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ORIGINAL PAPER

A SARS-CoV-2 Outbreak Among Nursing Home Residents Vaccinated with a Booster Dose of mRNA COVID-19 Vaccine

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Abstract

This study describes a SARS-CoV-2 outbreak caused by the Delta (B.1.617.2) variant in a nursing home in Central Italy during October–November 2021. Trained interviewers collected data from residents, staff, and administration officers with an agreed informed consent procedure. Thirty-two (44.5%) out of 72 residents (median age 89 years) and six (26.1%) of 23 healthcare workers were found to be infected with SARS-CoV-2. Infections occurred more often among residents with a higher index of independence in daily living activities, suggesting an increased risk for those with more interactions. Twenty-five infected residents (78.1%) received the booster dose of mRNA anti-COVID-19 vaccine > 7 days before SARS-CoV-2 onset. Half of the infected residents had mild symptoms, and only three required hospitalisation, one of whom died from COVID-19 complications. The study underlines the effectiveness of a booster dose in providing a high protection against severe disease and hospitalisation even among vulnerable individuals infected with the Delta variant of concern.

Keywords Elderly · COVID-19 · Mild disease · Third dose · Impact of vaccination

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Background

Nursing homes are considered a high risk setting for SARS-CoV-2 outbreaks, and residents are more likely to have severe COVID-19 outcome with high mortality rates, because of old age, multiple comorbidities, and/or secondary immunosuppression [1]. For these reasons, residents were prioritised in the COVID-19 vaccination strategic plan. By June 2021, a significant drop in the number of cases and deaths among nursing home residents and staff was observed, anticipating the decline detected in the general population [2].

Despite these encouraging results, waning immunity was reported to occur 6 months after completion of the primary vaccination course [3]. Furthermore, from July 2021, Italy in common with other European countries, experienced a resurgence of COVID-19 cases, linked to the circulation of the Delta (B.1.617.2) variant of concern (VOC) [4], which was predominant until mid-December 2021 [5]. Considering that vaccine effectiveness and attenuation of peak viral burden were reduced when infected with the B.1.617.2 variant [6], a booster dose of mRNA vaccines after the primary vaccination was considered crucial [7]. Concurrently, by the end of November 2021, the first sequence attributable to the VOC Omicron (B.1.1.529) was identified by the Italian surveillance network [8], which rapidly increased, became prevalent, and replaced Delta from January 2022 [9].

We here report a COVID-19 outbreak that occurred in a nursing home in the Molise region (Central Italy) in October–November 2021 among staff and residents, most of whom had received the third (booster) vaccine dose.

Methods

A nursing home outbreak was defined as two or more patients were infected by SARS-CoV-2 within 14 days. The outbreak was considered to have ended when no infections were reported after 7 days. Cases were diagnosed using the Reverse Transcriptase Polymerase Chain Reaction (RT-PCR), the gold standard for SARS-CoV-2 diagnosis. As part of the outbreak investigation, sociodemographic, epidemiological and vaccination data were collected from residents and staff by trained interviewers. Informed consent was obtained from all the participants. Statistical analysis was carried out using IBM® SPSS version 28.0.

Results

At time of the outbreak (October–November 2021), there were 23 healthcare workers (HCWs) and 72 residents in the facility. In accordance with national rules and local protocols, a rapid antigenic swab was required 24 h before to the entry of new guests, while a RT-PCR test of combined oral and nasopharyngeal swab was performed 24 h before the re-entry of each resident after hospitalisation. The green certificate issued by the European Commission was requested from all visitors, whose access was allowed for a maximum of two per resident in a dedicated space. SARS-CoV-2 screening of the staff was recommended according to national circulars using rapid antigenic tests every 3 days. When a visitor reported SARS-CoV-2 infection, residents who had close contact with the case were isolated in a single room for 7 days, undergoing antigenic test every 24 h.

Sixteen of 23 HCWs participated to the study (response rate 69.6%), 15 were female and one was male; the median age was 52.5 years, range 23–67 years. All HCWs had received full primary vaccination with two doses of COVID-19 mRNA vaccines, 93.8% with mRNA BNT162b2 (Comirnaty, Pfizer/BioNtech) and 6.2% with mRNA-1273 (Spikevax, Moderna). Seventy-five percent (n = 12) had the first vaccination dose in January 2021, and the second on February 2021. At time of the interview, seven HCWs reported to have received the additional (third) vaccination dose on November 11, 2021, and one each on October 29 and November 10, 2021, hence, during the ongoing of the outbreak.

Of the 72 nursing home residents, 71 participated at the study (response rate 98.6%): 52 (73.2%) were female; the median age was 89 years, range 59–101 years. All residents had received primary cycle of mRNA COVID-19 vaccines, mainly during January 2021 (data not shown), and 60 (84.5%) had received the third dose during October 2021. Data on boosters were not available for four residents, while the temporal interval for receiving the additional dose was not completed prior to the outbreak for the remaining residents. Indeed, a booster dose with Comirnaty was authorized 6 months after completion of the primary vaccination cycle for people aged 60 years and older, nursing homes staff and guests, health professionals and people with frailty over the age of 18 years on October 8, 2021 [10].

Sixty-six (93.0%) of residents reported multiple comorbidities, which comprised hypertension (n = 50, 75.8%), neurological or psychiatric-behavioural disorders (n = 42, 63.6%), cardiovascular (n = 41, 62.1%), endocrine (n = 19, 28.8%), or rheumatological diseases (n = 19, 28.8%), while 10 (15.2%) suffered from allergies, 8 (12.1%) respiratory diseases or diabetes, 6 (9.1%) gastrointestinal or renal diseases, and 4 (6.1%) had a diagnosis of cancer.

The index of independence in activities of daily living (ADL) [11] was calculated for 56 residents and regrouped into three categories: twenty of them were classified into group 1 of dependence (low ADL/score 0–1), eight into group 2 (intermediate ADL/score 2–4), and twenty-eight into group 3 of independence (high ADL/score 5–6).

The presumed index case of the outbreak, considered as the first subject identified as infected amongst the facility residents, was an asymptomatic 85-years-old man, who tested SARS-CoV-2 positive at RT-PCR testing using a combined oral and nasopharyngeal swab taken on October 18, 2021, at the admission to a regional hospital for other reasons. After the identification of the case, oral/nasopharyngeal swabs were also performed on residents and staff every six days until the outbreak had ended, and tested with RT-PCR. Furthermore, a cordon sanitaire was set up around the facility to discourage any un-necessary entrance and exit.

Between October 20 and November 2, 2021, 37 more cases were identified, for a total of 38. In detail, 32 out of 72 residents were found to be infected (attack rate 44.5%), with 21 additional cases detected after the index patient on October 20, 9 on October 26, and one on November 2, 2021. Furthermore, 6 out of 23 HCWs (attack rate 26.1%) were infected: 3 on October 20, 2 on October 26, and one on November 2, 2021. The COVID-19 cases of this outbreak were caused by the Delta variant.

Of 32 total infected residents (median age 89 years; range 66–99 years), 25 (78.1%) received a booster dose at different time before infection (Fig. 1). Information was not available for four infected residents who died, and three infected guests had only received two doses because they were not yet eligible. Amongst the uninfected residents (n = 39), all except four (89.7%) had received an additional dose before outbreak onset.

A significant relationship was found between residents who had received booster dose versus non-boosters and SARS-CoV-2 infection (Chi-square test, $p < 0.01$). In addition, the effect of a booster dose in relation to the outcome was assessed through Odds Ratio (OR), resulting 0.51 (95% confidence interval 0.15–1.79).

No statistically significant differences between demographic or clinical characteristics and outcome were observed. In particular, there were no differences by sex in the risk of infection (Chi-square test $p = 0.064$). Overall, three residents required hospitalisation for COVID-19 symptoms, but none of them was sufficiently ill to be admitted to the intensive care unit of the local hospital. Between October 18 and November 2, 2021, four subjects died, but only one showed bilateral interstitial pneumonia possibly related to COVID-19 (lethality rate 3.1%), while the others likely died from severe conditions already existing before COVID onset. Sixteen (50.0%) infected residents were symptomatic, with a mean number of 3.4 ± 3.7 symptoms (median 2; range 1–14), such as cough (n = 9, 56.3%), followed by cold (n = 7, 43.8%), muscle/joint pains and asthenia (each n = 5, 31.3%) (Table 1).

During the 2 weeks prior to the outbreak, 12 (37.5%) infected residents were visited by relatives from one up to 5

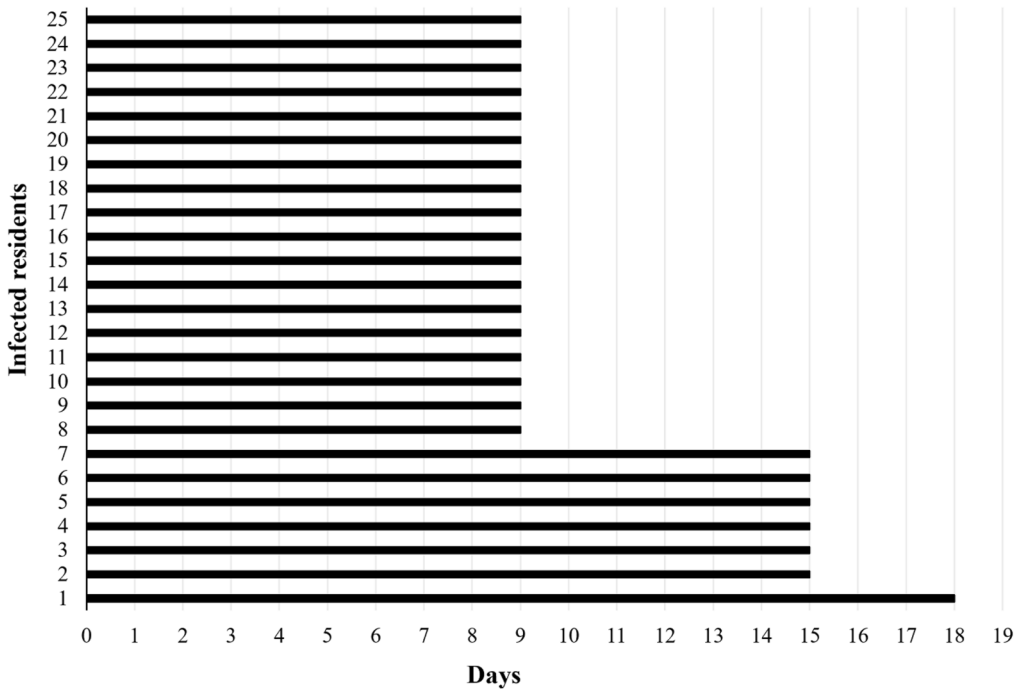

Fig. 1 Time (days) interval from date of third vaccine dose administration and positive result to molecular SARS-CoV-2 testing. Of note, 25 out of 32 infected residents had received the booster dose COVID-19 vaccine before outbreak, excluding four deceased subjects, and three residents who had not yet received the booster shot at time of testing because of time interval required; subject 1 received the third dose four days after the other residents

times for 15 min up to 2 h, and two of them moved outside the facility to visit family members.

Thirty (93.8%) infected residents had access to the canteen, and the epidemiological investigation identified two areas at different risk; 61.5% (24 out of 39) of the residents who had a seat in the high-risk (black) area became infected as compared with 31.6% (6 out of 19) in the low-risk (grey) area (Chi-square test p = 0.032). Interestingly, 16 out of 17 residents with ADL ≥ 2 (94.0%) had a seat in the black area (Fig. 2). Noteworthy, an air conditioning system was not available in the facility, and the windows in the canteen were equally distributed between the black and the grey square area, thus without difference in the ventilation.

All infected HCWs were symptomatic, with two reporting respiratory difficulties but no hospitalisation. Almost all of them reported rhinorrhea, cough, sore throat, asthenia (n = 5, 83.4%), followed by cold, chills and loss of smell (each n = 4, 66.7%), and headache, muscle/joint pains, and loss of taste (n = 3, 50.0%).

Table 1 COVID-19 clinical presentation among vaccinated residents stratified by sex

	Females (n = 12) N (%)	Males (n = 4) N (%)	Total (n = 16)* N (%)
Cough	7 (58.3)	2 (50.0)	9 (56.3)
Cold	5 (41.7)	2 (50.0)	7 (43.8)
Muscle/joint pains	3 (25.0)	2 (50.0)	5 (31.3)
Asthenia	4 (33.3)	1 (25.0)	5 (31.3)
Rhinorrhea	3 (25.0)	1 (25.0)	4 (25.0)
Breathlessness	1 (8.3)	2 (50.0)	3 (18.8)
Sore throat	1 (8.3)	1 (25.0)	2 (12.5)
Headache	1 (8.3)	1 (25.0)	2 (12.5)
Chills	1 (8.3)	1 (25.0)	2 (12.5)
Nausea	1 (8.3)	1 (25.0)	2 (12.5)
Fever < 38 °C	1 (8.3)	1 (25.0)	2 (12.5)
Fever 38–39 °C	1 (8.3)	0 (0)	1 (6.2)
Fever > 39 °C	0 (0)	1 (25.0)	1 (6.2)
Loss of taste	0 (0)	1 (25.0)	1 (6.2)
Vomit	0 (0)	1 (25.0)	1 (6.2)
Diarrhea	1 (8.3)	0 (0)	1 (6.2)
Abdominal pain	1 (8.3)	1 (25.0)	1 (6.2)
Confusion	1 (8.3)	0 (0)	1 (6.2)
Eye redness/ tearing	1 (8.3)	0 (0)	1 (6.2)

*Four residents died, hence, type of symptoms by sex was available only for 12 and 4 female and male individuals, respectively

Discussion and conclusions

Nursing home residents live in congregated settings, representing a high-risk for SARS-CoV-2 spread [12]. The outbreak described hereby was the first in the facility from the beginning of COVID-19 pandemic and generated concerns, due to the potential impact of the highly transmissible Delta variant on a vulnerable population. In the Molise Region, this variant became predominant in November 2021 [13]. In this outbreak, infections occurred significantly more often among residents with higher ADL, suggesting an increased risk for those with more mobility and interactions with other residents.

The impact of the outbreak was mitigated by the third (booster) dose of mRNA vaccine, which minimized the clinical impact of the infection among a highly vulnerable population, beyond showing high safety profile as previously reported [14]. Half of the infected residents developed mild symptoms, and only one death was likely to be associated with SARS-CoV-2 infection. Furthermore, 72% of the infected residents had received the third dose of the mRNA BNT162b2 vaccine > 1 week earlier the outbreak, and a

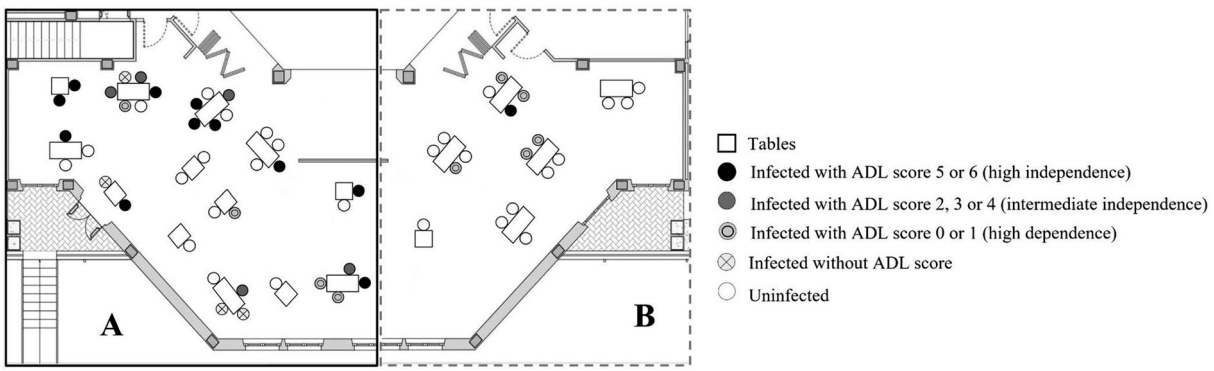

Fig. 2 Arrangement of residents at tables in the canteen in relation with status of SARS-CoV-2 infection and ADL groups. Black (**A**) and grey (**B**) squares correspond to high and low incidence areas of SARS-CoV-2 infections

smaller proportion (28%) > 2 weeks before the outbreak. A previous study reported that the booster dose of BNT162b2 mRNA vaccine, at least 12 days after the administration, given to individuals 60 years of age or older, lowered the rate of infection and the severity of illness by a factor of 11.3 and 19.5, respectively, as comparing age-matched non-boosted group [15]. In a secondary analysis of this study, the rate of confirmed infection was lower starting at 12 days after booster receipt than 4–6 days by an estimated factor of 5.4. Hence, the role of boosting was important even under this conservative assessment in mitigating the effects of waning immunity and immune evasion, especially during the emergence of VOCs [15]. In another study [16], a significant response within 1 week after receiving the third dose of the BNT162b2 mRNA COVID-19 vaccine was demonstrated, even among subjects who did not respond to previous doses. The effectiveness of mRNA vaccines against COVID-19 hospitalisation was also compared between adults either with or without immunocompromising conditions who had or had not received a third vaccine dose ≥ 7 days before COVID-19 onset [17], proving to be higher among booster recipients [18].

Undoubtedly, vaccination changed SARS-CoV-2 epidemiology in nursing homes despite the Delta variant reduced vaccine effectiveness against symptomatic infection [19]. Hence, a booster dose of mRNA vaccine resulted in a high protection against severe disease and hospitalisation among vulnerable population groups in contexts of circulation of the highly transmissible variants in close communities [20].

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Data Availability The Authors included all the data and material in the study although are available for further information whether requested.

Code Availability Not applicable.

Declarations

Conflict of 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.

Ethical Approval For this study, ethical approval was not requested as no experimental procedure was applied, and all the information provided by participants after signing an informed consent were anonymous.

Consent to Participate All the study participants signed an informed consent agreeing to provide data and availability for the survey.

Consent for Publication The Authors provide the consent for publication data or figure in the manuscript.

References

1. Ouslander, J. G., & Grabowski, D. C. (2020). COVID-19 in nursing homes: Calming the perfect storm. *Journal of the American Geriatrics Society, 68*(10), 2153–2162. https://doi.org/10.1111/jgs.16784
2. Istituto Superiore di Sanità. (2021). Report nazionale sorveglianza strutture residenziali socio-sanitarie nell'emergenza Covid-19. Retrieved January 10, 2022, from https://www.epicentro.iss.it/coronavirus/sars-cov-2-sorveglianza-rsa.
3. Lopez Bernal, J., Andrews, N., Gower, C., Gallagher, E., Simmons, R., Thelwall, S., Stowe, J., Tessier, E., Groves, N., Dabrera, G., Myers, R., Campbell, C. N. J., Amirthalingam, G., Edmunds, M., Zambon, M., Brown, K. E., Hopkins, S., Chand, M., & Ramsay, M. (2021). Effectiveness of Covid-19 vaccines against the B.1.617.2 (Delta) variant. *The New England Journal of Medicine, 385*(7), 585–594. https://doi.org/10.1056/NEJMoa2108891
4. Istituto Superiore di Sanità. (2021). Bollettino di prevalenza e distribuzione delle varianti di SARS-CoV-2 di interesse per la sanità pubblica in Italia. Rapporto n. 14 del 26 novembre 2021. Retrieved January 10, 2022, from https://www.iss.it/cov19-cosa-fa-iss-varianti/.
5. Istituto Superiore di Sanità. (2021). Stima della prevalenza delle varianti VOC (variants of concern) in Italia: Beta, gamma, delta, omicron e altre varianti di SARS-CoV-2. Retrieved February 14, 2022, from https://www.iss.it/web/guest/cov19-cosa-fa-iss-varianti/
6. U.S. Food and Drug Administration. (2021). Coronavirus (COVID-19) update: FDA expands eligibility for COVID-19 vaccine boosters. Retrieved February 14, 2022, from https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-expands-eligibility-covid-19-vaccine-boosters
7. Pouwels, K. B., Pritchard, E., Matthews, P. C., Stoesser, N., Eyre, D. W., Vihta, K.-D., House, T., Hay, J., Bell, J. I., Newton, J. N., Farrar, J., Crook, D., Cook, D., Rourke, E., Studley, R., Peto, T. E. A., Diamond, I., & Walker, A. S. (2021). Effect of delta variant on viral burden and vaccine effectiveness against new SARS-CoV-2 infections in the UK. *Nature Medicine, 27*(12), 2127–2135. https://doi.org/10.1038/s41591-021-01548-7
8. Istituto Superiore di Sanità. (2021). Comunicato Stampa N°65/2021—identificata dalla rete italiana una sequenza

riconducibile alla variante Omicron. Retrieved February 14, 2022, from https://www.iss.it/web/guest/cov19-cosa-fa-iss-varianti/
9. Istituto Superiore di Sanità. (2022). Comunicato stampa N°12/2022. Covid-19, flash survey Iss: Il 31 gennaio il 99,1% dei campioni positivi a Omicron. Retrieved February 14, 2022, from https://www.iss.it/web/guest/cov19-cosa-fa-iss-varianti/
10. Ministero della Salute. (2021). Aggiornamento delle indicazioni sulla somministrazione di dosi addizionali e di dosi "booster" nell'ambito della campagna di vaccinazione anti SARS-CoV-2/COVID-19. Ordinanza n.45886, 8 ottobre 2021.
11. Katz, T. F. (1963). A. D. L. Activities of daily living. *JAMA, 185*, 914–919. https://doi.org/10.1001/jama.1963.03060120024016
12. Ripabelli, G., Sammarco, M. L., Cannizzaro, F., Montanaro, C., Ponzio, G. V., & Tamburro, M. (2021). A coronavirus outbreak linked to a funeral among a Romani community in Central Italy. *Frontier in Medicine (Lausanne), 8*, 617264. https://doi.org/10.3389/fmed.2021.617264
13. Istituto Superiore di Sanità. Prevalenza e distribuzione delle varianti di SARS-CoV-2 di interesse per la sanità pubblica in Italia. Rapporto n. 15 del 10 dicembre 2021. Retrieved January 11, 2022, from https://www.epicentro.iss.it/coronavirus/sars-cov-2-monitoraggio-varianti-rapporti-periodici
14. Ripabelli, G., Tamburro, M., Buccieri, N., Adesso, C., Caggiano, V., Cannizzaro, F., Di Palma, M. A., Mantuano, G., Montemitro, V. G., Natale, A., Rodio, L., & Sammarco, M. L. (2022). Active surveillance of adverse events in healthcare workers recipients after vaccination with COVID-19 BNT162b2 vaccine (Pfizer-BioNTech, Comirnaty): A cross-sectional study. *Journal of Community Health, 47*(2), 211–225. https://doi.org/10.1007/s10900-021-01039-3
15. Bar-On, Y. M., Goldberg, Y., Mandel, M., Bodenheimer, O., Freedman, L., Kalkstein, N., Mizrahi, B., Alroy-Preis, S., Ash, N., Milo, R., & Huppert, A. (2021). Protection of BNT162b2 vaccine booster against Covid-19 in Israel. *The New England Journal of Medicine, 385*(15), 1393–1400. https://doi.org/10.1056/NEJMoa2114255
16. Gilboa, M., Mandelboim, M., Indenbaum, V., Lustig, Y., Cohen, C., Rahav, G., Asraf, K., Amit, S., Jaber, H., Nemet, I., Kliker, L., Bar-Haim, E., Mendelson, E., Doolman, R., Rubin, C., Regev-Yochay, G., & Kreiss, Y. (2022). Early immunogenicity and safety of the third dose of BNT162b2 mRNA Covid-19 vaccine among adults older than 60 years: Real-world experience. *The Journal of Infectious Diseases, 225*(5), 785–792. https://doi.org/10.1093/infdis/jiab584
17. Tenforde, M. W., Patel, M. M., Gaglani, M., Ginde, A. A., Douin, D. J., Talbot, H. K., Casey, J. D., Mohr, N. M., Zepeski, A., McNeal, T., Ghamande, S., Gibbs, K. W., Files, D. C., Hager, D. N., Shehu, A., Prekker, M. E., Erickson, H. L., Gong, M. N., Mohamed, A.,…IVY Network. (2022). Effectiveness of a third dose of Pfizer-BioNTech and moderna vaccines in preventing COVID-19 hospitalization among immunocompetent and immunocompromised adults—United States, August-December 2021. *MMWR Morbidity and Mortality Weekly Report, 71*(4), 118–1124. https://doi.org/10.15585/mmwr.mm7104a2
18. Barda, N., Dagan, N., Cohen, C., Hernán, M. A., Lipsitch, M., Kohane, I. S., Reis, B. Y., & Balicer, R. D. (2021). Effectiveness of a third dose of the BNT162b2 mRNA COVID-19 vaccine for preventing severe outcomes in Israel: An observational study. *The Lancet, 398*(10316), 2093–2100. https://doi.org/10.1016/S0140-6736(21)02249-2
19. Nicolay, N., Innocenti, F., Beauté, J., Učakar, V., GrgičVitek, M., Poukka, E., Hannila-Handelberg, T., Gauci, C., Melillo, T., Georgakopoulou, T., Jarkovsky, J., Slezak, P., Delgado-Sanz, C., Olmedo-Lucerón, C., Suija, H., Liausediene, R., O'Lorcain, P., Murphy, N., Peralta-Santos, A.,…Ravasi, G. (2021). Initial assessment of the COVID-19 vaccination's impact on case numbers, hospitalisations and deaths in people aged 80 years and older, 15 EU/EEA countries, December 2020 to May 2021. *Eurosurveillance, 6*(48), 2101030. https://doi.org/10.2807/1560-7917.ES.2021.26.48.2101030
20. Thompson, M. G., Natarajan, K., Irving, S. A., Rowley, E. A., Griggs, E. P., Gaglani, M., Klein, N. P., Grannis, S. J., DeSilva, M. B., Stenehjem, E., Reese, S. E., Dickerson, M., Naleway, A. L., Han, J., Konatham, D., McEvoy, C., Rao, S., Dixon, B. E., Dascomb, K.,…Ong, T. C. (2022). Effectiveness of a third dose of mRNA vaccines against COVID-19-associated emergency department and urgent Care encounters and hospitalizations among adults during periods of delta and omicron variant predominance—VISION network, 10 states, August 2021-January 2022. *MMWR Morbidity and Mortality Weekly Report, 71*(4), 139–145. https://doi.org/10.15585/mmwr.mm7104e3