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## Evaluation of serological assays for SARS-CoV-2 antibody testing from dried blood spots collected from cohorts with prior SARS-CoV-2 infection ☆☆☆★



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### ABSTRACT

**Background:** Dried blood spot (DBS) specimens are a useful serosurveillance tool particularly in hard-to-reach populations but their application for detecting SARS-CoV-2 infection is poorly characterised.

**Objectives:** To compare detection of naturally acquired SARS-CoV-2 antibodies in paired DBS and serum specimens using commercially available serological immunoassays.

**Study Design:** Specimens were collected through St Vincent's Hospital observational post COVID-19 cohort study (ADAPT). Laboratory spotted DBS from venepuncture were initially tested on seven assays, a DBS validation completed on three with clinically collected fingerstick DBSs tested on one.

**Results:** Sensitivity for Euroimmun nucleocapsid (NCP) IgG ELISA from laboratory spotted DBS (n=145), Euroimmun spike, IgG ELISA from laboratory spotted DBS (n=161), and Binding Site total antibody ELISA from clinically collected fingerstick DBS (n=391) was 100% (95% CI: 95.8-100%), 100% (95% CI: 95.8-100%) and 92.9% (95% CI: 89.5-95.5%), respectively. Specificity was 66.2% (95% CI: 53.6-77.0%), 96% (95% CI: 88.7-99.1%) and 98.8% (95% CI: 93.3-99.9%), respectively. All three assays' results displayed a strong positive correlation between DBS compared to paired serum.

**Conclusions:** The Binding Site™ spike total antibody and Euroimmun™ spike IgG ELISAs provided good analytical performance, demonstrating that DBS specimens could facilitate specimen collection in the epidemiological surveillance of SARS-CoV-2 infection. This is highly applicable in populations and settings where venepuncture is problematic (including community based regional/remote settings, nursing homes, prisons, and schools).

### Summary

Testing for SARS-CoV-2 antibodies in dried blood spot (DBS) can facilitate serosurveillance in hard-to-reach populations and inform

public health responses including vaccination strategies. We concluded that DBS specimens have comparable sensitivity and specificity to serum for the detection of SARS-CoV-2 antibodies.

☆ The authors confirm that this manuscript has not been published previously and is not currently being considered for publication elsewhere.

☆☆ **Previously presented:** Interim findings from this research have been presented in a WHO report.

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## 1. Background

The World Health Organization declared a global pandemic in March 2020 due to an atypical pneumonia, which originated in Wuhan, China. The viral agent determined to have caused the outbreak has since been classified as a “Severe acute respiratory syndrome Coronavirus-2 (SARS-CoV-2) commonly known as COVID-19” [1,2]. As of the 8<sup>th</sup> of August 2021, there have been over 200 million cases of COVID-19 and over 4.2 million deaths [3].

Counting of reported cases of SARS-CoV-2 infection can underestimate the true number of infections in the community because individuals who have no, or mild symptoms often do not present for viral testing. Serosurveys can facilitate key epidemiological questions by estimating the proportion of a population impacted by a pathogen and complement other public health surveillance systems to monitor epidemic curves and vaccination rates [4].

Current methods for detecting SARS-CoV-2 antibodies require trained phlebotomists to collect blood by venepuncture, generally within a healthcare setting, and cold-chain transfer of samples to laboratories for testing within specified timeframes [5]. These steps represent major barriers for field surveys of SARS-CoV-2 antibodies, in settings of public health importance, such as schools. Robust and minimally invasive options are needed to increase the coverage of testing for SARS-CoV-2 antibodies in the community.

A well-established alternative is the use of capillary fingerstick blood collected on blotting paper, known as ‘dried blood spot’ or DBS specimen, a technology that has facilitated serological testing for a variety of other viral infections (e.g., HIV, hepatitis B and C) antenatal screening and public health surveillance [6–8]. It is a highly feasible method for specimen collection in community settings, with value when specimens are required from vulnerable or hard-to-reach populations [9–11]. Although commercial assays for SARS-CoV-2 are available, not all include DBS as an approved sample type and the performance characteristics of DBS from clinically collected real-world specimens is not well described.

Three commercially available assays were investigated based on literature reviews and manufacturer’s DBS kit instructions for use (IFU) claims. They include assays that target the Nucleocapsid protein (NCP) (Euroimmun SARS-CoV-2 NCP), Spike IgG protein (Euroimmun SARS-CoV-2 spike IgG) and Spike total antibody (Binding Site).

## 2. Objectives

Within this study we aimed to a) examine feasibility of commercial platforms for antibodies against SARS-CoV-2 IgA, IgG and total antibody from DBS; b) select suitable assay candidates to undertake a DBS validation to determine assay performance characteristics and c) select one assay to test the ADAPT clinically collected fingerstick DBS specimens comparing against matched serum.

## 3. Study design

### 3.1. Study participants

ADAPT is an ongoing prospective, observational cohort study of patients seen at St Vincent’s Hospital Sydney (Australia) who tested PCR positive for SARS-CoV-2 infection [12,13]. Each patient is followed for a period of 24-months from the time of diagnosis, with up-to 8 time-point collections. All participants provided written, informed consent before study procedures began. The study was approved by St. Vincent’s Hospital, Sydney Human Research Ethics Committee (reference, 2020/ETH00964) [12].

### 3.2. Assay selection criteria

Seven (7) assays were selected for DBS evaluation; 2 automatic analysers (Abbott Architect anti-NCP IgG and Diasorin Liaison XL anti-

spike IgG) and 5 plate based enzyme linked immunosorbent assay’s (ELISAs) (Euroimmun anti-NCP IgG, Euroimmun anti-spike IgG, Euroimmun anti-spike IgA, Binding Site anti-spike IgG/A/M and Wantai anti-spike IgG/A/M) (see Table 1). Assays were selected to distinguish between the NCP (naturally acquired response) and spike protein targets (naturally acquired and/or vaccine induced response). A DBS validation was performed on the Euroimmun anti-NCP IgG, Euroimmun anti-spike IgG and Binding Site anti-spike IgG/A/M (see Table 1).

### 3.3. Procedures

Whole blood collected via EDTA tubes were used to manufacture laboratory spotted DBS prior to centrifugation to complete feasibility testing. Two full DBS cards (10 spots, 50 $\mu$ L whole blood per spot) were manufactured per participant timepoint collection onto a Whatman 903 protein saver card [order number WHA10534612] Thermofisher, Scoresby, VIC, Australia). DBS cards were air dried overnight in a class II biological safety cabinet then stored in gas impermeable bags (Whatman Bag Specimen Storage BITRAN 6  $\times$  6inch [catalogue number FSB19-240-119]) containing two desiccant packs (1gm Silica gel [catalogue number SG23401], Desicco, Sydney, NSW, Australia).

### 3.4. Study assessments

Feasibility focused on testing laboratory spotted DBS from venepuncture collection due to preserving the real-world clinically collected fingerstick DBSs to be tested on one assay. Validation work using laboratory spotted DBS considered diagnostic accuracy of the Binding Site (N=165), Euroimmun Spike (N=161) and Euroimmun NCP (N=145) SARS-CoV-2 ELISAs. Validation numbers differ between assays due to either the Euroimmun borderline results being excluded from analyses and initially limited kit availability from Binding Site.

Clinically collected fingerstick DBS samples tested on Binding Site included all ADAPT fingerstick cards (N=391) and serum collected as of the 16<sup>th</sup> of February 2021.

DBS samples were punched using the BSD600plus automated puncher (BSD Robotics, Queensland) and tested in singlicate. The DBS elution protocol for Euroimmun was performed according to manufacturer’s instructions for use [14,15]. For Binding Site, a 6mm disc was eluted in 200 $\mu$ L phosphate buffered saline + 0.5% Tween20 (PBST) + 5% skim milk powder in an uncoated 96-well microwell plate, overnight at 2-8 degree Celsius. Sera were thawed the day of testing with paired samples run on the same plate to account for intra-run plate variation. Testing was performed at St Vincent’s Centre for Applied Medical Research, St Vincent’s Hospital, between 4<sup>th</sup> June 2020 and 16<sup>th</sup> February 2021. Run and sample validity was determined by manufacturer’s IFU.

### 3.5. Statistical analysis

All analyses were performed using Stata 14.2 (StataCorp software, LLC., College Station, Texas) and GraphPad Prism6 (GraphPad software, Inc., San Diego, Calif.).

## 4. Results

### 4.1. Feasibility of SARS-CoV-2 ELISAs

ELISAs considered in the evaluation are summarised in Table 1 with a small number (N=10) of DBS samples tested. Following an initial proof-of-principal, the Abbott Architect and Diasorin Liaison XL failed to detect SARS-CoV-2 from DBS and were removed from further analyses. Feasibility testing expanded on the remaining 5 ELISAs with sub-optimal results generated from the Euroimmun anti-spike IgA and Wantai anti-spike IgG/A/M. No further testing on these two platforms was continued.

**Table 1**  
Commercially available SARS-CoV-2 antibody assays.

Assay	Type	ELISA Target	Use of DBS sample
Abbott Architect	Automated analyser	Nucleocapsid protein (NCP) IgG target	Currently not approved by manufacturer
Diasorin Liaison XL	Automated analyser	Spike protein (Spike) IgG target.	Currently not approved by manufacturer
Euroimmun – NCP IgG	Manual ELISA	NCP IgG target	Approved by manufacturer as a screening assay. DBS elution buffer and elution method described in IFU. Incubation steps require use of 37C incubator.
Euroimmun - Spike IgG	Manual ELISA	Spike IgG target	Approved as confirmation assay post NCP reactive result. DBS elution buffer and elution method described in IFU. Incubation steps 37C.
Euroimmun - Spike IgA	Manual ELISA	Spike IgA target	Approved as a supplemental assay. DBS elution buffer and elution method described in IFU. Incubation steps 37C.
Binding site – Spike total antibody	Manual ELISA	Spike IgG/A/M	Approved by manufacturer. Elution buffer and method not described in IFU. Standardised in-house elution buffer and elution method used. Incubation steps at room temperature.
Wantai total antibody	Manual ELISA	Spike receptor binding domain (RBD) total antibody	Not approved by manufacturer. Standardised in-house elution buffer and elution method used. Incubation steps 37C. Assay input volume 100µL serum.

**Table 2**  
Comparison of three leading candidates for SARS-CoV-2 testing with laboratory manufactured DBS specimens.

Sample Size Tested	Binding Site n = 165	Euroimmun Spike n = 161	Euroimmun NCP n = 144
<b>Dried Blood Spots Tested</b>	Laboratory spotted from venepuncture collection – ADAPT study and biorepository	Laboratory spotted from venepuncture collection – ADAPT study and biorepository	Laboratory spotted from venepuncture collection – ADAPT study and biorepository
<b>Sensitivity</b>	94.67%	100%	100%
<b>(95% Confidence Interval)</b>	(86.9 – 98.53)	(95.80 – 100)	(95.14 – 100)
<b>Specificity</b>	100%	96.0%	66.20%
<b>(95% Confidence Interval)</b>	(95.1 – 100)	(88.75 – 99.17)	(53.99 – 77.00)
<b>Positive Predictive Value</b>	100%	95.74%	76.29%
<b>(95% Confidence Interval)</b>		(89.66-98.32)	(69.71-81.81)
<b>Negative Predictive Value</b>	95.74%	100%	100%
<b>(95% Confidence Interval)</b>	(89.66-98.32)		
<b>Correlation (R<sup>2</sup>)</b>	0.96	0.96	0.96
<b>Bias</b>	0.219	0.90	0.81
<b>(95% Limits of Agreement)</b>	(-0.524 to 0.963)	(-1.03 to 2.88)	(-0.01 to 1.64)
<b>DBS Approved Sample Type</b>	Yes	Yes	Yes
<b>DBS Elution Buffer Provided</b>	No	Yes	Yes
<b>DBS Elution Method Described</b>	No	Yes	Yes
<b>Incubation Temperature</b>	Room temperature	37°C	37°C

4.2. Validation of SARS-CoV-2 ELISAs

Further validation work using laboratory spotted DBS with paired sera considered diagnostic accuracy of Binding Site total antibody (N=165), Euroimmun Spike (N=161) and Euroimmun NCP (N=144) SARS-CoV-2 ELISAs. Results are summarised in Table 2 and detailed below. Euroimmun results that fell within the assay grey zone were considered borderline and were excluded in analyses, as described by manufacturers IFU [15,16].

4.2.1. Binding Site Spike total antibody

Among 165 paired samples, sensitivity of DBS compared to serum was 94.7% (95% CI, 86.9–98.5%) and specificity 100% (95% CI, 95.9 – 100%) (Table 4). Correlation between paired samples was strong (R2 = 0.96) (Fig. 1). Bland-Altman plot analysis demonstrated a bias of 0.219 serum to cut-off ratio (S/CO). The limits of agreement indicate that 95% of the difference between serum and DBS on the Binding

Site ELISA was between -0.524 and 0.963 S/CO (Fig. 3). The average number of days from PCR positivity until study collection time point for these samples was 105.

4.2.2. Euroimmun Spike IgG

Among 161 paired samples, sensitivity of DBS compared to serum was 100% (95% CI, 95.8–100%) and specificity 96% (95% CI, 88.7 – 99.1%) (Table 4). Correlation between paired samples was strong (R2 = 0.96) (Fig. 2). Bland-Altman plot analysis demonstrated a bias of 0.90 S/CO. The limits of agreement indicate that 95% of the difference between serum and DBS on the Spike IgG ELISA was between -1.03 and 2.88 S/CO (Fig. 3). The average number of days from PCR positivity until study collection time point was 103.

4.2.3. Euroimmun NCP IgG

Among 144 paired samples, sensitivity of DBS compared to serum was 100% (95% CI, 95.8–100%) and specificity 66.2% (95% CI,

**Table 3**  
Results from ADAPT study fingerstick collected DBS.

Sample Size Tested	Binding Site n = 391
Dried Blood Spots Tested	Fingerstick collected – ADAPT study
Sensitivity	92.90%
(95% Confidence Interval)	(89.45 – 95.50)
Specificity	98.77%
(95% Confidence Interval)	(93.31 – 99.97)
Positive Predictive Value	99.65%
(95% Confidence Interval)	(97.6–99.95)
Negative Predictive Value	80%
(95% Confidence Interval)	(72.57–85.81)
Correlation (R <sup>2</sup> )	0.90
Bias	0.223
(95% Limits of Agreement)	(-0.76 to 1.21)
DBS Approved Sample Type	Yes
DBS Elution Buffer Provided	No
DBS Elution Method Described	No
Incubation Temperature	Room temperature

**Table 4**  
Sensitivity and specificity of A: Binding Site SARS-CoV-2 Spike IgG/A/M among laboratory spotted DBS, B: Euroimmun SARS-CoV-2 Spike Ab. among laboratory spotted DBS (LoD = S/CO Ratio 0.14), C: of Euroimmun SARS-CoV-2 NCP among laboratory spotted DBS (LoD = S/CO Ratio 0.21), D: Binding Site SARS-CoV-2 Spike IgG/A/M among clinically collected DBS.

		A: Binding Site Spike IgG/A/M Serum ( $\geq$ LOD)		Total
		Detected	Undetected	
Binding Site Spike IgG/A/M DBS ( $\geq$ LOD)	Detected	71	0	71
	Undetected	4	90	94
Total		75	90	165
B: Euroimmun Spike Serum ( $\geq$ LOD)				
Euroimmun Spike DBS ( $\geq$ LOD)	Detected	86	3	89
	Undetected	0	72	72
Total		86	75	161
C: Euroimmun Serum NCP ( $\geq$ LOD)				
Euroimmun NCP DBS ( $\geq$ LOD)	Detected	74	23	98
	Undetected	0	47	47
Total		74	70	144
D: Binding Site Spike IgG/A/M Serum ( $\geq$ LOD)				
Binding Site Spike IgG/A/M DBS ( $\geq$ LOD)	Detected	285	1	286
	Undetected	21	84	105
Total		306	85	391

53.6–77%) (Table 4). Correlation between paired samples was strong ( $R^2 = 0.96$ ) (Fig. 2). Bland-Altman plot analysis demonstrated a bias of 0.81 S/CO. The limits of agreement indicate that 95% of the difference between serum and DBS on the NCP IgG ELISA was between -0.01 and 1.64 S/CO (Fig. 3). The average number of days from PCR positivity until study collection time point was 103.

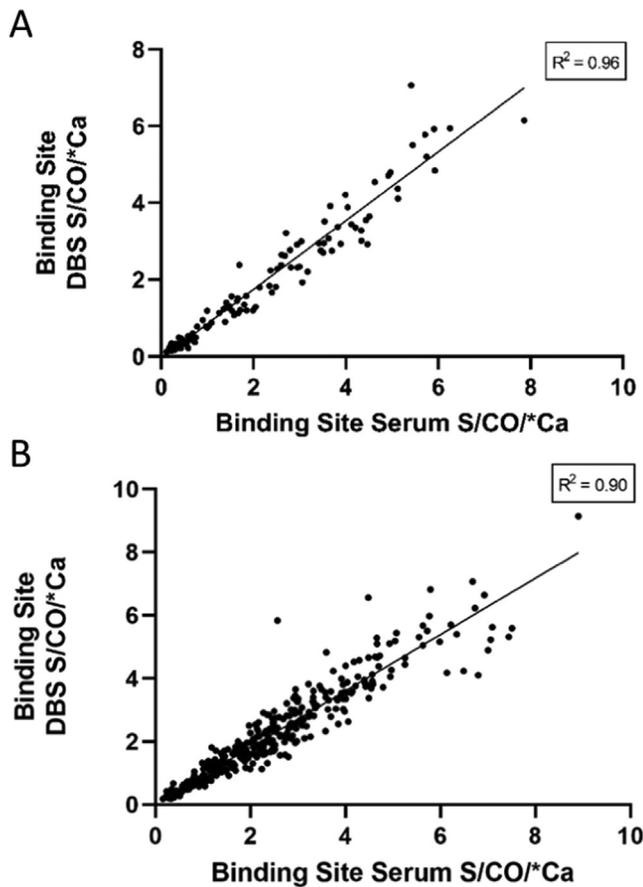
#### 4.3. Validation of Binding Site Spike using clinically collected fingerstick DBS

Among 391 paired samples, sensitivity of DBS compared to serum was 92.9% (95% CI, 89.5– 95.5%) with specificity 98.8% (95% CI, 93.3–99.9%) (Table 4). Correlation between paired samples was a strong ( $R^2 = 0.91$ ) (Fig. 1). Bland-Altman plot analysis demonstrated a bias of 0.233 S/CO. The limits of agreement indicate that 95% of the difference between serum and DBS on the Binding Site ELISA was between -0.76 and 1.21 S/CO (Fig. 3). The average number of days from PCR positivity until study collection time point was 137.

## 5. Discussion

In this study, we evaluated the analytical performance of DBS for the detection of SARS-CoV-2 antibodies compared to matched serum on commercially available assays. Our evaluation determined that both the Binding Site spike total antibody and Euroimmun spike IgG ELISAs provided good analytical performance. The Euroimmun NCP demonstrated comparable sensitivity, albeit much lower specificity from DBS. Future work could consider evaluating DBS on high throughput analysers with assays that are both qualitative and quantitative such as the Abbott Architect SARS-CoV-2 IgG and Diasorin LXL SARS-CoV-2 IgG, however, DBS as a sample type has yet to be approved by the manufacturer or regulated. This research demonstrates that DBS have the potential to play a role in the epidemiological surveillance of SARS-CoV-2 infection and vaccination prevalence, specifically in populations and settings that are difficult to reach.

When testing laboratory spotted DBS for the detection of SARS-CoV-2 antibodies, the Binding Site spike total antibody and Euroimmun spike

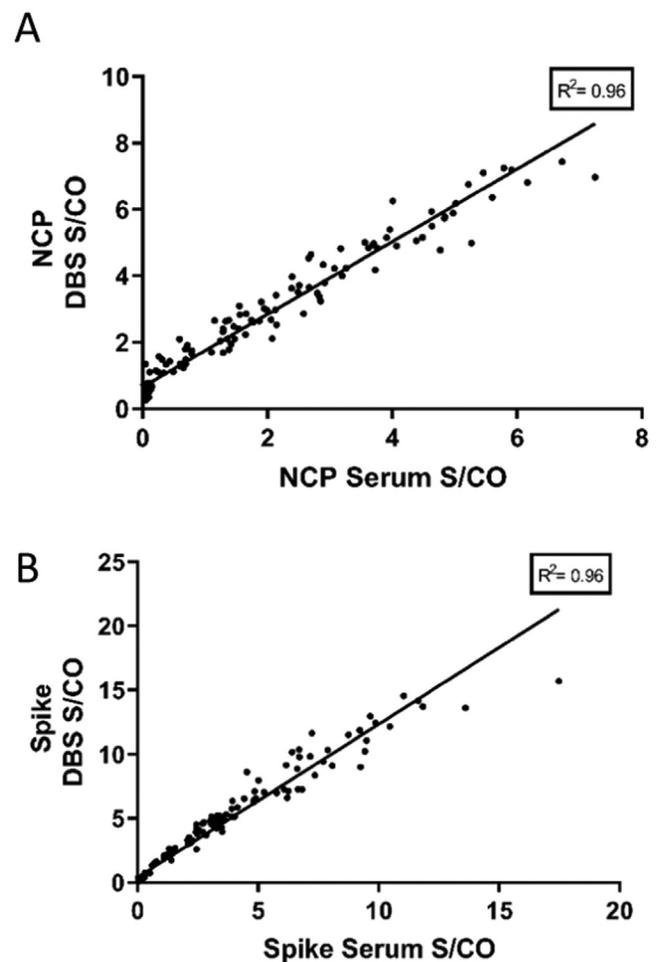


**Fig. 1.** Correlation analysis of A: Binding Site between the quantitative outcome of manufactured DBS and paired serum among ADAPT and ADAPT-C cohorts,  $R^2 = 0.96$ ; the diagonal line represents identical results B: Binding Site between the quantitative outcome of clinically collected DBS and paired serum among ADAPT and ADAPT-C cohorts,  $R^2 = 0.90$ ; the diagonal line represents identical results.

IgG ELISA's provided good clinical performance in terms of sensitivity and specificity and strongly correlated to sera. Although there was limited published literature that evaluated spike total antibody detection from DBS, Cook et al demonstrated good clinical performance on serum (98.4%, 94.7% sensitivity and specificity) and a strong correlation between serum and DBS ( $r=0.959$ ) [16], further an in-house method by Morley et al. also demonstrated acceptable diagnostic performance (98% sensitivity, 100% specificity) [17]. The Euroimmun IgG ELISA DBS results are also comparable to several recently published studies [18–21] (Table 1 supplementary Material).

We found that the specificity for the Euroimmun NCP ELISA was considerably lower when compared to the assays targeting the spike protein. Testing of both Euroimmun Spike and NCP ELISAs were conducted in parallel, and we identified that our in-house negative DBS controls consistently returned borderline or positive results on the NCP assay only. These controls were manufactured in a pre-SARS-CoV-2 era in quarter 2, 2019 and we hypothesize that the NCP protein target may have caused cross-reactivity to other viruses with the IFU highlighting that cross-reactivity is likely within the Coronavirus family, especially SARS-CoV-1. The literature supports evidence of DBS performance on the Euroimmun Spike ELISA ([19, 21]), however, is limited in describing the performance of the Euroimmun NCP ELISA with DBS ([21]). In addition, there is no published literature that we are aware of on the performance of DBS with the Binding Site spike total antibody ELISA.

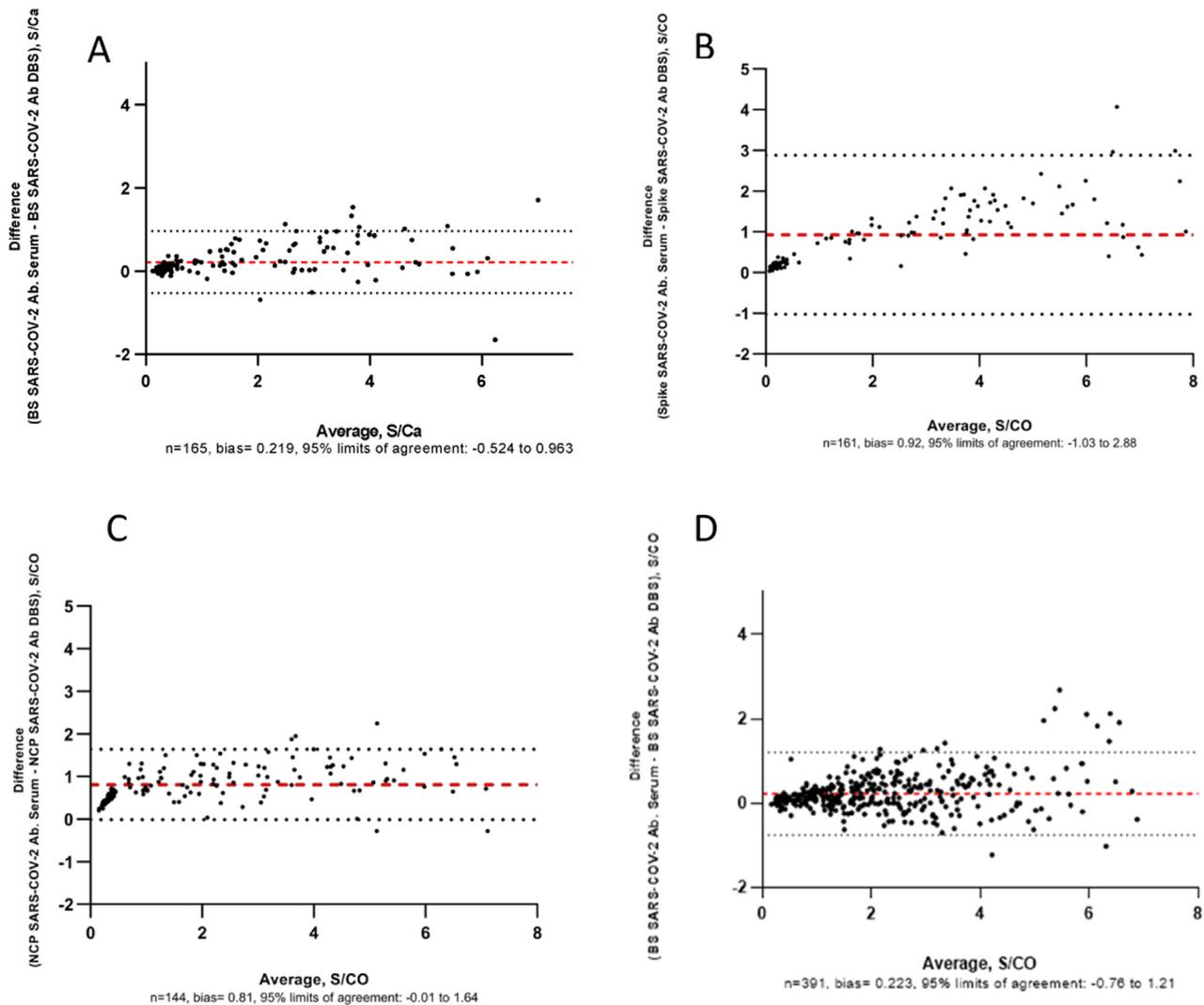
The preliminary results and specificity issues (based on laboratory spotted DBS) indicated that the Binding Site spike total antibody assay



**Fig. 2.** Correlation analysis of A: Euroimmun NCP between manufactured DBS and paired serum in ADAPT, ADAPT-C and 2020 repository cohorts,  $R^2 = 0.96$ ; the diagonal line represents identical results. B: Euroimmun Spike between manufactured DBS and paired serum in ADAPT, ADAPT-C and 2020 repository cohorts,  $R^2 = 0.96$ ; the diagonal line represents identical results.

was the best candidate to perform clinically collected fingerstick DBS testing. However, when testing real-world collected samples on Binding Site, we observed a slightly lower sensitivity of 92.9% (89.5-95.5, 95% CI) and specificity of 98.8% (93.3-99.9, 95% CI). This may be due to inherent differences in spot quality (effecting overall whole blood sample volume and specimen viability – considering sample collection and storage conditions) between controlled laboratory manufactured DBS versus patient collected specimens. Additionally, Binding Site does not have in-built borderline or grey zone parameters to triage uncertain/equivocal results to supplemental testing. If an in-house grey zone of 20% less than the cut-off is applied for reflex testing, DBS sensitivity could be further improved.

As the pandemic continues to evolve and new SARS-CoV-2 variants emerge it will be important to perform population-level serosurveillance studies [22], to determine herd immunity and to inform vaccine strategy, including the timing and frequency of booster use [23]. However, studies suggest that assay selection is critical due to antibody waning effect and correlation to neutralising antibody (NAbs). Assays targeting the IgG spike protein demonstrated antibody detection post infection after a period of four to eight months [22,24,25], with assays targeting total antibody showing detection up to ten months [25] in comparison to a quicker and more significant decline in anti-nucleocapsid IgG values [25]. Further, as vaccination and booster uptake increase, there are further complexities in the kinetics of viral neutralisation to



**Fig. 3.** Bland-Altman analysis of A: Binding Site to show bias and agreement in detection of SARS-CoV-2 antibodies from manufactured DBS and paired serum; the dashed line represents bias (0.219 S/CO); the 2 dotted lines represent the 95% confidence interval (-0.52 to 0.96), B: Euroimmun Spike to show bias and agreement in detection of SARS-CoV-2 antibodies from DBS and paired serum; the dashed line represents bias (0.92 S/CO); the 2 dotted lines represent the 95% confidence interval (-1.03 to 2.88), C: Euroimmun NCP to show bias and agreement in detection of SARS-CoV-2 antibodies from DBS and paired serum; the dashed line represents bias (0.812 S/CO); the 2 dotted lines represent the 95% confidence interval (0.01 to 1.64), D: Binding Site to show bias and agreement in detection of SARS-CoV-2 antibodies from DBS and paired serum; the dashed line represents bias (0.223 S/CO); the 2 dotted lines represent the 95% confidence interval (-0.76 to 1.21).

consider [26]. Surveillance data could be inaccurate unless the following confounders are considered; variant (driving the strength of immune response) [27], previous infection, vaccination and booster status.

Future work could further explore the scale up and utility of DBS on automated and high throughput commercial analysers with qualitative and quantitative assays, with particular emphasis on pre and post vaccination sero-surveillance to determine immunity status. Several small studies have shown promising results for this application including the Abbott Architect SARS-CoV-2 IgG and the Elecsys Roche Anti-SARS-CoV-2 which showed a high correlation to plasma [18,28]. However, DBS testing has not yet been approved by the manufacturers and would require an in-house method. It is our understanding that subsequent assay versions of the Abbott Architect assay, together with software updates may enable future successful DBS testing. Moreover, additional exploration of multiplex assays that can differentiate between viral proteins (S1 and NCP) with improved sensitivity may be useful in the context of the post vaccination era to determine active infection [29,30].

This study has limitations. Firstly, the sample size for evaluating Euroimmun was approximately 50% less than Binding Site due to using

laboratory spotted DBS from venepuncture to preserve the clinically collected fingerstick DBSs for analysis on one assay. Initial feasibility on Binding Site using the same laboratory spotted DBS from venepuncture samples as Euroimmun identified superior results and therefore, Binding Site was selected to test ADAPT clinically collected fingerstick DBSs. Secondly, 11 Euroimmun spike results and 28 Euroimmun NCP results were excluded from analyses as either a DBS or serum result fell within the borderline range defined by the IFU. This same approach is described in both IFU's when defining performance metrics [15,16]. These highlights the need to develop a SARS-CoV-2 testing algorithm, with a two-step approach to screen and confirm both initially reactive and borderline results. Finally, all samples were tested in singlicate without reproducibility or cross-reactivity investigations.

Our results highlight that the assays targeting antibody response to the spike protein for SARS-CoV-2 infection provide superior performance compared to NCP assays, the advantage with Binding Site is that all incubation steps at room temperature, providing greater utility in a limited resource setting. When coupled with DBS collection, this testing approach could have excellent application for epidemiological surveil-

lance across many settings. Additionally, our research highlights that DBS could be a suitable sample type to facilitate post vaccination monitoring, important for public health surveillance and for populations in nursing homes, schools, and isolation.

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### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Supplementary materials

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