donate with various campaigns. The outcome is a snapshot of the ABO (001), RH (004), and JK (009) BGSs in modern Ireland.

**ACKNOWLEDGEMENTS**

The authors wish to acknowledge the support of all colleagues (past and present) at the ADG Laboratory in the IBTS. The research was undertaken as part of the distance learning MSc Biomedical Science course at the University of Ulster, under the supervision of Stuart Adshead (RIP). A scientific writing and publishing workshop provided by the Academy of Clinical Science and Laboratory medicine (ACSLM) in 2019 incentivized the writing of this manuscript.

**FUNDING**

All funding was through the ADG Department at the IBTS, where all resources for the study were provided. The ADG department had no involvement in study design, collection, writing of the report and the decision to submit the report for publication. The testing of all donors occurred within the daily operations at the ADG laboratory.

**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

**COMPETING INTERESTS**

The authors have no competing interests.

**AUTHOR CONTRIBUTIONS**

Conceptualization: Anne Browne.
Data Curation: Anne Browne
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**Investigation:** Anne Browne
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**Project Administration:** Anne Browne
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All authors have read and approved the final version of the manuscript.

Anne Browne had full access to all data in this study and takes complete responsibility for the integrity of the data and accuracy of the data analysis.

**TRANSPARENCY STATEMENT**

I Anne Browne affirm that this manuscript is an honest, accurate and transparent account of the study been reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

**DATA AVAILABILITY STATEMENT**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Browne A, Kinsella A, Keogh M, Morris K, Field S. A snapshot of ABO, RH, and JK blood group systems in modern Ireland. Health Sci Rep. 2021;4:e292. https://doi.org/10.1002/hsr2.292