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Expanding access to SARS-CoV-2 IgG and IgM serologic testing using fingerstick whole blood, plasma, and rapid lateral flow assays

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ABSTRACT

Serologic testing for SARS-CoV-2 antibodies can be used to confirm diagnosis, estimate seroprevalence, screen convalescent plasma donors, and assess vaccine efficacy. Dried blood spot (DBS) samples have been used for serology testing of various diseases in resource-limited settings. We examined the use of DBS samples and capillary blood (fingerstick) plasma collected in Microtainer tubes for SARS-CoV-2 testing with the automated Abbott ARCHITECT™ SARS-CoV-2 IgG and IgM assays and use of venous whole blood with a prototype PANBIO™ rapid point-of-care lateral flow SARS-CoV-2 IgG assay. The ARCHITECT™ SARS-CoV-2 IgG assay was initially optimized for use with DBS, venous and capillary plasma, and venous whole blood collected from patients with symptoms and PCR-confirmed COVID-19 and negative asymptomatic controls. Linearity and reproducibility was confirmed with 3 contrived DBS samples, along with sample stability and signal recovery after 14 days. ARCHITECT™ SARS-CoV-2 IgG and IgM assay results showed high concordance between fingerstick DBS and venous DBS samples, and between fingerstick DBS and venous whole blood samples ($n = 61$). Fingerstick plasma collected in Microtainer tubes ($n = 109$) showed 100% concordant results (R^2=0.997) with matched patient venous plasma on the ARCHITECT™ SARS-CoV-2 IgG assay. High concordance of assay results (92.9% positive, 100% negative) was also observed for the PANBIO™ SARS-CoV-2 IgG assay compared to the ARCHITECT™ SARS-CoV-2 IgG assay run with matched venous plasma ($n = 61$). Fingerstick DBS and plasma samples are easy and inexpensive to collect and, along with the use of rapid point-of-care testing platforms, will expand access to SARS-CoV-2 serology testing, particularly in resource-limited areas.

Introduction

Serologic testing for SARS-CoV-2 antibodies can be used to complement PCR-based diagnostic testing [1] and may assist in identifying asymptomatic cases or those with past infection as potential donors for convalescent plasma therapy. The COVID-19 pandemic has presented unique barriers to achieving widespread serologic testing, such as logistical and infrastructure challenges that limit the number of testing sites, transportation issues that reduce patient access to testing, and reluctance among patients to seek out testing in clinical settings that may pose increased exposure risk. Additionally, current serologic assays utilize venous-derived plasma, which requires trained phlebotomists and laboratory equipment. Removing these hurdles would increase access to SARS-CoV-2 serologic testing and improve viral tracking. Innovative approaches to expand serologic testing include the development of fully automated systems to increase throughput and rapid point-of-care platforms, as well as the use of samples that can be collected at home or in drive-through settings.

In low- and middle-income countries (LMICs) that lack capacity for venous blood draws or where transporting and storing blood samples is difficult, the use of dried blood spot (DBS) has improved access to diagnostic testing for various infectious diseases [2]. DBS are collected by applying blood from capillary puncture (fingerstick) directly to an absorbent paper card, which are dried and can be sent through the mail to centralized labs for testing. DBS are now widely used in low-resource settings for diagnosis and therapeutic monitoring of HIV and HBV [3-5]. Rapid lateral flow assays that utilize capillary blood further simplify serologic testing by combining sample collection and the assay in a single step, reducing the need for equipment and training. Capillary plasma can also be collected in Microtainer tubes, which eliminates the

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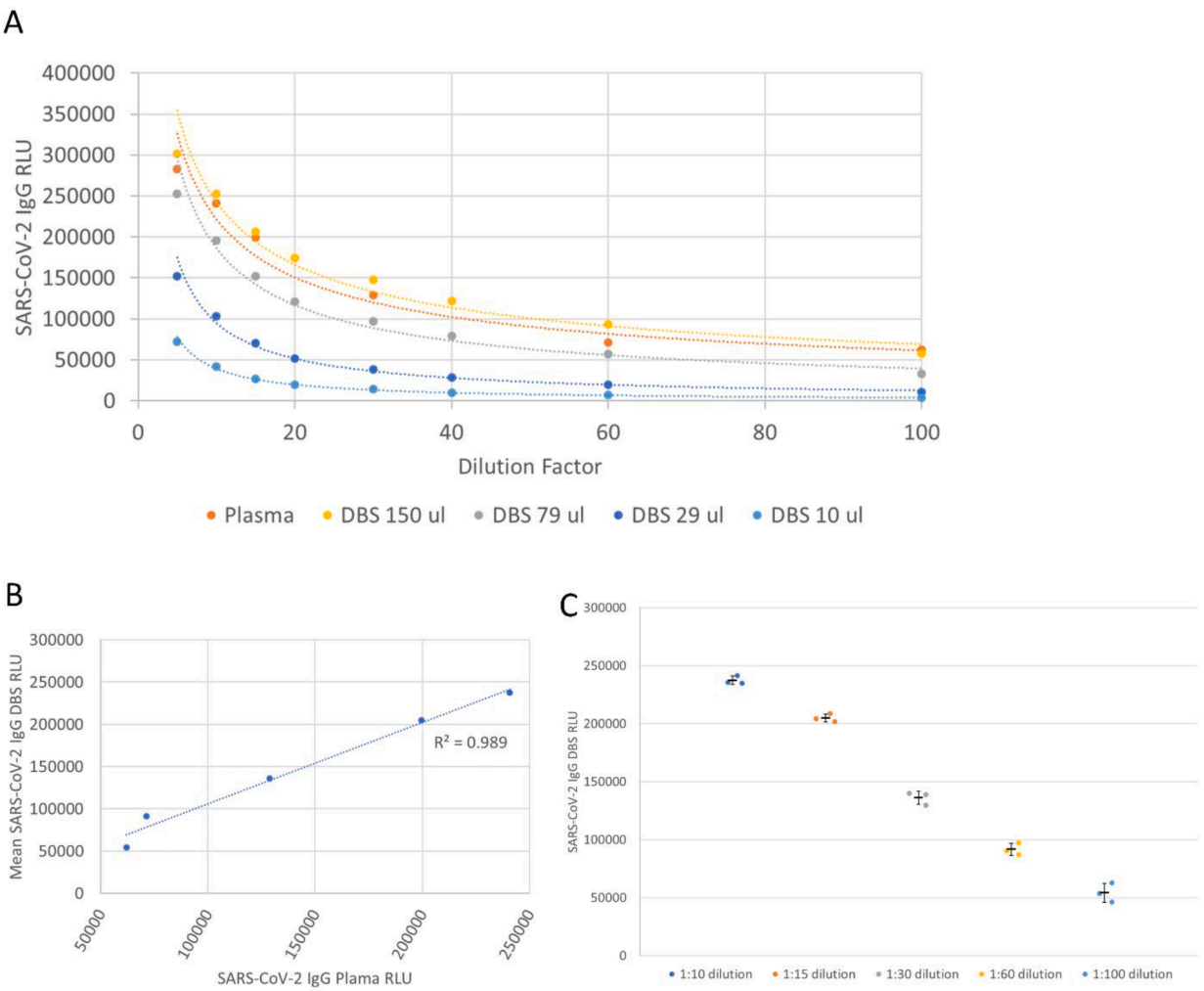

Fig. 1. Optimization of ARCHITECT SARS-CoV-2 IgG assay volumes for DBS. (A) Dilution series of DBS samples compared to venous plasma. DBS Sample volumes of 150, 79, 29, and 10 μL were tested. (B) Linearity of DBS and plasma sample RLUs. (C) Reproducibility of DBS results between 1:10 and 1:100 dilutions.

need for venipuncture. Previous studies found no difference in IgG serologic assay results when using capillary versus venous plasma [6, 7].

In this study, we assessed the feasibility of using DBS and capillary plasma as the starting material for the Abbott ARCHITECT™ SARS-CoV-2 IgG assay, approved under Emergency Use Authorization (EUA) to detect IgG antibodies against the SARS-CoV-2 nucleocapsid protein in human serum and plasma, and a prototype ARCHITECT SARS-CoV-2 IgM assay that detects IgM antibodies against the spike protein. We also examined clinical performance of these assays using DBS generated from venous or capillary whole blood compared to plasma. Finally, we performed a preliminary evaluation of the Abbott PANBIO™ lateral flow SARS-CoV-2 IgG assay performance compared to the ARCHITECT SARS-CoV-2 IgG assay.

Materials and methods

Study design and participants

Contrived DBS samples were used to optimize ARCHITECT™ SARS-CoV-2 IgG assay parameters, followed by a clinical performance study (IRB# 20041610-IRB01) to compare performance with DBS generated from fingerstick, DBS generated from venous blood, and venous plasma. Study participants presented to Rush University Medical Center with a diagnosis of COVID-19 after a positive SARS-CoV-2 PCR-based diagnostic test or with symptoms suggestive of COVID-19. A negative control cohort without COVID-19 symptoms was also collected.

The Microtainer study (IRB# 20,062,506-IRB01) compared ARCHITECT™ SARS-CoV-2 IgG assay performance using capillary fingerstick or venous plasma. Participants (n = 109) enrolled at Rush University Medical Center with a diagnosis of COVID-19 after a positive SARS-CoV-2 PCR-based diagnostic test or with symptoms suggestive of COVID-19. A negative control cohort without COVID-19 symptoms was also collected. After providing informed consent, venous blood was collected into vacutainer tubes and fingerstick blood was collected in microtainer tubes and tested with the ARCHITECT SARS-CoV-2 IgG assay to obtain comparative Index results.

PANBIO lateral flow SARS-CoV-2 IgG assay performance using whole blood was compared to the ARCHITECT SARS-CoV-2 IgG assay run with matched plasma using samples collected as described above under IRB# 20,041,610-IRB01. Testing was performed by pipetting 20 μL of venous whole blood and 20 μL of assay buffer into the appropriate wells of a PANBIO lateral flow cartridge, and results were read after 10 min according to the manufacturer's instructions. Testing and result reporting was performed blinded, with the test performer having no knowledge of which samples were SARS-CoV-2 IgG positive or negative based on previous ARCHITECT SARS-CoV-2 IgG assays with matched patient plasma samples.

DBS sample collection and testing

After providing informed consent, venous (12 ml) and fingerstick blood was collected from each study participant (n = 61). Five DBS

Table 1
SARS-CoV-2 IgG Results for DBS Sample 1 Stored for Various Times and Temperatures.

Room Temperature									
Dilution Factor	Day 1 RLU (Baseline)	Day 3 RLU	Day 3% Change from Day 1	Day 7 RLU	Day 7% Change from Day 1	Day 10 RLU	Day 10% Change from Day 1	Day 14 RLU	Day 14% Change from Day 1
1:10	237,264	240,740	1.47	244,689	3.13	254,242	7.16	238,611	0.57
1:15	204,980	200,346	−2.26	203,135	−0.90	205,646	0.32	191,857	−6.40
1:30	136,179	142,553	4.68	142,430	4.59	138,537	1.73	140,650	3.28
1:60	91,597	92,878	1.40	94,688	3.37	88,727	−3.13	84,020	−8.27
1:100	54,250	61,603	13.55	65,145	20.08	62,722	15.62	56,354	3.88
Average% Change			3.77		6.06		4.34		−1.39
−20 °C									
Dilution Factor	Day 1 RLU (Baseline)	Day 3 RLU	Day 3 % Change from Day 1	Day 7 RLU	Day 7 % Change from Day 1	Day 10 RLU	Day 10 % Change from Day 1	Day 14 RLU	Day 14 % Change from Day 1
1:10	237,264	255,167	7.55	236,172	−0.46	251,854	6.15	251,173	5.86
1:15	204,980	207,286	1.12	193,937	−5.39	194,688	−5.02	215,351	5.06
1:30	136,179	147,493	8.31	139,861	2.70	134,729	−1.06	145,339	6.73
1:60	91,597	82,838	−9.56	87,657	−4.30	93,684	2.28	85,284	−6.89
1:100	54,250	62,118	14.50	60,771	12.02	56,825	4.75	55,920	3.08
Average% Change			4.38		0.92		1.42		2.77
+37 °C									
Dilution Factor	Day 1 RLU (Baseline)	Day 3 RLU	Day 3 % Change to Day 1	Day-7 RLU	Day 7 % Change to Day 1	Day 10 RLU	Day 10 % Change to Day 1	Day 14 RLU	Day 14 % Change to Day 1
1:10	237,264	242,619	2.26	211,637	−10.80	231,496	−2.43	N/A	N/A
1:15	204,980	201,680	−1.61	185,222	−9.64	177,411	−13.45	N/A	N/A
1:30	136,179	142,385	4.56	119,879	−11.97	122,425	−10.10	N/A	N/A
1:60	91,597	89,201	−2.62	71,614	−21.82	69,715	−23.89	N/A	N/A
1:100	54,250	56,840	4.77	48,533	−10.54	45,016	−17.02	N/A	N/A
Average% Change			1.47		−12.95		−13.38		

RLU, relative light units.

samples each were generated from fingerstick and venous blood. A 6 ml aliquot of venous blood was frozen and stored at −80 °C and the remainder was processed into plasma. Deidentified plasma, whole blood, and DBS samples were shipped to Abbott Diagnostics (Abbott Park, IL) on dry ice. DBS results from IgG and IgM assays were compared to matched plasma to evaluate clinical performance of the sample type.

All samples were run on an Abbott ARCHITECT *i*2000SR instrument using the EUA-approved SARS-CoV-2 IgG (List 6R86) assay and prototype SARS-CoV-2 IgM assay (Abbott Diagnostics, Abbott Park, IL) per the ARCHITECT operations manual and assay package insert instructions, with volume modifications for the DBS samples based on optimization experiments. The qualitative SARS-CoV-2 IgG and IgM assays use chemiluminescent microparticles to detect IgG bound to the SARS-CoV-2 nucleocapsid protein or IgM bound to the SARS-CoV-2 spike protein. Assay results are measured in Relative Light Units (RLU) and reported as an index value of the ratio of specimen to calibrator RLU signal (S/C or S/Co). Index values ≥1.4 S/C indicate a SARS-CoV-2 IgG seropositive result and index values ≥1.0 S/C indicate a SARS-CoV-2 IgM seropositive result. The diagnostic accuracy of the ARCHITECT SARS-CoV-2 IgG assay [8-10] and prototype ARCHITECT SARS-CoV-2 IgM assay [11] have been previously reported.

DBS assay optimization

Assay volume optimization and stability studies used venous plasma from commercially available SARS-CoV-2 IgG-positive patients that was serially diluted in negative whole blood. DBS samples were generated by pipetting 70 μL of each blood dilution to the center of a 12-mm Whatman 903 (GE Healthcare/LabMate) DBS card (5 replicate spots/card) and dried overnight. DBS were punched into 1.5-mL Eppendorf tubes to which 300 μL elution buffer (1X PBS pH 7.4, 0.25% Triton X-100) was added. Samples were placed on a room temperature shaker for 1 hour and eluate was transferred into 2 mL cryogenic tube. Samples were centrifuged for 2 min at 10,000 RCF before running on the ARCHITECT *i*2000SR using the SARS-CoV-2 IgG or IgM assays.

Linearity and stability were assessed using contrived DBS samples generated from 3 commercially available SARS-CoV-2 IgG-positive patients. DBS cards were placed in plastic bags (Minigrip, LabMate) with 1 g silica gel desiccant (Uline) and stored at −20 °C, room temperature, or 37 °C in an incubator. After 1, 3, 7, 10, and 14 days, DBS samples were eluted as described above and 150 μL was run on the ARCHITECT SARS-CoV-2 IgG assay. Plasma and venous blood DBS samples from 4 study participants were tested in triplicate to assess reproducibility.

Results

ARCHITECT SARS-CoV-2 IgG assay performance with DBS

A commercially available SARS-CoV-2 IgG positive plasma sample (Sample 1) was serially diluted into negative whole blood for DBS production. DBS were eluted and run with modified SARS-CoV-2 IgG assay parameters to assess recovery at different sample volume inputs compared to control dilutions in normal plasma. A general DBS workflow diagram is presented in Supplemental Figure 1. A sample volume of 150 μl showed comparable DBS RLU results to plasma and was selected for the remaining experiments (Fig. 1A). Linearity and reproducibility were assessed by performing serial dilutions of 3 commercially available SARS-CoV-2 IgG-positive plasma samples in negative blood or normal plasma for DBS and controls, respectively. Testing was performed in triplicate and RLUs from the control dilutions were plotted against mean RLU results from the DBS dilutions. Linearity within the 3 samples showed strong correlations ($R^2 = 0.989$, 0.995, and 0.999) of recovered SARS-CoV-2 IgG signal from DBS compared to plasma (Fig. 1B and Supplemental Figure 2A). SARS-CoV-2 IgG signal recovery from DBS was also reproducible across all 3 samples (Fig. 1C and Supplemental Figure 2B), with%CV values below 6% for all tested conditions except the 1:100 dilution of Sample 1, which had a%CV of 15.33%.

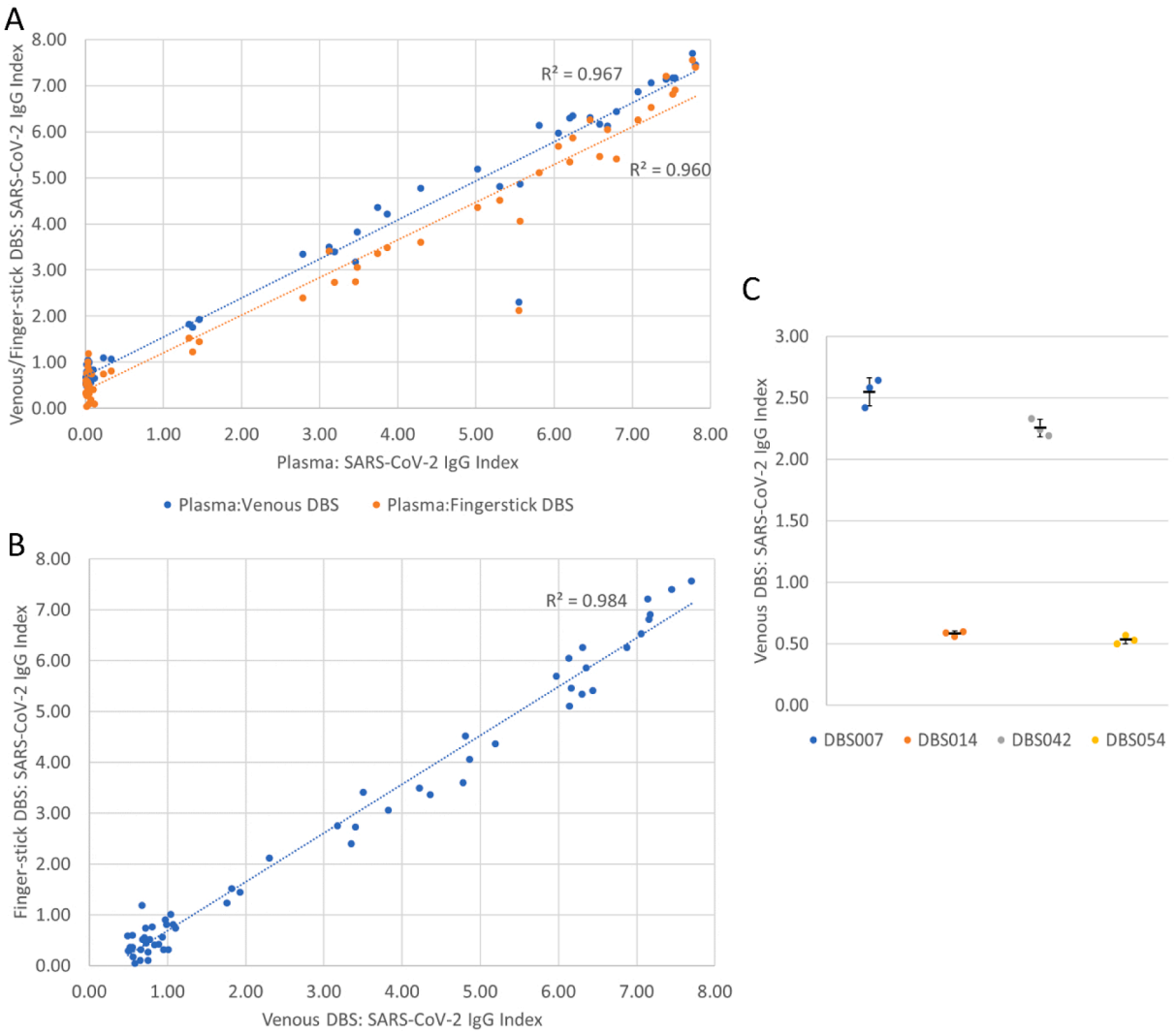

Fig. 2. Concordance of ARCHITECT SARS-CoV-2 IgG assay index values for various blood samples. (A) Venous plasma (gold standard) and DBS samples produced from venous or capillary (fingerstick) whole blood. (B) Index comparisons between paired DBS samples produced from venous or capillary (fingerstick) whole blood. DBS samples were eluted in PBS + 0.25% Triton X-100 and 150 μL was used for the IgG assay. (C) Reproducibility of SARS-CoV-2 assay results with venous whole blood DBS. Samples from 2 positive and 2 negative participants were tested in triplicate. Standard deviations in the index values were 0.02, 0.04, 0.11, and 0.07.

DBS stability

SARS-CoV-2 IgG stability in DBS was tested across multiple dilutions of the 3 positive samples at room temperature (RT), −20 °C, and 37 °C and at 1, 3, 7, 10, and 14-day intervals (Table 1: Sample 1, and Supplemental Table 1: Samples 2/3). Day 14 37 °C data is not available due to an instrument error during testing. The average percent change in RLUs across dilution series to the day 1 baselines for each sample showed minimal changes (<±4%) in signal recovery at 14 days at RT and −20 °C, and moderate signal loss (>±12%) by day 7 at 37 °C (Table 1 and Supplemental Table 1).

Clinical performance of the SARS-CoV-2 IgG assay with DBS

A total of 61 participants provided informed consent to have venous blood drawn and receive a fingerstick to generate up to 5 DBS samples. Plasma samples from each participant were tested using the ARCHITECT SARS-CoV-2 IgG assay to generate baseline reactivity levels (Index value). These were compared to Index values from the DBS testing of fingerstick and venous DBS. Results showed good correlation to plasma (R^2 = 0.960 and 0.967; Fig. 2A). SARS-CoV-2 IgG index values tracked closely (R^2 = 0.984) between fingerstick and venous DBS (Fig. 2B). Reproducibility was confirmed by testing venous DBS from 2 index positive and 2 index negative participants in triplicate (Fig. 2C). Interpretation concordance between plasma and venous or fingerstick DBS was 59/61 (96.7%) and 60/61 (98.4%), respectively (Supplemental Table 2). Of note, discordant results occurred in 2 participants who each had previously tested positive for SARS-CoV-2 by both PCR and SARS-CoV-2 IgG. At the time of sample collection for this study, these 2 participants had begun to serorevert and their SARS-CoV-2 IgG plasma index values (1.33 and 1.37 S/C) were near the 1.4 S/C assay cutoff.

Clinical performance of SARS-CoV-2 IgM assay with DBS

Patients who are recently infected with SARS-CoV-2 begin producing IgM as early as 5 days after SARS-CoV-2 infection [12] and serologic testing for SARS-CoV-2 IgM may help confirm SARS-CoV-2 diagnosis in patients who present with symptoms but are negative for PCR-based testing [13]. We examined the performance of the prototype ARCHITECT SARS-CoV-2 IgM assay with DBS, using 150 μl of DBS eluate. Matched patient plasma was tested for SARS-CoV-2 IgM using unmodified assay parameters to obtain comparative results. Matched index values from plasma compared favorably to DBS index values (Fig. 3A) and showed strong correlation for both fingerstick (R^2 = 0.975) and

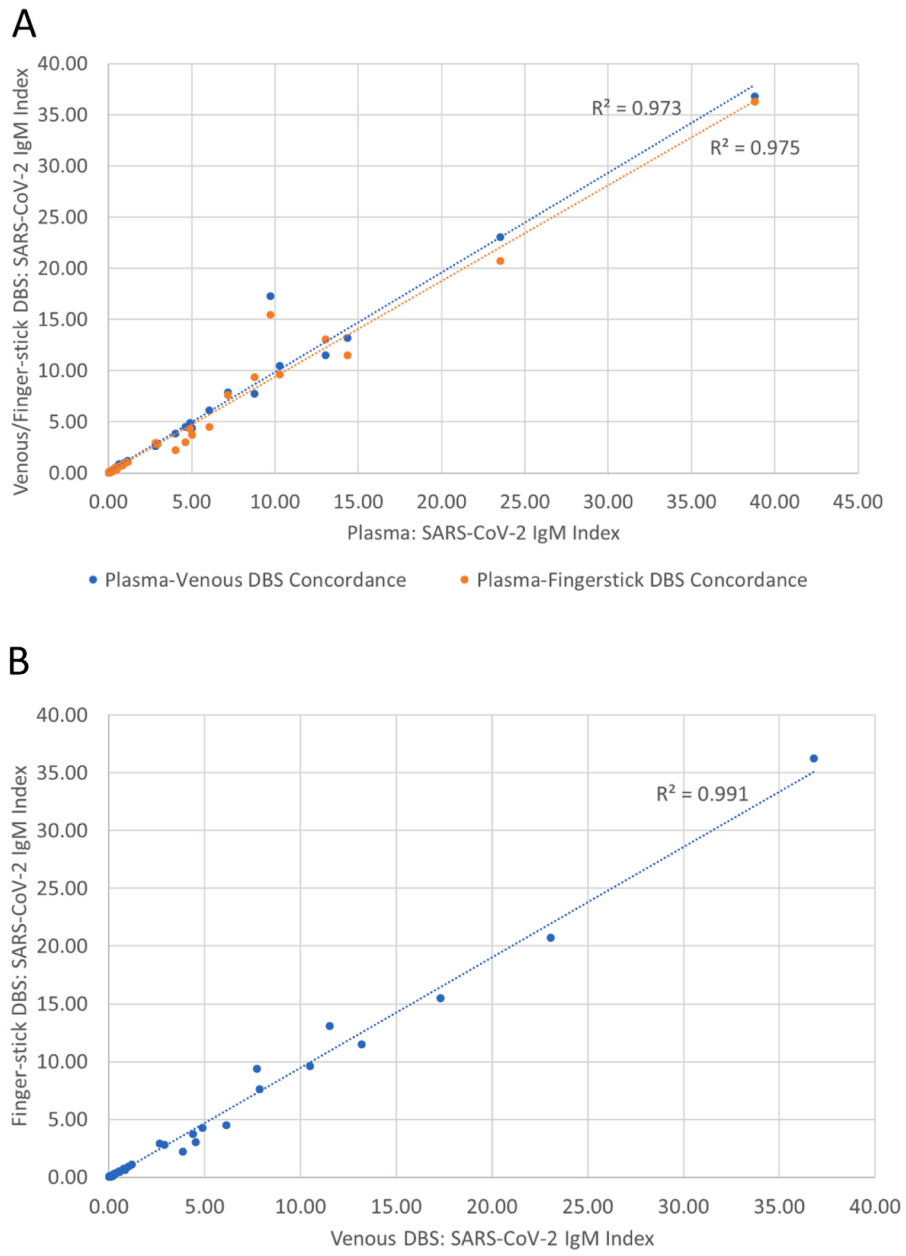

Fig. 3. Concordance of ARCHITECT SARS-CoV-2 IgM assay index values for fingerstick and venous whole blood DBS samples and plasma samples. (A) Comparison of plasma index results to venous and fingerstick DBS index results. (B) Equivalency of index values between matched venous and fingerstick DBS results.

venous ($R^2 = 0.973$) DBS. Further comparison showed equivalence ($R^2 = 0.991$) between matched DBS from fingerstick or venous blood (Fig. 3B). Concordance between reported results for plasma and venous or fingerstick DBS samples was 60/61 (98.4%) and 61/61 (100%), respectively (Supplemental Table 3). Like the SARS-CoV-2 IgG assay, the single discordant venous DBS sample occurred in a seroreverting patient whose SARS-CoV-2 IgM plasma index was 0.96, near the assay cutoff.

Clinical performance of PANBIO SARS-CoV-2 IgG with venous whole blood

Qualitative SARS-CoV-2 IgG reactivity from each of the 61 DBS study participants was determined using venous whole blood with the prototype PANBIO lateral flow SARS-CoV-2 assay (Abbott Rapid Diagnostics Jena GmbH). ARCHITECT SARS-CoV-2 IgG concordance with the PANBIO interpretation was 26/28 (92.9%) and 33/33 (100%), respectively (Table 2). One of the two discordant samples was from a study participant who had an ARCHITECT index of 1.46, which is near the assay cutoff.

Clinical performance of SARS-CoV-2 IgG using fingerstick plasma

A total of 109 participants provided informed consent to have venous blood drawn and receive a fingerstick to generate matched plasma samples collected in Vacutainer and Microtainer tubes, respectively. One participant was excluded due to insufficient fingerstick plasma collected. Matched samples were tested using the ARCHITECT SARS-CoV-2 IgG assay and index values were compared (Fig. 4). Correlation was high ($R^2 = 0.997$) between index values from fingerstick and venous plasma, and index interpretation concordance was 100% (108/108), demonstrating equivalency between fingerstick and venous plasma.

Table 2
Concordance of Results Interpretation of PANBIO Rapid Point-of-Care SARS-CoV-2 IgG Using Whole Blood and ARCHITECT SARS-CoV-2 IgG Using Venous Plasma.

Sample ID	ARCHITECT Plasma IgG Interpretation	PANBIO Whole Blood IgG Interpretation
DBS001	Negative	Negative
DBS002	Positive	Positive
DBS003	Positive	Positive
DBS004	Negative	Negative
DBS005	Negative	Negative
DBS006	Positive	Positive
DBS007	Positive	Positive
DBS008	Negative	Negative
DBS009	Negative	Negative
DBS010	Negative	Negative
DBS011	Negative	Negative
DBS012	Positive	Positive
DBS013	Negative	Negative
DBS014	Negative	Negative
DBS015	Negative	Negative
DBS016	Negative	Negative
DBS017	Positive	Positive
DBS018	Positive	Positive
DBS019	Positive	Positive
DBS020	Positive	Positive
DBS021	Positive	Positive
DBS022	Negative	Negative
DBS023	Negative	Negative
DBS024	Positive	Positive
DBS025	Negative	Negative
DBS026	Positive	Positive
DBS027	Positive	Positive
DBS028	Negative	Negative
DBS029	Positive	Positive
DBS030	Positive	Positive
DBS031	Positive	Negative
DBS032	Positive	Positive
DBS033	Negative	Negative
DBS034	Negative	Negative
DBS035	Negative	Negative
DBS036	Positive	Positive
DBS037	Positive	Positive
DBS038	Negative	Negative
DBS039	Negative	Negative
DBS040	Negative	Negative
DBS041	Negative	Negative
DBS042	Positive	Positive
DBS043	Negative	Negative
DBS044	Negative	Negative
DBS045	Negative	Negative
DBS046	Negative	Negative
DBS047	Positive	Positive
DBS048	Positive	Positive
DBS049	Negative	Negative
DBS050	Positive	Positive
DBS051	Negative	Negative
DBS052	Negative	Negative
DBS053	Negative	Negative
DBS054	Negative	Negative
DBS055	Negative	Negative
DBS056	Positive	Positive
DBS057	Positive	Positive
DBS058	Positive	Positive
DBS059	Negative	Negative
DBS060	Positive	Negative
DBS061	Positive	Positive
Total Concordance (n = 61)		59/61
Percent Concordance to Plasma		96.7

Discussion

We investigated various ways to expand and improve access to SARS-CoV-2 antibody testing using sample types that require less processing and handling than current methods, which require trained phlebotomists. Our results confirm the feasibility of using DBS for SARS-CoV-2 IgG and IgM detection and showed good concordance with plasma index values on the ARCHITECT SARS-CoV-2 IgG and IgM assays. Furthermore, the robust reproducibility and equivalence observed between fingerstick and venous DBS suggests that this method could be utilized in routine clinical testing as an alternative to current venous plasma. SARS-CoV-2 IgG DBS had higher background in known negative samples, but the results were below the index threshold. Future experiments with varying elution conditions will be conducted to further optimize background reduction. Importantly, DBS generated from venous and fingerstick blood produced concordant assay results and were stable for 2 weeks at room temperature ($<\pm$10% change). This observed stability has important implications for the potential use of DBS in large field collection studies in low income geographies where access to freezer storage may be limited or unavailable; these results highlight the benefit that DBS could bring to such collection studies. Notably, two participants had negative IgG results with plasma but positive results with DBS. These 2 participants with discordant IgG results and 1 participant with discordant IgM results had previous positive PCR and IgG results and were found to be in the process of seroreversion at the time the sample used in this study was collected. Thus, these are not false positives with DBS and may indicate an increased sensitivity of DBS relative to plasma using current assay cutoffs. These findings have important implications for expanding access to SARS-CoV-2 serologic testing in areas with low capacity for venous blood draws or lack of refrigerated sample storage.

Our findings show consistency with previous reports on the use of DBS for SARS-CoV-2 serologic testing [14,15]. DBS have been used in PCR and serologic testing for both diagnosis and monitoring of other viral infections, such as HIV, HBV, and HCV, thereby extending testing to rural and remote populations worldwide [2]. A previous study confirmed the utility of DBS with ARCHITECT HIV, HCV, and HBV serologic assays, reporting specificity of 100% and sensitivities ranging from 97% to 100% [16]. Karp et al. recently reported the development of a SARS-CoV-2 IgG PCR-based diagnostic assay using at-home collection of fingerstick DBS and shipped to a central lab for testing [17]. Willingness to collect DBS samples at home and ship them to a central lab for testing was recently confirmed in a survey study of 153 US adults [18].

We also demonstrated equivalency between venous and fingerstick plasma with the SARS-CoV-2 IgG assay. Fingerstick plasma has been used to detect IgG for the confirmation of celiac disease diagnosis [19] and to detect both IgG and IgM after suspected measles or Rubella infection [7, 20]. Collection of fingerstick plasma in Microtainer tubes is quick and easy and does not require a phlebotomist, making it an attractive alternative to venipuncture for use in SARS-CoV-2 curbside or drive-through testing sites.

Finally, we have shown good concordance between ARCHITECT SARS-CoV-2 IgG assay run with plasma and the PANBIO rapid point-of-care lateral flow SARS-CoV-2 IgG assay using venous whole blood. The ability to rapidly, accurately, and affordably determine seroprevalence in a population will be an important tool in the growing arsenal of SARS-CoV-2 diagnostic testing, particularly in resource-limited areas. The simplicity of performing the lateral flow assay with whole blood also eliminates the need for centrifugation and plasma separation steps, further reducing cost and complexity of obtaining a result.

Expanding access to SARS-CoV-2 antibody testing will likely require combinations of different testing methods. We have shown that expanding testing capabilities using DBS, Microtainers, and rapid point-of-care tests is feasible and that results delivered with these methods are comparable to current testing approaches.

Author contributions

MA designed and performed DBS experiments, analyzed the data, and wrote the manuscript. VH performed feasibility and stability DBS

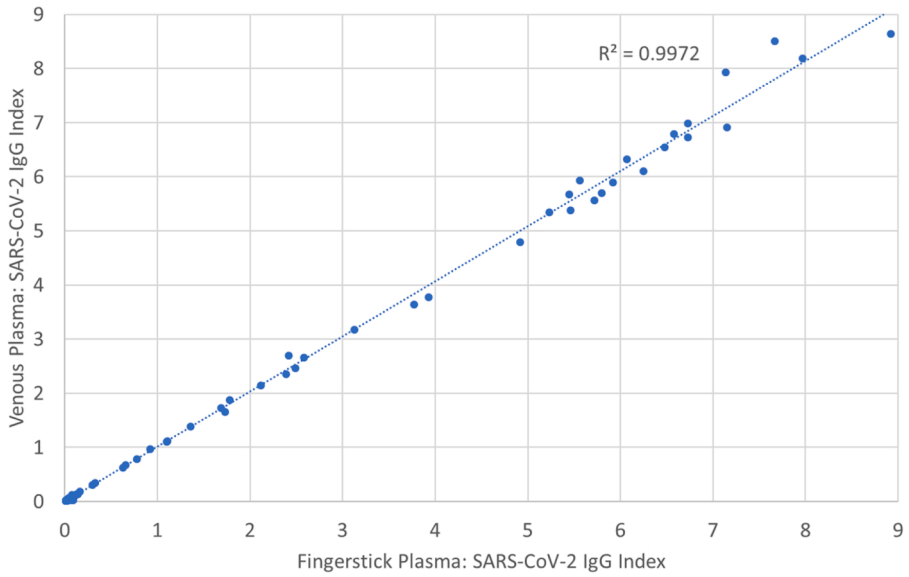

Fig. 4. Concordance of ARCHITECT SARS-CoV-2 IgG assay index values for matched fingerstick and venous plasma samples. Fingerstick whole blood was collected in Microtainers and centrifuged to obtain fingerstick plasma. Matched venous plasma was collected during the same visit and both plasma samples were tested for SARS-CoV-2 IgG. Index values from fingerstick and venous plasma were plotted to show a linear relationship. .

experiments and analyzed the data. AV performed the PANBIO testing, RT created modified ARCHITECT assay files, JM performed the specimen collection and analyzed the data. GC directed the research and analyzed the data. All authors reviewed the manuscript.

Declaration of Competing Interest

MA, VH, AV, RT, and GC are employees and shareholders of Abbott Laboratories. JM has no conflicts to disclose.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jcv.2021.104855.

References

[1] J.J. Deeks, J. Dinnes, Y. Takwoingi, C. Davenport, R. Spijker, S. Taylor-Phillips, et al., Antibody tests for identification of current and past infection with SARS-CoV-2, Cochrane Database Syst. Rev. 6 (2020), Cd013652, https://doi.org/10.1002/14651858.Cd013652.

[2] E. Tuaillon, D. Kania, A. Pisoni, K. Bollore, F. Taieb, E.N. Ontsira Ngoyi, et al., Dried blood spot tests for the diagnosis and therapeutic monitoring of HIV and Viral Hepatitis B and C, Front. Microbiol. 11 (2020) 373, https://doi.org/10.3389/fmicb.2020.00373.

[3] B. Lange, J. Cohn, T. Roberts, J. Camp, J. Chauffour, N. Gummadi, et al., Diagnostic accuracy of serological diagnosis of hepatitis C and B using dried blood spot samples (DBS): two systematic reviews and meta-analyses, BMC Infect. Dis. 17 (2017) 700, https://doi.org/10.1186/s12879-017-2777-y.

[4] M.M. Manak, H.R. Hack, A.L. Shutt, B.A. Danboise, L.L. Jagodzinski, S.A. Peel, Stability of human immunodeficiency virus serological markers in samples collected as HemaSpot and Whatman 903 dried blood spots, J. Clin. Microbiol. 56 (2018), https://doi.org/10.1128/jcm.00933-18.

[5] S. Vázquez-Morón, P. Ryan, B. Ardizone-Jiménez, D. Martín, J. Troya, G. Cuevas, et al., Evaluation of dried blood spot samples for screening of hepatitis C and human immunodeficiency virus in a real-world setting, Sci. Rep. 8 (2018) 1858, https://doi.org/10.1038/s41598-018-20312-5.

[6] N.A. Pinsky, T.R. Loepfe, R.M. Jacobson, R.A. Vierkant, G.A. Poland, Comparison of fingerstick versus venipuncture for antibody testing of measles and rubella, Scand. J. Infect. Dis. 35 (2003) 107–109, https://doi.org/10.1080/0036554021000027008.

[7] M. Vejtorp, J. Leerhoy, Rubella IgG antibody detection by ELISA using capillary blood samples collected on filter paper and in microtainer tubes, Acta Pathol. Microbiol. Scand. B 89 (1981) 369–370, https://doi.org/10.1111/j.1699-0463.1981.tb00202_89b.x.

[8] A. Bryan, G. Pepper, M.H. Wener, S.L. Fink, C. Morishima, A. Chaudhary, et al., Performance characteristics of the Abbott Architect SARS-CoV-2 IgG Assay and seroprevalence in Boise, Idaho, J. Clin. Microbiol. 58 (2020), https://doi.org/10.1128/JCM.00941-20.

[9] M.S. Tang, K.G. Hock, N.M. Logsdon, J.E. Hayes, A.M. Gronowski, N.W. Anderson, et al., Clinical performance of two SARS-CoV-2 serologic assays, Clin. Chem. 66 (2020) 1055–1062, https://doi.org/10.1093/clinchem/hvaa120.

[10] E.S. Theel, J. Harring, H. Hilgart, D. Granger, Performance characteristics of four high-throughput immunoassays for detection of IgG antibodies against SARS-CoV-2, J. Clin. Microbiol. 58 (2020), https://doi.org/10.1128/jcm.01243-20.

[11] Ng D., Goldgof G., Shy B., Levine A., Balcerek J., Bapat S.P., et al. SARS-CoV-2 Seroprevalence and Neutralizing Activity in Donor and Patient Blood from the San Francisco Bay Area. medRxiv. 2020:2020.05.19.20107482. doi: 10.1101/2020.05.19.20107482.

[12] L. Guo, L. Ren, S. Yang, M. Xiao, D. Chang, F. Yang, et al., Profiling early humoral response to diagnose novel coronavirus disease (COVID-19), Clin. Infect. Dis. 71 (2020) 778–785, https://doi.org/10.1093/cid/ciaa310.

[13] Infectious Diseases Society of America. Infectious Diseases Society of America Guidelines on the Diagnosis of COVID-19: Serologic Testing. Updated https://www.idsociety.org/practice-guideline/covid-19-guideline-serology/. Accessed September 17, 2020.

[14] M. Thevis, A. Knoop, M.S. Schaefer, B. Dufaux, Y. Schrader, A. Thomas, et al., Can dried blood spots (DBS) contribute to conducting comprehensive SARS-CoV-2 antibody tests? Drug Testing Analysis 12 (2020) 994–997, https://doi.org/10.1002/dta.2816.

[15] T.W. McDade, E.M. McNally, A.S. Zelikovich, R. D'Aquila, B. Mustanski, A. Miller, et al., High seroprevalence for SARS-CoV-2 among household members of essential workers detected using a dried blood spot assay, PLoS ONE 15 (2020), e0237833, https://doi.org/10.1371/journal.pone.0237833.

[16] R.S. Ross, O. Stambouli, N. Gruner, U. Marcus, W. Cai, W. Zhang, et al., Detection of infections with hepatitis B virus, hepatitis C virus, and human immunodeficiency virus by analyses of dried blood spots–performance characteristics of the ARCHITECT system and two commercial assays for nucleic acid amplification, Virol. J. 10 (2013) 72, https://doi.org/10.1186/1743-422X-10-72.

[17] D.G. Karp, K. Danh, D. Seftel, P. Robinson, C.T. Tsai, A serological assay to detect SARS-CoV-2 antibodies in at-home collected finger-prick dried blood spots, medRxiv (2020), https://doi.org/10.1101/2020.05.29.20116004.

[18] M. Valentine-Graves, E. Hall, J.L. Guest, E. Adam, R. Valencia, K. Shinn, et al., At-home self-collection of saliva, oropharyngeal swabs and dried blood spots for SARS-CoV-2 diagnosis and serology: post-collection acceptability of specimen collection process and patient confidence in specimens, PLoS ONE 15 (2020), e0236775, https://doi.org/10.1371/journal.pone.0236775.

[19] J. Terryberry, J. Tuomi, S. Perampalam, R. Peloquin, E. Brouwer, D. Schuppan, et al., Diagnostic accuracy of a fully automated multiplex celiac disease antibody panel for serum and plasma, Clin. Chem. Lab. Med. 57 (2019) 1207–1217, https://doi.org/10.1515/cclm-2019-0088.

[20] R.F. Helfand, H.L. Keyserling, I. Williams, A. Murray, J. Mei, C. Moscatiello, et al., Comparative detection of measles and rubella IgM and IgG derived from filter paper blood and serum samples, J. Med. Virol. 65 (2001) 751–757, https://doi.org/10.1002/jmv.2100.