Impact of COVID-19 Containment Strategies and Meningococcal Conjugate ACWY Vaccination on Meningococcal Carriage in Adolescents

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Objectives: To examine if COVID-19 containment strategies were associated with reduced pharyngeal carriage of meningococci in adolescents. Also, to observe if carriage prevalence of meningococcal A, C, W and Y differed in meningococcal conjugate ACWY vaccinated and unvaccinated adolescents.

Design: Repeat cross-sectional study of pharyngeal carriage.

Setting: In 2020, recruitment commenced from February to March (pre-COVID-19) and recommenced from August to September (during COVID-19 measures) in South Australia.

Participants: Eligible participants were between 17 and 25 years of age and completed secondary school in South Australia in 2019.

Results: A total of 1338 school leavers were enrolled in 2020, with a mean age of 18.6 years (standard deviation 0.6). Pharyngeal carriage of disease-associated meningococci was higher during the COVID-19 period compared with the pre-COVID-19 period (41/600 [6.83%] vs. 27/738 [3.66%]; adjusted odds ratio [aOR], 2.03; 95% CI: 1.22–3.39; $P = 0.01$). Nongroupable carriage decreased during COVID period (1.67% vs. 3.79%; aOR, 0.45; 95% CI: 0.22–0.95). Pharyngeal carriage of groups A, C, W and Y was similar among school leavers vaccinated with meningococcal conjugate ACWY (7/257 [2.72%]) compared with those unvaccinated (29/1081 [2.68%]; aOR, 0.86; 95% CI: 0.37–2.02; $P = 0.73$). Clonal complex 41/44 predominated in both periods.

Conclusions: Meningococcal carriage prevalence was not impacted by public health strategies to reduce severe acute respiratory syndrome coronavirus 2 transmission and is unlikely to be the mechanism for lower meningococcal disease incidence. As international travel resumes and influenza recirculates, clinicians must remain vigilant for signs and symptoms of meningococcal disease. Vaccinating people at the highest risk of invasive meningococcal disease remains crucial despite containment strategies.

Keywords: meningococcal, carriage, COVID-19

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All authors were involved in the design of the study. M.M. participated in the data collection, entry and cleaning. L.E.X.L. conducted the whole genome sequencing. Analyses was conducted by J.B. and M.M., with all authors involved in the interpretation. M.M. wrote the draft article. All authors reviewed and approved the final version for publication.

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Social distancing dramatically decreases the transmission of common infectious diseases in children, such as influenza, croup, common colds, pneumonia and bronchiolitis.[1] The implementation of social and physical distancing, international quarantine and lockdowns in response to COVID-19 during the year 2020 provided a unique opportunity to assess the impact of these measures on the pharyngeal carriage of meningococci among adolescents.

Neisseria meningitidis (often referred to as meningococcus) is a commensal bacteria of humans residing in the pharynx and transmitted through respiratory droplets or saliva exchange. The peak prevalence of meningococcal carriage in adolescents and young adults in high-income countries is attributed to increases in behaviors that facilitate the spread of respiratory droplets and saliva. These activities include going to pubs and clubs, smoking, drinking alcohol and intimate kissing.[2,3] The overwhelming majority of people who acquire carriage of meningococci remain asymptomatic and clear the bacteria in weeks, months or in some cases, a year or more.[4] A small number of people who acquire meningococci develop invasive meningococcal disease (IMD). Before the COVID-19 pandemic, there was an increase in group W and Y disease prevalence in Australia from 2015, prompting the introduction of a meningococcal conjugate ACWY (MenACWY) vaccine on the National Immunisation Schedule for 14–16-year-olds in 2019.[5] Herd protection afforded by monovalent conjugate A and C vaccines has been a critical factor in reducing the incidence of invasive meningococcal A and C disease globally.[6,7] While there is some evidence for herd protection effects of multivalent MenACWY, the impact may not be as pronounced as monovalent conjugate meningococcal vaccines.[8]

In South Australia, IMD cases decreased from 36 in 2017, 34 in 2018, 27 in 2019, to 5 in 2020.[9,10] The observed reduction in IMD in 2020 followed the introduction of a 4CMenB infant program beginning October 2018, and an adolescent program commencing February 2019, with 1 year of catch up for 16–20-year-olds. An adolescent MenACWY program for adolescents was also introduced in April 2019. An international network of laboratories in 21 countries has also identified that IMD cases declined in all countries, in 2020, after COVID-19 containment measures. Using a time series analysis, the study showed a sharp reduction in the predicted trend of IMD cases based on the number of cases per week in the 2 years prior.[11]

The dramatic reduction in IMD cases in South Australia was partly because of the direct protection after the infant and adolescent 4CMenB program that commenced in 2018/19. However, a reduction of IMD has been observed across Australia and globally in places without MenB vaccine programs. The observed reduction in IMD in Australia and other countries could be because of several factors, including a reduction in circulating influenza.[12,13] Previous studies have identified a temporal association between influenza and IMD,[14,15] with one study demonstrating an increased risk of IMD in people who had serological evidence of influenza infection in the previous month.[16] This association could be because of its effect on transmission, colonization, circulatory invasion because of damage to the pharyngeal epithelium, or altered host immune

function.[15,16] Another potential factor could be reducing the transmission of meningococci through social distancing and quarantine.

This article examined differences in meningococcal carriage prevalence between adolescent school leavers in South Australia swabbed before and after introducing social distancing and lockdown measures in response to COVID-19, during a year of low influenza and IMD incidence. We also sought to detect differences in the prevalence of meningococcal A, C, W and Y carriage between MenACWY vaccinated and unvaccinated school leavers during the first year after the introduction of the MenACWY program in South Australia.

METHODS

Study Design

This analysis uses data from an investigator-led repeat cross-sectional "school leaver" study conducted in South Australia (2018–2020) that assessed meningococcal carriage in young adults the year after finishing school.[2] This research is a secondary analysis of the final year of that study, in which oropharyngeal swabs were collected both before COVID containment strategies and after the easing of strategies in 2020. During 2017 and 2018, a cluster-randomized controlled trial conducted in South Australia provided 4CMenB vaccination at baseline (intervention) or after 12 months (control) to over 30,000 high school students ("B Part of it" study).[17] After the randomized controlled trial, from 2019, both 4CMenB and MenACWY vaccines were made freely available for adolescents through the school immunization program in South Australia. In 2020, recruitment commenced on 24 February and continued until 4 March (hereafter "pre-COVID-19"). Recruitment was then paused because of COVID-19 restrictions and recommenced from 17 August until 11 September 2020 (hereafter "COVID-19-period").

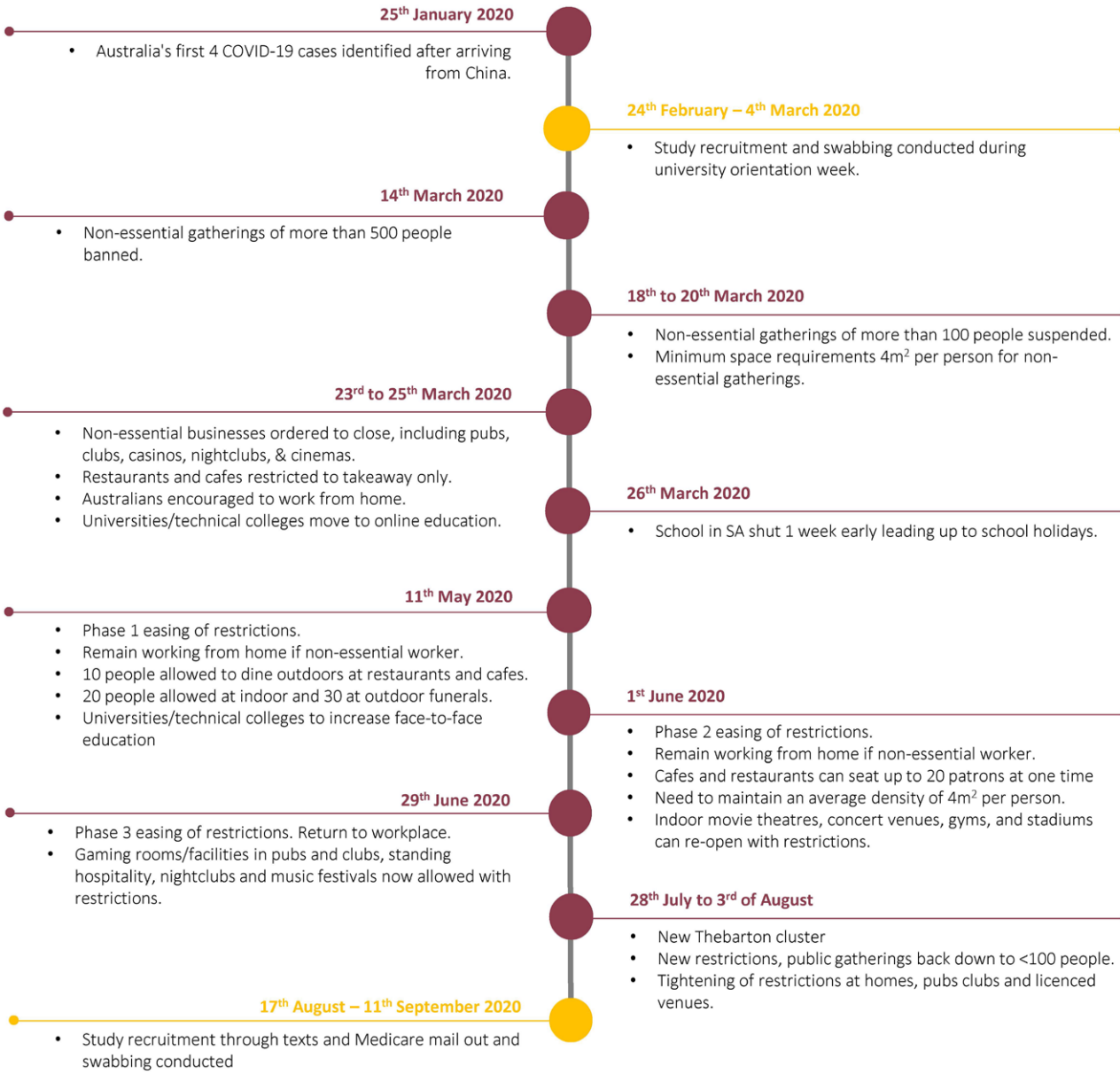

Figure 1. Timeline of COVID-19 restrictions in South Australia from January 25, to August 3, 2020.

Participants

Eligible adolescents must have completed secondary school in South Australia in 2019 and be between 17 and 25 years of age. Participants were recruited using mail-outs, text messages, education stalls during university orientation week, social media advertising and a Medicare mail-out to 18-year-olds in urban Adelaide and selected rural locations for generalizability in South Australia.

Study Process

Each participant provided written consent and had an oropharyngeal swab taken by trained nursing or medical staff. Questionnaires that identified potential risk factors for carriage were completed, and participants were reimbursed $40 for their time and travel costs. MenACWY and 4CMenB vaccination status was ascertained via the Australian Immunisation Register.

Swabs were placed in 2 mL skim milk-tryptone-glucose-glycerol medium and transported to the state-wide pathology service, SA Pathology. Direct screening for meningococcal DNA (*porA* gene) was conducted using polymerase chain reaction (PCR), with further analysis conducted to determine the meningococcal genogroup (A, B, C, W, X or Y) on any positive *porA* test.[18] Disease-associated carriage is defined as detection of the *porA* and capsular genes for groups A, B, C, W, X or Y. Nongroupable carriage is defined as detection of the *porA* gene and failure to detect any of the capsular genogroups listed above. As described previously,[19] any samples yielding a *porA* positive reverse transcription PCR were cultured for *Neisseria* species on selective agar, and multilocus sequence typing and fine typing were defined using the PUBMLST database.[20]

Statistical Analysis

As this is a secondary analysis/posthoc, sample size calculations for comparing specific time periods and comparisons based on MenACWY status were not conducted a priori. Logistic regression was used to examine the effects of COVID-19 containment measures, MenACWY vaccination and 4CMenB vaccination on meningococcal carriage, with effects described as odds ratios (ORs) and 95% CIs. Participants who were vaccinated <28 days before their swab were considered unvaccinated for comparisons between vaccinated and unvaccinated groups. Recruitment in 2020 was lower than anticipated owing to COVID-19 restrictions, resulting in low numbers of observed events. For this reason, variables used in the regression analysis were limited to the COVID-19 containment period, MenACWY vaccine and 4CMenB vaccine receipt. All analyses were performed using Stata v.15 (Statacorp, College Station, TX).

COVID-19 Restrictions in South Australia

After university orientation week in early March 2020, containment measures were progressively introduced by the state and federal government in response to the COVID-19 pandemic, with most nonessential gatherings and services effectively banned and shut down as of late March 2020. At the same time, foreign travellers were no longer able to come to Australia because of border measures introduced to curb the spread of the virus. Australian citizens could return but were required to undergo 14 days of quarantine. Study recruitment was paused until the easing of containment measures in August. During the heaviest restrictions, people were mandated to work or study from home, and environments conducive to the spread of respiratory droplets, such as pubs, clubs and entertainment venues, were shut. With the easing of restrictions, these venues were permitted to reopen with physical distancing and dramatically reduced capacity limits in place (Fig. 1).[21,22]

Ethics Approval

The study was approved by the Women's and Children's Health Network Human Research Ethics Committee and prospectively registered at ClinicalTrials.gov: NCT03419533.

RESULTS

A total of 1343 school leavers were enrolled in 2020. Five school leavers were excluded from all analyses of carriage prevalence because of missing swab data. Participants had a mean age of 18.6 years (standard deviation 0.6), and the majority were female (809 [60.9%]) (Table 1). Just over half of the participants were swabbed between February and March (738 [55.2%]), with the remainder swabbed between August and September (600 [44.8%]). Compared with the pre-COVID-19 period, the proportions of both 4CMenB-vaccinated and MenACWY-vaccinated participants were higher during the COVID-19-period (4CMenB: pre-COVID-19, 514/738 [69.6%], COVID-19-period 505/600 [84.2%], MenACWY: pre-COVID-19, 92/738 [12.5%], COVID-19-period, 165/600 [27.5%]). The proportion of school leavers spending 2 or more

TABLE 1. Participant Characteristics by COVID-19 Period

Participant characterstics	Pre-COVID-19† Period	COVID-19† period	Total†
	(N = 738)	(N = 600)	(N = 1338)
Age in years			
Mean (SD)	18.33 (0.64)	18.82 (0.41)	18.55 (0.60)
IRSD quintile*			
1 (most disadvantaged)	118 (16.3)	93 (15.7)	211 (16.0)
2	103 (14.2)	85 (14.3)	188 (14.3)
3	137 (18.9)	89 (15.0)	226 (17.1)
4	140 (19.3)	144 (24.2)	284 (21.5)
5 (least disadvantaged)	226 (31.2)	183 (30.8)	409 (31.0)
Gender (female)	430 (58.8)	379 (63.5)	809 (60.9)
Meningococcal B vaccination (2 doses)	514 (69.6)	505 (84.2)	1019 (76.2)
MenACWY vaccination	92 (12.5)	165 (27.5)	257 (19.2)
Working status			
Full time work	18 (2.4)	31 (5.2)	49 (3.7)
Part time work	11 (1.5)	76 (12.7)	87 (6.5)
Part time work + study	139 (18.9)	109 (18.2)	248 (18.5)
Full time study	557 (75.6)	274 (45.7)	831 (62.2)
Not working or studying	7 (0.9)	86 (14.3)	93 (7.0)
Smoking in the last week	20 (2.7)	12 (2.0)	32 (2.4)
Smoked water pipe in last month	21 (2.8)	9 (1.5)	30 (2.2)
Ethnicity			
Aboriginal Torres Strait Islander	13 (1.8)	15 (2.5)	28 (2.1)
Caucasian	425 (59.9)	464 (78.2)	889 (68.2)
Asian	210 (29.6)	76 (12.8)	286 (21.9)
Middle Eastern	11 (1.5)	8 (1.3)	19 (1.5)
African	16 (2.3)	3 (0.5)	19 (1.5)
Other	35 (4.9)	27 (4.6)	62 (4.8)
Days out in the last week			
None	368 (51.4)	373 (62.5)	741 (56.4)
1	196 (27.4)	162 (27.1)	358 (27.3)
2 or more	152 (21.2)	62 (10.4)	214 (16.3)
Drank alcohol in last month	515 (71.7)	420 (70.5)	935 (71.2)
People kissed in the last week			
None	446 (62.8)	350 (59.6)	796 (61.4)
1 or more	264 (37.2)	237 (40.4)	501 (38.6)
In current relationship	213 (29.6)	198 (33.2)	411 (31.2)

*Index of relative socio-economic disadvantage (IRSD).
†n (%) presented unless otherwise indicated (excludes missing values).

days out in the last week halved in the COVID-19 period (62/597 [10.4%]) compared with pre-COVID-19 (152/716 [21.2%]). However, the proportion of people kissing 1 or more people in the last week was relatively consistent between the 2 periods. It was also similar between those kissing 2 or more people in the last week pre COVID-19 compared with during COVID-19 (3.8% vs. 3.6%). As well as those kissing 1 or more people while in a relationship (pre COVID-19 [87.3%] vs. COVID-19 period [91.8%]).

Pharyngeal carriage of disease-associated meningococci increased during the COVID-19 period compared with pre COVID-19 (41/600 [6.83%] vs. pre 27/738 [3.66%], adjusted OR [aOR], 2.03; 95% CI: 1.22–3.39; *P*=0.01). The increase was mostly because of changes in the carriage of groups B (aOR, 2.94; 95% CI: 1.50–5.79) and Y (aOR 2.76; 95% CI: 1.27–6.03), as per Tables 2 and 3. There was a decrease in nongroupable carriage in the COVID-19 period compared with the pre-COVID-19 period (10/600 [1.67%] vs. pre 28/738 [3.79%], aOR 0.45, 95% CI: 0.22–0.95; *P*=0.04).

Pharyngeal carriage of groups A, C, W and Y was similar among school leavers vaccinated with MenACWY (7/257 [2.72%]) compared with those unvaccinated (29/1081 [2.68%]; aOR, 0.86; 95% CI: 0.37–2.02; *P* = 0.73). No significant differences in carriage were detected between MenACWY vaccinated and unvaccinated

TABLE 2. Carriage by COVID-19 Period and MenACWY Vaccination Status

	Pre-COVID-19			COVID-19 Period		
Genogroup‡	MenACWY Unvaccinated (N = 646), n (%)	MenACWY Vaccinated (N = 92), n (%)	Total Pre (N = 738), n (%)	MenACWY Unvaccinated (N = 435), n (%)	MenACWY Vaccinated (N = 165), n (%)	Total During (N = 600), n (%)
Disease-associated*	26 (4.02)	1 (1.09)	27 (3.66)	30 (6.90)	11 (6.67)	41 (6.83)
Groups A, C, W or Y	13 (2.01)	0 (0)	13 (1.76)	16 (3.68)	7 (4.24)	23 (3.83)
Any	52 (8.05)	3 (3.26)	55 (7.45)	39 (8.97)	12 (7.27)	51 (8.50)
Group A	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Group B	12 (1.86)	1 (1.09)	13 (1.76)	22 (5.06)	8 (4.85)	30 (5.00)
Group C	1 (0.15)	0 (0)	1 (0.14)	1 (0.23)	1 (0.61)	2 (0.33)
Group W	3 (0.46)	0 (0)	3 (0.41)	0 (0)	0 (0)	0 (0)
Group X	1 (0.15)	0 (0)	1 (0.14)	1 (0.23)	0 (0)	1 (0.17)
Group Y	10 (1.55)	0 (0)	10 (1.36)	15 (3.45)	6 (3.64)	21 (3.50)
Nongroupable†	26 (4.02)	2 (2.17)	28 (3.79)	9 (2.07)	1 (0.61)	10 (1.67)

*Disease-associated genogroups defined as genogroups A, B, C, W, X or Y.

†"Nongroupable" carriage is defined as failure to detect genogroup A, B, C, W, X or Y, in those with *porA* detected.

‡"Disease-associated" and 'Groups A, C, W, Y' are less than the individual genogroup total because more than one isolate has been detected in some participants.

TABLE 3. Unadjusted and Adjusted Analyses of Carriage Prevalence in School Leavers by COVID-19 Period, MenACWY, and MenB Vaccination Status in 2020

	Unadjusted Effect		Adjusted‡ Effect	
Exposure by Genogroup	Unadjusted OR (95% CI)	Unadjusted *P*	Adjusted OR (95% CI)	Adjusted *P*
Disease-associated*				
COVID-19-period vs. pre-COVID-19	1.93 (1.17–3.18)	0.01	2.03 (1.22–3.39)	0.01
MenACWY vaccinated vs. unvaccinated	0.90 (0.47–1.70)	0.74	0.77 (0.40–1.48)	0.43
4CMenB vaccinated vs. unvaccinated	1.02 (0.57–1.81)	0.95	0.91 (0.50–1.63)	0.74
Groups A, C, W or Y				
COVID-19-period vs. pre-COVID-19	2.22 (1.12–4.43)	0.02	2.35 (1.16–4.77)	0.02
MenACWY vaccinated vs. unvaccinated	1.02 (0.44–2.35)	0.97	0.86 (0.37–2.02)	0.73
4CMenB vaccinated vs. unvaccinated	0.94 (0.44–2.01)	0.87	0.80 (0.37–1.75)	0.58
Any				
COVID-19-period vs. pre-COVID-19	1.15 (0.78–1.72)	0.48	1.21 (0.81–1.82)	0.36
MenACWY vaccinated vs. unvaccinated	0.67 (0.38–1.19)	0.17	0.64 (0.36–1.13)	0.13
4CMenB vaccinated vs. unvaccinated	1.08 (0.67–1.73)	0.76	1.08 (0.67–1.75)	0.75
Group B				
COVID-19-period vs. pre-COVID-19	2.94 (1.52–5.68)	0.001	2.94 (1.50–5.79)	0.002
MenACWY vaccinated vs. unvaccinated	1.12 (0.53–2.36)	0.77	0.87 (0.41–1.87)	0.72
4CMenB vaccinated vs. unvaccinated	1.38 (0.63–3.01)	0.42	1.13 (0.51–2.50)	0.76
Group Y				
COVID-19-period vs. pre-COVID-19	2.64 (1.23–5.65)	0.01	2.76 (1.27–6.03)	0.01
MenACWY vaccinated vs. unvaccinated	1.01 (0.41–2.49)	0.98	0.82 (0.33–2.05)	0.67
4CMenB vaccinated vs. unvaccinated	1.08 (0.46–2.52)	0.87	0.89 (0.37–2.14)	0.80
Nongroupable†				
COVID-19-period vs. pre-COVID-19	0.43 (0.21–0.89)	0.02	0.45 (0.22–0.95)	0.04
MenACWY vaccinated vs. unvaccinated	0.35 (0.11–1.16)	0.09	0.41 (0.12–1.35)	0.14
4CMenB vaccinated vs. unvaccinated	1.18 (0.54–2.60)	0.68	1.44 (0.65–3.20)	0.37

*Disease-associated genogroups defined as genogroups A, B, C, W, X or Y.

†"Nongroupable" carriage is defined as failure to detect genogroup A, B, C, W, X or Y, in those with *porA* detected.

‡Adjusted for all 3 exposures of interest. NOTE: All models are based on N = 1338 observations.

school leavers for any individual genogroups or nongroupable carriage (Table 3).

Culturing of *por*A PCR-positive samples yielded 64 isolates (60% recovery: pre COVID-19, 29/55 [53%]; COVID-19 period 35/51 [69%]). The predominant clonal complexes (ccs) were as follows: cc41/44 (12/64 isolates, 19%); cc32 (10/64, 16%); and cc23 (7/64, 11%) (Table 4 and Fig. 2). The overall low number of individual ccs detected precluded regression analyses to compare changes in prevalence between periods.

DISCUSSION

Our findings indicate that COVID-19 restrictions did not result in a reduction in the carriage of meningococci. From late March 2020, South Australia was placed under "lockdown" restrictions to assist in limiting the spread of COVID-19 for approximately 2 months, and universities moved to online learning. Even as restrictions were gradually eased from June 2020, social distancing directives and the capping of numbers at pubs, clubs and private social gatherings were anticipated to have reduced meningococci transmission during this period. We found the opposite of the anticipated reduction, with significant increases in disease-associated meningococcal carriage. This increase was mainly driven by groups B and Y, among those swabbed during the COVID-19 period despite increased 4CMenB and MenACWY vaccine uptake. Of note, intimate kissing rates did not change during the period, which may explain no reduction in carriage. The circulation of some respiratory viruses such as rhinovirus also seemed unaffected by COVID-19 containment measures in Australia, contrary to the dramatic decrease in influenza notifications.[23] The difference is thought to be because of the closure of interjurisdictional and international borders, as influenza proliferation is usually aided by new seeding from the global influenza virus population.[23]

Meningococcal carriage in university students typically increases as the year progresses. This increase is thought to be primarily because of increased uptake and participation in activities associated with carriage acquisition, such as smoking, intimate kissing and close contact in pubs, clubs and parties.[3] Although opportunities for large-group social interactions were limited in the COVID-19 period, any gatherings of smaller groups may have been sufficient in continuing to facilitate the spread of meningococci. Behavioral risk factors for carriage during COVID-19 were similar to that of the pre-COVID-19 period and included drinking alcohol, smoking and intimate kissing in the weeks leading up to the swab. The main difference in behavior during the COVID-19 period was that fewer people reported going to a pub, club or party twice or more each week than before the pandemic. It is also possible that rapid acquisition of meningococci occurred among naive school leavers upon easing of restrictions.

Meningococci are highly diverse, with thousands of sequence types. Despite their diversity, meningococci are classified into cc groups based on their similarity to a central allelic profile.[24] Some ccs are classified as hypervirulent lineages, which are essential in understanding meningococci's virulent lineages.[24] Hypervirulent lineages are responsible for a disproportionate number of IMD cases compared with their carriage prevalence in asymptomatic people.[24,25] In South Australia, the primary disease-associated lineage is cc 41/44 (*PorA* type P1.7-2,4), which made up 83% of sequenced isolates from IMD cases in 2016 because of serogroup B IMD.[26] Approximately 19% of sequenced carriage isolates in 2020 were cc 41/44. Of the 12 sequenced cc 41/44 meningococci, 50% were *PorA* type P1.7-2,4. Carriage of nongroupable meningococci and less invasive lineages can potentially benefit by inducing cross-protection to more virulent strains.[27] It is not clear what role COVID-19 containment measures may have had in the reduction of nongroupable carriage.

From April 2019 in South Australia, the conjugate MenACWY-tetanus toxoid vaccine was funded by the National Immunisation Program and delivered as part of the school vaccination program for year 10 students (approximately 15 years of age). The 2020 school leavers represent the first cohort to have had MenACWY-tetanus toxoid included as part of their school vaccination program, resulting in markedly higher rates of MenACWY vaccination in 2020 school leavers compared with earlier cohorts, such that its effect on the carriage of meningococci could be explored, albeit in a relatively small sample. Consistent with the results of several other small carriage studies, there were no observed reductions in the carriage of meningococcal A, C, W or Y.[8] To date, there is no evidence to suggest that large population MenACWY vaccination programs in adolescents increase the prevalence of serogroups not contained in the vaccine. The most extensive carriage study investigating carriage after a monovalent conjugate C vaccine program showed no evidence of serogroup replacement.[28] Ongoing surveillance of multivalent conjugate vaccines in population programs such as MenACWY is required to monitor herd protection effects. The effect of 4CMenB on meningococcal carriage in South Australia has been discussed in detail previously.[2,4,17]

The main limitation of this study is the lower than anticipated recruitment for 2020. Adjustment for potential confounding variables in models comparing carriage between COVID-19 periods and between MenACWY vaccinated and unvaccinated participants was limited because of low event numbers. These results should be interpreted with caution as the small sample size confers low statistical power for detecting small effects, and the models may be subject to residual confounding.

From this study, there is evidence to suggest that the transmission of meningococci is likely to continue despite ongoing COVID-19 restrictions, including physical and social distancing measures. Clinicians will need to remain vigilant for signs, and symptoms of IMD, especially as restrictions are progressively eased and international travel returns with the inevitable increase in circulation of influenza. Vaccinating those at the most significant risk of IMD remains crucial even when physical and social distancing measures are in place and when the background incidence of IMD is low.

TABLE 4. Clonal-Complexes of Recovered Isolates by COVID-19 Period

	Pre-COVID		During COVID-19		Total	
Clonal Complex	n	%	n	%	n	%
41/44*	4	13.8	8	22.9	12	18.8
32	2	6.9	8	22.9	10	15.6
23	2	6.9	5	14.3	7	10.9
198	4	13.8	2	5.7	6	9.4
35	3	10.3	3	8.6	6	9.4
1157	3	10.3	0	0.0	3	4.7
167	1	3.4	2	5.7	3	4.7
22	3	10.3	0	0.0	3	4.7
1136	1	3.4	1	2.9	2	3.1
162	0	0.0	1	2.9	1	1.6
269	1	3.4	0	0.0	1	1.6
4821	1	3.4	0	0.0	1	1.6
53	1	3.4	0	0.0	1	1.6
60	0	0.0	1	2.9	1	1.6
No cc	3	10.3	4	11.4	7	10.9
Total	29	100	35	100	64	100

*Six were *porA* type P1.7-2,4.

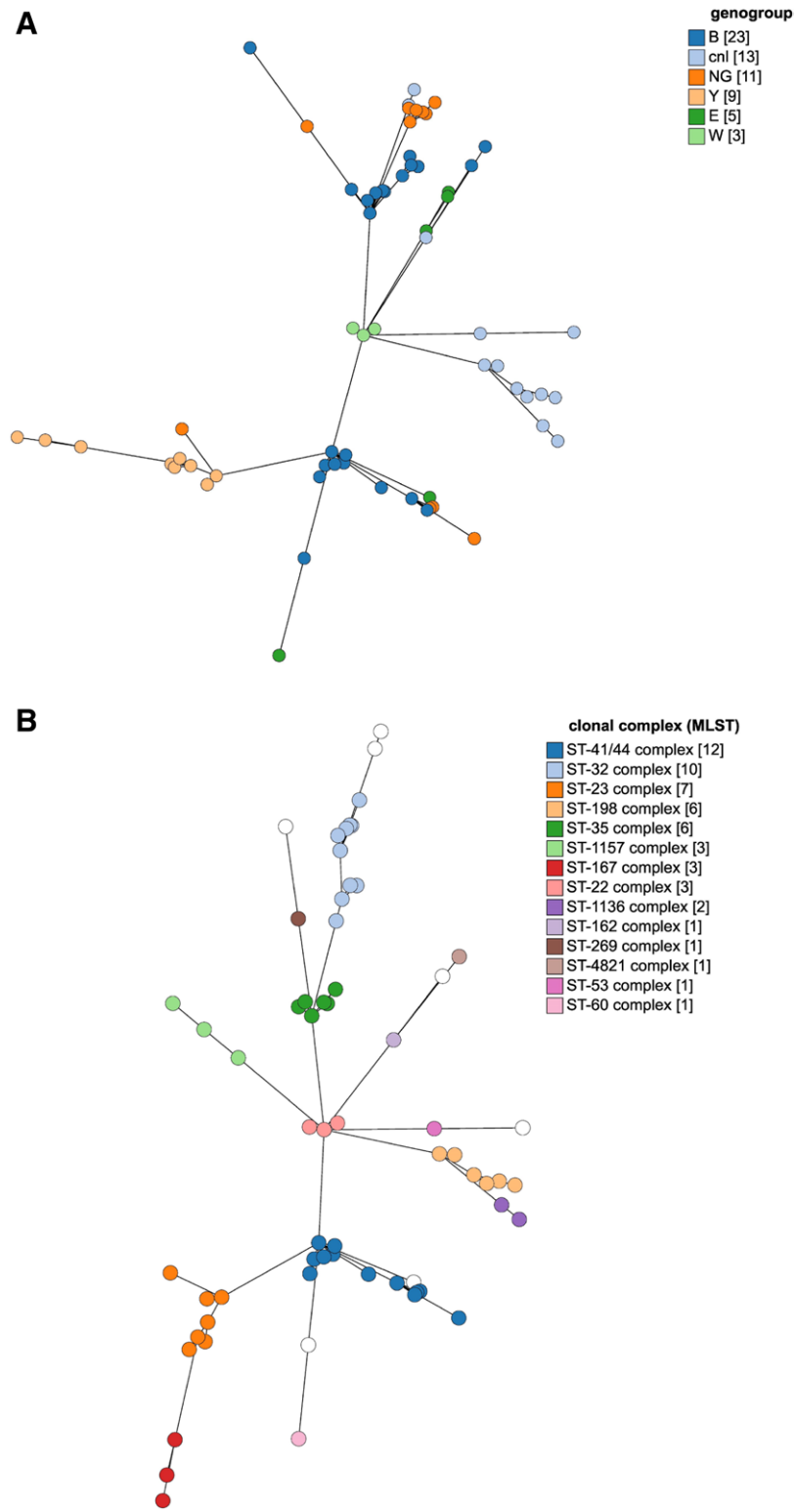

Figure 2. GrapeTree analysis using cgMLST v1.0 on the PubMLST.org/neisseria website of 64 meningococci isolated from the 106 meningococcal positive participants by (A) genogroup; (B) cc. Open circles indicate isolates with no value (ie, unassigned to a cc).

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