Original Paper

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Prevalence of antibodies to SARS-CoV-2 in Irish hospital healthcare workers

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Abstract

Hospital healthcare workers (HCWs) are at increased risk of contracting COVID-19 infection. We aimed to determine the seroprevalence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) antibodies in HCWs in Ireland. Two tertiary referral hospitals in Irish cities with diverging community incidence and seroprevalence were identified; COVID-19 had been diagnosed in 10.2% and 1.8% of staff respectively by the time of the study (October 2020). All staff of both hospitals ($N = 9038$) were invited to participate in an online questionnaire and blood sampling for SARS-CoV-2 antibody testing. Frequencies and percentages for positive SARS-CoV-2 antibody were calculated and adjusted relative risks (aRR) for participant characteristics were calculated using multivariable regression analysis. In total, 5788 HCWs participated (64% response rate). Seroprevalence of antibodies to SARS-CoV-2 was 15% and 4.1% in hospitals 1 and 2, respectively. Thirty-nine percent of infections were previously undiagnosed. Risk for seropositivity was higher for healthcare assistants (aRR 2.0, 95% confidence interval (CI) 1.4–3.0), nurses (aRR: 1.6, 95% CI 1.1–2.2), daily exposure to patients with COVID-19 (aRR: 1.6, 95% CI 1.2–2.1), age 18–29 years (aRR: 1.4, 95% CI 1.1–1.9), living with other HCWs (aRR: 1.3, 95% CI 1.1–1.5), Asian background (aRR: 1.3, 95% CI 1.0–1.6) and male sex (aRR: 1.2, 95% CI 1.0–1.4). The HCW seroprevalence was six times higher than community seroprevalence. Risk was higher for those with close patient contact. The proportion of undiagnosed infections call for robust infection control guidance, easy access to testing and consideration of screening in asymptomatic HCWs. With emerging evidence of reduction in transmission from vaccinated individuals, the authors strongly endorse rapid vaccination of all HCWs.

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Background

Healthcare workers (HCWs), and those they live with, are at increased risk of contracting COVID-19 viral infection [1–3]. Raised antibody levels to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) are an excellent indicator of COVID-19 infection [4]. To date there are no published literature on the seroprevalence of antibodies to SARS-CoV-2 infection in Irish HCWs, but it is known from surveillance data that a high proportion of the COVID-19 cases notified were HCWs [5]. Understanding the transmission and potential immunity dynamics of SARS-CoV-2 in hospitals in Ireland is key to controlling this pandemic at national and hospital levels and adds valuable information to the growing evidence based on the transmission patterns of COVID-19 among HCWs.

Hospital 1 is a tertiary referral hospital in the south inner city of Dublin, the capital city of Ireland (population 1.2 million) and has almost 4700 employees and just over 1000 beds. From March to May 2020 (first wave of the pandemic in Ireland [6]) 9.6% of the staff of Hospital 1 tested positive for SARS-CoV-2 infection via polymerase chain reaction (PCR), and by the start of October (the start of the second wave of the pandemic in Ireland [6]) 10.2% of staff had tested positive by PCR. Hospital 2 is a comparable tertiary referral hospital with almost 4400 employees and over 500 beds, located in Galway, in the West of Ireland (population 80 000); 1.8% of its HCWs had a PCR-confirmed infection at some stage during the time period from March to May 2020 and this remained at 1.8% until the start of October 2020. Hospital 1 is one of the largest acute hospitals in Dublin city; hospital 2 is the main acute hospital serving the city of Galway. Both hospitals received patients with COVID-19 infection throughout the first wave of the pandemic in Ireland, and breakdown by ward and specialty is similar. The community incidence of COVID-19 infection in County Galway was significantly lower than that in County Dublin during this time period, which covered the first wave of the pandemic in Ireland and the start of the second wave [6]. The community seroprevalence was also significantly lower in the West of Ireland as compared with the greater Dublin area; community seroprevalence was 3.1% for hospital 1 and 0.6% for hospital 2 in June 2020 [7, 8].

The purpose of the study was to determine the prevalence of anti-SARS-CoV-2 antibodies in HCWs in these two hospitals with diverging community and healthcare rates of infection to improve the understanding of HCWs' risk factors (demographic, living arrangements and work-related risks) for SARS-CoV-2 infection and to inform risk reduction activities and help health services to prepare for further waves of the pandemic. The study will be repeated in April 2021 to assess changes in overall seroprevalence, changes in individual serostatus over time and antibody response to COVID-19 vaccination.

Methods

Study design

This is a cross-sectional study of the seroprevalence of circulating antibodies to SARS-CoV-2, carried out from 14th to 23rd October 2020. All staff members of both hospitals were invited to participate in an online self-administered consent process and online questionnaire, followed by blood sampling for SARS-CoV-2 antibody testing. Electronic consent and patient reported outcomes were captured using Castor; an eClinical platform that enables decentralised clinical trials [9]. Technical support and walk-in phlebotomy clinics were provided for participants who had difficulty with the online consent process. Information collected in the questionnaire included demographic information, contact details, place and type of work, level of contact with patients, previous COVID-19 symptoms and testing, history of close contact with a confirmed case of COVID-19 and living arrangements. Blood samples were processed anonymously. All samples were tested on two testing platforms: the Abbott Architect SARS-CoV-2 immunoglobulin (Ig)-G assay and the Roche Elecsys anti-SARS-CoV-2 immunoassay [10–12]. Samples with an index result in the Abbott manufacturer's suggested positive and greyzone underwent additional testing in the National Virus Reference Laboratory (NVRL) using the Wantai SARS-CoV-2 AB ELISA distributed by Fortress Diagnostics [13]. A positive result on any of the three assays was considered a positive result. Results were discussed in person with any participant who requested this.

Statistical analysis

Frequencies and percentages were calculated for socio-demographic, epidemiological and clinical characteristics, including antibody results. Characteristics of those with a positive SARS-CoV-2 antibody result were compared to those with undetectable antibody, using the chi-square test. Univariate logistic regression was used to calculate relative risks along with their 95% confidence intervals (CIs) to assess the association between SARS-CoV-2 antibody result and characteristics of the study participants. Multivariable regression analysis was conducted to control for negative and positive confounding and to calculate adjusted relative risks (aRR). No explicit finite population correction or reweighting was carried out. All analyses were conducted in Stata 16 (StataCorp, 2019; College Station, TX, LLC) and R 4.0.3 (R Core Team, 2020, www.R-project.org/).

Results

Participation rates and demographics

All staff working in both hospitals (9038 people) were invited to participate in the study. In hospitals 1 and 2, 65% (3042/4692) and 63% (2745/4395) of staff participated in both questionnaire and blood sample, respectively.

The socio-demographic characteristics of participants were similar in both hospitals. Seventy-seven percent were female, with a median age of 39.5 years (IQR 30.4–48.9); 5.1% of participants were >60 years of age. Regarding ethnicity, 77% of participants were white Irish, 10% Asian (13% in hospital 1 and 7% in hospital 2), 9.5% other white background (majority born in Poland, USA and UK) and 2% African or any other black background. Ninety-one percent of participants live with others, and 31% live with other HCWs. The majority (36%) of participants were nursing staff, 19% were allied health care staff, 17% medical/dental staff, 13% administration staff, 7.5% general support staff, 5% healthcare assistants (HCAs) and 2% other HCWs, broadly reflecting the HCW breakdown of the hospital staff (Table 1). Participation rates among staff groupings were also similar in both hospitals; nurses and HCA were slightly underrepresented at 59% and 39% uptake respectively. In all other groups participation rates were above 60%.

Table 1. Participant characteristics by hospital and total number of participants

Participant characteristics	Hospital 1 (N = 3042)		Hospital 2 (N = 2745)		P value[a]	Total (n = 5788)	
	n	%	n	%		N	%
Age groups							
18–29	728	24	632	23	0.717	1350	23
30–39	831	27	785	29		1617	28
40–49	793	26	722	26		1515	26
50–59	532	18	468	17		1001	17
Over 60	158	5.2	146	5.3		304	5.3
Sex							
Female	2326	77	2152	78	0.117	4478	77
Male	716	24	592	22		1308	23
Missing	–	–	1	0.04		1	0.02
Ethnicity							
Irish	2262	74	2182	80		4444	77
Any other white background	267	8.8	284	10	<0.001	551	10
Any Asian background	393	13	184	7	<0.001	577	10
Any African or black background	65	2.1	48	1.8		113	2.0
Other	55	1.8	46	1.7		101	1.8
Missing	–	–	1	0.04		1	0.02
Country of birth[a]							
Ireland	2182	72	2091	76		4273	74
Country of birth[a]							
UK	152	5.0	192	7.0		344	5.9
India	201	6.6	98	3.6		299	5.2
Philippines	166	5.5	25	0.9		191	3.3
Poland	24	0.8	48	1.8		72	1.2
USA	22	0.7	38	1.4		60	1.0
Other	295	9.7	253	9.2		548	9.5
Education							
Primary	27	0.9	2	0.1	<0.001	29	0.5
Secondary	420	14	264	10		684	12
Third level	1300	43	1245	45		2545	44
Post-graduate	1295	43	1232	45		2527	44
Missing	–	–	2	0.1		2	0.03
Role							
Admin	454	15	349	13	<0.001	803	14
Medical/dental	460	15	522	19		982	17
Nursing/midwifery	1045	34	1019	37		2064	36
Allied health	616	20	475	17		1012	19
General support	255	8.4	179	6.5		434	7.5
Health care assistant	157	5.2	129	4.7		286	4.9
Other	55	1.8	72	2.6		127	2.2
Lives with							

(Continued)

Table 1. (Continued.)

Participant characteristics	Hospital 1 (N = 3042)		Hospital 2 (N = 2745)		P value[a]	Total (n = 5788)	
	n	%	n	%		N	%
Alone	256	8.4	223	8.1	0.020	479	8.3
Lives with							
With others	2768	91.0	2518	91.7		5286	91.3
Missing	18	0.6	4	0.2		22	0.4
Lives with HCW							
Yes	928	31	839	31	0.983	1767	31
Lives with HCW							
No	2060	68	1859	68		3919	68
Missing	54	1.8	47	1.7		101	1.8

[a]Calculated using the χ^2 test.

Previous testing and COVID-19-related characteristics of the participants

Hospital 1 staff had a higher percentage of previously confirmed COVID-19 infection; 9.6% of participants reported having tested positive at some stage by PCR compared to 2.7% of participants in hospital 2 (Table 2). Table 2 highlights the COVID-19-related characteristics of the participants by hospital.

Seroprevalence of antibodies to SARS-CoV-2

In hospital 1, the overall seroprevalence of antibodies to SARS-COV-2 was 15% (464/3042). Regarding the level of patient contact, the seroprevalence was 21% (108/510) in participants reporting daily contact with patients with known or suspected COVID-19 infection (we defined this as the high-risk group), 17% (269/1611) in those who reported daily contact with patients without known or suspected COVID-19 infection (intermediate-risk group) and 9.5% (87/918) in those who reported little or no patient contact (low-risk group). In hospital 2, the overall seroprevalence of antibodies to SARS-COV-2 was 4.1% (112/2745); 7.1% (28/392) in the high-risk group; 4.6% (75/1634) in the intermediate-risk group and 1.3% (9/717) in the low-risk group.

When looking at seroprevalence by role, the combined data for both hospitals showed the highest seroprevalence in HCAs, with 18% of those participating in the study having detectable antibodies. This was followed by nurses at 13% and medical/dental staff at 10%. The group with the lowest seroprevalence was the administration staff at 6%. Figure 1 shows the proportion of each staff group with detectable antibodies by hospital.

SARS-CoV-2 antibody and previous diagnosis and symptoms

Ninety-five percent (350/367) of those who had previously confirmed infection by PCR had detectable antibodies. In total, 227/576 (39%) of those with positive antibodies had not previously been diagnosed with COVID-19 infection; this represented 3.9% of all participants. Although 63% (142/227) of these participants with a previously undiagnosed infection reported having had symptoms at some stage, it is impossible to know if these symptoms coincided with the time of undiagnosed infection. Sixteen percent (90/576) of those with detectable antibodies had experienced no symptoms consistent with COVID-19.

Risk factors for antibody positivity to SARS-CoV-2

Tables 3 and 4 show the prevalence of SARS-CoV-2 IgG antibodies by participant characteristics for both hospitals combined. (For the prevalence of SARS-CoV-2 IgG antibodies by participant characteristics for the individual hospitals see Tables A–D, Supplementary annex).

On multivariable analysis of the combined hospital data the aRR of detectable antibody was higher for the following characteristics: working in hospital 1 (aRR 3.7, 95% CI 3.0–4.5, P < 0.001), working as an HCA (aRR 2.0, 95% CI 1.4–3.0, P = 0.001), working as a nurse (aRR 1.6, 95% CI 1.1–2.2, P = 0.007), daily exposure to patients with confirmed or suspected COVID-19 infection (aRR 1.6, 95% CI 1.2–2.1, P = 0.002), daily contact with patients not known or suspected to have COVID-19 infection (aRR 1.4, 95% CI 1.1–1.8, P = 0.008), age 18–29 years (aRR 1.4, 95% CI 1.1–1.9, P = 0.006), living with others (aRR 1.5, 95% CI 1.0–2.1, P = 0.048), living with other HCW (aRR 1.3, 95% CI 1.1–1.5, P = 0.007), being of Asian background (aRR 1.3, 95% CI 1.0–1.6, P = 0.028) and male sex (aRR 1.2, 95% CI 1.0–1.4, P = 0.046) (Table 5). (For multivariable analysis by hospital see Tables A and F, Supplementary annex.)

Discussion

Overall seroprevalence

The seroprevalence between hospitals 1 and 2 differed by four-fold, reflecting the difference in incidence and seroprevalence in the community in the two locations; the seroprevalence in both locations was six times the community seroprevalence [7, 8]. A Swedish study found HCW seroprevalence to be three times higher than the community seroprevalence during the first wave of the pandemic [14]. A Greek study found HCW seroprevalence to be between 10 and 22 times higher than the general population [15]; this was attributed in part to insufficient use/availability of personal protective equipment (PPE) in the hospital setting. Infection prevention and control (IPC) measures were the same in hospitals 1 and 2 (based on national guidelines) and there have been no issues with PPE availability in either of the hospitals involved in our study at any stage thus far during the pandemic. In both hospitals staff were re-deployed to improve the hospital's capacity to deal with the outbreak, however staff were not

Table 2. COVID-19-related characteristics by hospital and total number of participants

Participant characteristics	Hospital 1 (N = 3042)		Hospital 2 (N = 2745)		P value[a]	Total (N = 5788)	
	n	%	N	%		n	%
Contact of a COVID-19 case							
Yes	1185	39	519	19	<0.001	1704	30
No	1847	61	2224	81		4071	70
Missing	10	0.3	2	0.1		12	0.2
Setting of close contact							
Contact at work	1039	88	456	88	0.916	1495	88
Contact outside of work	146	12	63	12		209	12
Daily contact with COVID-19 patients							
Contact with COVID-19 patients	510	17	392	14	<0.001	902	16
Contact with patients without COVID-19	1611	53	1634	60		3245	56
No patient contact	918	30	717	26		1635	28
Missing	3	0.1	2	0.1		5	0.1
Previous COVID-19 symptoms							
No symptoms	1359	45	1517	55	<0.001	2876	50
Had symptoms	1683	55	1228	45		2911	50
Severity							
No symptoms	1359	45	1517	55	<0.001	2876	50
Only minor symptoms	1214	40	945	34		2159	37
Significant symptoms	442	15	259	9.4		701	12
Hospitalised	27	0.9	24	0.9		51	0.9
Previous COVID-19 PCR test							
Yes	1685	55	1093	40	<0.001	2778	48
No	1353	45	1650	60		3003	52
Missing	4	0.1	2	0.1		6	0.1
Previous positive COVID-19 PCR test							
Yes	292	9.6	75	2.7	<0.001	367	6.3
No	2746	90.3	2668	97.2		5414	93.6
Missing	4	0.1	2	0.1		6	0.1

[a]Calculated using the χ^2 test.

deployed to areas that would have been outside of their scope of practice, and all staff had training on the correct use of PPE. The seroprevalence in hospital 1 was similar to that found in a recent unpublished study in another hospital in the same city [16], suggesting that one of the main risks for infection in HCWs is the community incidence; a higher community incidence means that HCWs are more likely to be exposed by the nature of their work which involves direct contact with other people, both patients and other HCWs. Although this risk disproportionately affected those with closer patient contact, the risk to HCWs was higher than in the community, even for those who reported little or no patient contact.

The seroprevalence in both hospitals fell within the wide range (1–45%) previously described in other studies [15–21], and fell either side of the European estimate of 8.5% from the meta-analysis published in November 2020 [22].

Previous symptoms and testing

Five percent of participants with a previous PCR-confirmed COVID-19 infection did not have detectable antibodies. The manufacturers' reported test sensitivity is >95% for each assay used [11–13], so while some of these may be false negative results, it is also possible that these participants did not mount an antibody response following infection with COVID-19, or that they had antibody levels below the limits of detection of the test. We feel that a false-positive PCR result is less likely, but also possible.

In both hospitals, the seroprevalence was higher than the known PCR-confirmed diagnoses of COVID-19 infection of the same timeframe (15% vs. 10% in hospital 1, and 4.1% vs. 1.8% in hospital 2), and was also higher than the self-reported previously confirmed diagnoses (15% vs. 9.6% in hospital 1, 4.1% vs. 2.7% in hospital 2). Sixteen percent of participants with positive antibodies reported never having experienced symptoms that
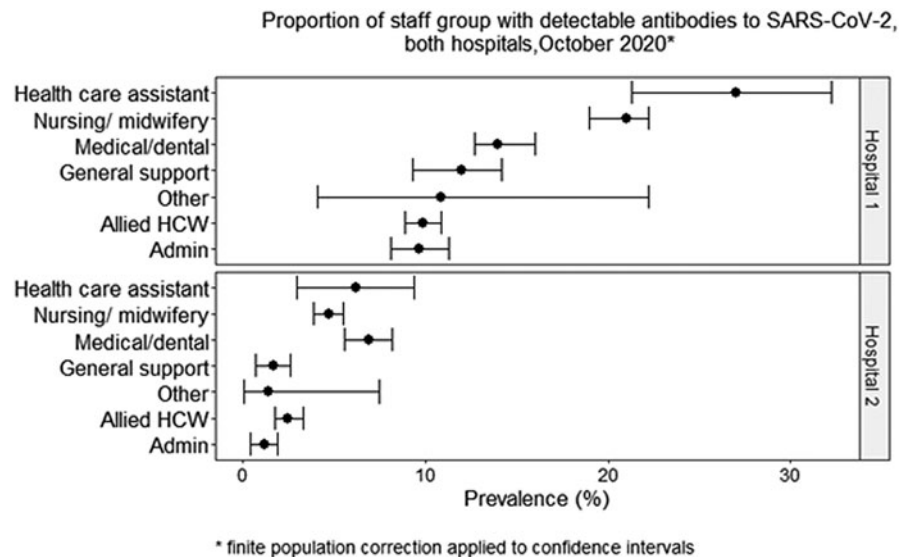
Fig. 1. Proportion of staff group with detectable antibodies to SARS-CoV-2, both hospitals, October 2020.

* finite population correction applied to confidence intervals

were consistent with infection with COVID-19. Thirty-nine percent of infections in our study were undiagnosed, even though both hospitals had onsite PCR testing available to HCWs with symptoms or close contact with a confirmed case of COVID-19 from mid-March 2020. It is likely that these undiagnosed HCWs were working during the infectious period, with potential for onwards transmission to patients and other staff members if proper use of PPE and other IPC measures were not strictly adhered to. This highlights the importance of early detection and reinforces the importance of clear messaging to HCWs about not working when symptomatic. It also highlights the necessity for universal adherence to standard infection control precautions at all times, compliance with transmission-based precautions and appropriate use of PPE including face masks in the hospital setting, irrespective of symptoms [23]. This finding also supports the recommendation for screening of asymptomatic staff when a patient case of hospital-acquired infection, or hospital outbreak of infection with COVID-19 occurs [24]. Mass serial screening of asymptomatic HCWs should be considered. This intervention has been shown to be effective in certain settings [25, 26]. However, the frequency of testing that would be required to have a significant impact on transmission of infection from HCWs has not been established, and other studies have found the impact of this intervention to be uncertain and the logistical challenges it poses to the health service are significant [27–29].

Risk factors for antibody positivity

The main risk factors identified to be significantly associated with SARS-CoV-2 antibody positivity were working in hospital 1, being an HCA, being a nurse, performing roles associated with close patient contact (especially those working directly with COVID-19 patients), living with others, living with other HCWs, being of Asian ethnicity, being aged 18–29 years and being male. Similar risk factors have also been identified in other studies, including the meta-analysis of European studies [22, 30, 31]. Those of Asian background had a higher risk than those of white Irish background. This was a significant finding on multivariable analysis (MVA), with other factors including exposure accounted for. It is possible that there are other social

factors relating to ethnicity that were not evaluated in our study and that are contributing to this risk. Studies conducted in other countries have also found Black individuals to be at a higher risk, and many studies have found higher risk in combined BAME (Black, Asian and Minority Ethnic) groups. Black individuals in our study did have a higher overall seroprevalence at 19%, and a higher relative risk of antibody positivity, however this finding was not statistically significant on multivariate analysis, possible due to smaller number of Black participants compared to Asian participants. Other studies have highlighted close patient contact as a risk factor for disease acquisition [32], including specifically the role of nurse or HCAs [15, 31]. We found daily contact with patients with COVID-19 infection to carry a higher relative risk of antibody positivity with comparison to daily contact with patients without COVID-19 infection. Studies have differed on this result; a German study showed a higher seroprevalence among the intermediate risk group with comparison to the high-risk group, potentially due to less scrupulous adherence to infection control precautions including the use of PPE on non-COVID wards [17]. A Spanish study found no significant correlation between role or direct patient contact and antibody positivity, although community incidence was higher in their setting [18].

Having a household contact is known to be a significant risk factor for disease acquisition [33]. In our study, living with others (and especially living with other HCWs) was significantly associated with antibody positivity, which supports the theory that a proportion of the HCW contracting COVID-19 are doing so in their home environment. Other studies have found some correlation between size of household and antibody positivity [18] but to the best of our knowledge this is the first study to find a statistically significant correlation between living with other HCWs and being antibody positive.

Limitations

Our study has several limitations. First, information on COVID-19 symptoms and test results were self-reported and thus could be biased. Second, although the uptake rate of 64% overall is good for an opt-in study, there may be a selection bias; it is possible that those who chose not to take part did so

Table 3. Prevalence of SARS-CoV-2 antibodies by participant characteristics, both hospitals

| Participant characteristics | Total N | SARS-CoV-2 antibody detected | | P value[a] |
		n	% (95% CI)	
Age groups (years)				
18–29	1350	177	13 (11–15)	<0.001
30–39	1617	168	10 (8.9–12)	
40–49	1515	124	8.2 (6.9–9.7)	
50–59	1001	77	7.7 (6.1–9.5)	
Over 60	304	30	9.9 (6.8–14)	
Sex				
Female	4478	422	9.4 (8.6–10)	0.013
Male	1308	154	12 (10–14)	
Ethnicity				
Irish	4444	384	8.6 (7.8–9.5)	<0.001
Any other white background	551	62	11 (8.7–14.2)	
African and any other black background	113	16	14 (8.3–22)	
Asian background	577	107	19 (16–22)	
Other	101	7	6.9 (2.6–15)	
Country of birth[a]				
Ireland	4273	373	8.7 (7.9–9.6)	<0.001
UK	344	32	9.3 (6.5–13)	
India	299	54	18 (14–31)	
Philippines	191	47	25 (19–31)	
Poland	72	10	14 (6.9–24)	
USA	60	3	5.0 (1.0–14)	
Other	548	57	10 (8.0–13)	
Education				
Primary	29	4	14 (3.9–32)	0.055
Secondary	684	61	8.9 (6.9–11)	
Third level	2545	283	11 (9.9–12)	
Post-graduate	2527	228	9.0 (7.9–10)	
Role				
Admin	803	48	6.0 (4.4–7.9)	<0.001
Medical/dental	982	102	10 (8.6–13)	
Nursing/midwifery	2064	263	13 (11–14)	
Allied health	1091	73	6.7 (5.3–8.3)	
General support	434	33	7.6 (5.3–11)	
Health care assistant	286	50	18 (13–22)	
Other	127	7	5.5 (2.2–11)	
Lives with				
Alone	479	28	5.9 (3.9–8.3)	0.007
With others	5286	546	10 (9.5–11)	
Missing	22	2	9.1 (1.1–29)	
Lives with HCW				

(Continued)

Table 3. (*Continued.*)

Participant characteristics	Total	SARS-CoV-2 antibody detected		P value[a]
	N	n	% (95% CI)	
Yes	1767	234	13 (12–15)	<0.001
No	3919	332	8.5 (7.6–9.4)	
Missing	101	10	9.9 (4.9–18)	

[a]Calculated using the χ^2 test.

Table 4. Prevalence of SARS-CoV-2 antibodies by COVID-19-related characteristics, both hospitals

Participant characteristics	Total	SARS-CoV-2 IgG detected		P value[a]
	N	n	% (95% CI)	
Contact of a COVID-19 case				
Yes	1704	325	19 (17–21)	<0.001
No	249	249	6.1 (5.4–6.9)	
Missing	10	2	167 (2.1–48)	
Setting of close contact				
Contact at work	1495	269	18 (16–20)	0.002
Contact outside of work	209	56	27 (21–33)	
Workplace exposure				
Daily contact with COVID-19 patients	902	136	15 (13–18)	<0.001
Daily contact with patients without COVID	3245	344	11 (9.6–12)	
No patients contact	1635	96	5.9 (4.9–7.1)	
Previous COVID-19-like symptoms				
No symptoms	2876	92	3.2 (2.6–3.9)	<0.001
Had symptoms	2911	484	17 (15–18)	
Previous COVID-19 PCR test				
Yes	2778	474	17 (16–19)	<0.001
No	3003	102	3.4 (2.8–4.1)	
Previous positive COVID-19 PCR test				
Yes	367	350	95.4 (92.7–97.3)	<0.001
No	5414	226	4.2 (3.7–4.7)	

[a]Calculated using the χ^2 test.

due to busier workload, for example, those working on a COVID-19 ward, and therefore with a higher risk of COVID-19 infection. One of the main reasons for overall good recruitment was the incentive of each participant receiving their individual result. This too may introduce a selection bias; those who already know that they have had COVID-19 infection may have been less interested in participating, as well as those who may have already had private antibody testing done elsewhere, which could lead to an under-estimate in the true seroprevalence. Conversely, those who had a previously confirmed infection by PCR may have had more interest in participating to see if they had gained antibodies (and potential immunity). Third, although the communication strategy was an important part of the recruitment process, the study took part during our second wave of the pandemic, and therefore also relied heavily on engagement with information

technology (IT) platforms (email, messenger groups and hospital intranet) and less on face-to-face announcements. The online consent process, questionnaire and blood test booking system risks exclusion of those who are less literate in IT. This was identified as a potential limitation from the start, and attempts were made to mitigate this selection bias. Multilanguage information and plain English were used, and groups identified as potentially at risk of exclusion on this basis were targeted directly for inclusion in the study, with small-group sessions to aid consent and questionnaire completion and walk-in clinics for phlebotomy. In the fourth instance, in testing on two different platforms, we chose to prioritise sensitivity over specificity. However, the rate of discordant results was low, and unlikely to have had a significant effect on the results; there were only 21 samples with a positive result on the Abbott Architect assay that did not have a

Table 5. Association between risk factors and the presence of SARS-CoV-2 antibodies, both hospitals

Participant characteristics	Unadjusted relative risk (95% CI)	*P* value	aRR (95% CI)	*P* value
Hospital				
Hospital 2	Ref.			
Hospital 1	**3.7 (3.1–4.6)**	**<0.001**	**3.7 (3.0–4.5)**	**<0.001**
Age groups (years)				
18–29	**1.7 (1.3–2.2)**	**<0.001**	**1.4 (1.1–1.9)**	**0.006**
30–39	1.4 (1.1–1.8)	0.022	1.2 (0.9–1.5)	0.217
40–49	1.1 (0.8–1.4)	0.656	1.0 (0.8–1.3)	0.978
50–59	Ref.			
Over 60	1.3 (0.9–1.9)	0.224	1.4 (0.9–2.0)	0.112
Sex				
Female	Ref.			
Male	**1.3 (1.1–1.5)**	**0.012**	**1.2 (1.0–1.4)**	**0.046**
Ethnicity				
Irish	Ref.			
Any other white background	1.3 (1.0–1.7)	0.041	1.3 (1.0–1.6)	0.068
African and other black background	1.6 (1.0–2.7)	0.037	1.3 (0.8–2.0)	0.299
Asian background	**2.2 (1.8–2.6)**	**<0.001**	**1.3 (1.0–1.6)**	**0.028**
Other	0.8 (0.4–1.7)	0.549	0.6 (0.2–1.3)	0.177
Country of birth				
Ireland	Ref.		Did not enter	
India	2.1 (1.6–2.7)	<0.001		
Philippines	2.8 (2.2–3.7)	<0.001		
UK	1.1 (0.8–1.5)	0.717		
Poland	1.6 (0.9–2.9)	0.119		
USA	0.6 (0.2–1.7)	0.324		
Other	1.2 (0.9–1. 6)	0.193		
Education				
Primary	1.5 (0.6–3.8)	0.365	Did not enter	
Secondary	1.0 (0.8–1.3)	0.933		
Third level	1.2 (1.0–1.5)	0.013		
Post-graduate	Ref.			
Role				
Admin	Ref.			
Doctor/Dental	1.7 (1.3–2.4)	0.001	1.2 (0.8–1.7)	0.327
Nursing	**2.1 (1.6–2.9)**	**<0.001**	**1.6 (1.1–2.2)**	**0.007**
HCA	**2.9 (2.0–4.2)**	**<0.001**	**2.0 (1.4–3.0)**	**0.001**
General support	1.3 (0.8–2.0)	0.270	0.9 (0.6–1.4)	0.687
Allied HCW	1.1 (0.8–1.6)	0.531	0.9 (0.6–1.3)	0.635
Other	0.9 (0.4–2.0)	0.837	1.0 (0.5–2.1)	0.941
Lives with				
Alone	Ref.			
With others	**1.8 (1.2–2.6)**	**0.002**	**1.5 (1.0–2.1)**	**0.048**
Lives with HCW				

(*Continued*)

Table 5. (*Continued.*)

Participant characteristics	Unadjusted relative risk (95% CI)	P value	aRR (95% CI)	P value
No	Ref.			
Yes	**1.6 (1.4–1.8)**	**<0.001**	**1.3 (1.1–1.5)**	**0.007**
Contact of a COVID-19 case				
No	Ref.		Did not enter	
Yes	3.1 (2.7–3.6)	<0.001		
Close contact at work[a]				
No	1.5 (1.2–1.9)	0.002	Did not enter	
Yes	Ref.			
Workplace exposure to COVID-19 patients				
No patient contact	Ref.			
Daily contact with patients without COVID-19	**1.8 (1.5–2.3)**	**<0.001**	**1.4 (1.1–1.8)**	**0.008**
Daily contact with COVID-19 patients	**2.6 (2.0–3.3)**	**<0.001**	**1.6 (1.2–2.1)**	**0.002**
Previous COVID-19-like symptoms				
No	Ref.		Did not enter	
Yes	5.2 (4.2–6.5)	<0.001		

[a]Calculated for close contacts of COVID-19 cases only (*n* = 1704).

positive result on either the Roche Elecsys assay or the Wantai ELISA. In the fifth instance, this population was surveyed in October, at the start of the second wave of the pandemic in Ireland. A proportion of the HCW workforce in Ireland is transient, and the staff included in the study may not have worked in the same hospital during the first wave of the pandemic. However, over 90% of participants in each hospital reported that had been working in the same hospital during the first wave of the pandemic. And finally, even though the sample size was large, some covariate partners were small and thus rendered further analysis lacking in statistical power and precision (e.g. interactions terms or further stratified analysis).

Conclusion and recommendations

The overall seroprevalence of antibodies to SARS-CoV-2 was 15% in hospital 1 and 4.1% in hospital 2, reflecting the difference in community incidence and seroprevalence in each area, and suggesting that the main risk factor for acquisition of COVID-19 infection in HCWs is the local community incidence. The HCW seroprevalence was six times the community seroprevalence in each area. Specific risk factors for antibody positivity included being an HCA or nurse, daily contact with patients (especially those known or suspected to have COVID-19 infection), age 18–29 years, living with others, in particular living with other HCWs, being of Asian background and being male. The degree of previously undiagnosed and asymptomatic infections highlights the need for ongoing universal adherence to infection control guidance including the use of appropriate PPE in the hospital setting, as well as the importance of early case detection. It is essential that HCWs have easy access to testing, even with mild or no symptoms. As the national COVID-19 vaccination programme is rolled out, we expect that access to testing for HCWs will still be critical. Screening of asymptomatic HCWs in the setting of hospital-acquired patient infection or outbreaks is

important and regular screening of asymptomatic HCWs needs to be considered depending on local epidemiology.

This study is a unique comparison between two hospitals in the areas of differing community incidence, in which IPC measures were the same. It is the first study, to the best of our knowledge, to specifically delineate the relationship between living with other HCWs and risk of antibody positivity. This study is paramount in improving understanding of transmission dynamics and HCW risk factors (demographic, workplace- and household-related) in hospitals in Ireland. The high proportion of undiagnosed infections underscores the importance of all interventions to reduce infection in the hospital setting. This bundle should include robust infection control guidance and adherence to that guidance, with scrupulous attention to standard and transmission-based precautions including the use of appropriate PPE in the hospital setting, easy access to testing for HCWs and prompt outbreak investigation. This study will be crucial in informing the vaccination strategy and roll-out of HCWs in Ireland. Emerging evidence of reduced transmission of infection by vaccine recipients [34] endorses prompt vaccination of all HCWs.

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