Vaccination and COVID-19 Dynamics in Dialysis Patients

Supplemental Material

Statistical model

Infection dates

Infection dates in hemodialysis patients were actually those of diagnoses (either suspicious clinical symptom or chest scan / positive RT-PCR), which can be approximately considered as the dates of symptoms onset (1). Dates for severe infections in the general population were those of hospital admissions. In order to relate severe infections in dialysis patients (with known dates of symptoms onset) to those occurring simultaneously in the general population (with known dates of hospital admission), we subtracted the expected delay between symptoms onset and hospital admission. The chosen 11-day lag applied to hospitalization dates relies on previous estimates (2) and was already used in several modeling studies (3,4).

Modeling

We modeled weekly incidences SARS-CoV-2 severe infections (COVID-19 cases leading to hospital admissions) in dialysis patients from same-age incidences in the general population, with the use of hierarchical Bayesian Poisson regressions accounting for spatial autocorrelation.

All multivariable models were built from the following pattern:

$$log\left(\frac{E\left(n_{a,d,w}\right)}{e_{a,d,w}}\right) = \alpha + \beta\ log\left(N_{a,d,w}\right) + \gamma_a\ a + \cdots + \omega_d$$

With:

- $E\left(n_{a,d,w}\right)$: expected number of cases in dialysis patients for age class a in department d on week w ($n_{a,d,w}$ following a Poisson distribution);
- $e_{a,d,w}$: exposed (at-risk) MHD patients for the same age / department / week;
- $N_{a,d,w}$: estimated incidence of severe infections in the general population for age class a in department d on week w;
- β, γ_a: fixed effects to be estimated;
- ω_d: random effect accounting for spatial autocorrelation in department d;
- ... : optional predictors with their associated fixed effects.

Spatial random effects were estimated with a covariance structure depending on neighborhood departments from a BYM model (5). Bayesian inference was performed using integrated nested Laplace approximation (6) and weakly informative priors.

Optional predictors were considered to fit the models:

- estimated incidence of severe infections in the general population for age class a in department d on week $w-1$;
- epidemic wave on week w (dummy variables to identify epidemic waves 1 to 3);
- vaccination coverage (1st dose) in the general population in department d on week $w-3$ (either in the age class a or globally);
- vaccination coverage (1st dose) in MHD patients in department d on week $w-3$ (data stratified by age class was not available).

Other regression models (zero-inflated Poisson and negative binomial) were also considered to improve goodness-of-fit.

Predictors were selected to improve goodness-of-fit according to the Watanabe–Akaike information criterion (WAIC).
The following models were selected:

$$\text{M}_1: \quad log\left(\frac{E(n_{a,d,w})}{e_{a,d,w}}\right) = \alpha + \beta\ log(N_{a,d,w}) + \beta' log(N_{a,d,w-1}) + \gamma_a\ a + \omega_d$$

$$\text{M}_2: \quad log\left(\frac{E(n_{a,d,w})}{e_{a,d,w}}\right) = \alpha + \beta\ log(N_{a,d,w}) + \beta' log(N_{a,d,w-1}) + \gamma_a\ a + \delta\ k_w + \omega_d$$

With k_w taking values according to the epidemic wave (k_w = 0 if week w falls into the 1st wave and 1 otherwise) and δ the associated fixed effect to be estimated.

$$\text{M}_3: \quad log\left(\frac{E(n_{a,d,w})}{e_{a,d,w}}\right) = \alpha + \beta\ log(N_{a,d,w}) + \beta' log(N_{a,d,w-1}) + \gamma_a\ a + \delta\ k_w + \xi_0\ u_{a,d,w-5} + \xi_a\ a \times\ u_{a,d,w-5} + \zeta\ v_{a,d,w-3} + \omega_d$$

With $u_{a,d,w}$ and $v_{a,d,w}$ the vaccination coverages in MHD patients and in the general population, respectively, for age class a on week w in department d, ξ_0 and ζ the associated fixed effects and ξ_a the fixed effect for interaction between a and $u_{a,d,w}$ to be estimated. The 3- and 5-week time lapses were set to account for a humoral response likely to impact incidence in the general population (7–10) and dialysis patients (11,12), respectively .
All analyses were conducted with R statistical software version 4.0. Models were fitted with the INLA package (13).

Supplemental Tables

Supplemental Table 1 : Description of the study populations

	Dialysis patients (%)	General population (%)
Female sex	38.5	52.8
Age class (years)		
• 25-35	2.2	16.3
• 35-45	4.7	17.6
• 45-55	8.7	18.6
• 55-65	16.3	17.9
• 65-75	28.5	16.0
• 75-85	26.1	8.7
• > 85	13.6	4.9
Medical history		
• Diabetes	44.1	
• Cancer	10.2	
• Respiratory disease	15.8	
• Coronary heart disease	24.8	
• Peripheral artery disease	22.8	
• Stroke	12.1	
• Obesity	25.0	

Supplemental Table 2 : Crude number of hospitalizations, total at-risk population, cumulative incidence in dialysis and the general population and relative risk of hospitalization according to age classes and epidemic waves

		Dialysis patients			General population			
Age class	wave	At-risk subjects	COVID-19 hospitalizations	Cumulative incidence (%)	At-risk subjects	COVID-19 hospitalizations	Cumulative incidence (%)	Relative risk (95% CI)
25-55	1st	7050	159	2.3%	24,184,787	18,981	0.1%	28.7 (24.6, 33.6)
	2nd	7204	116	1.6%	24,122,679	26,903	0.1%	14.4 (12, 17.3)
	3rd	6986	75	1.1%	24,060,571	34,460	0.1%	7.5 (6, 9.4)
55-75	1st	19,304	512	2.7%	15,328,488	32,833	0.2%	12.4 (11.3, 13.5)
	2nd	20,522	612	3%	15,433,881	56,158	0.4%	8.2 (7.6, 8.9)
	3rd	20,144	395	2%	15,539,273	60,795	0.4%	5 (4.5, 5.5)
> 75	1st	16,974	562	3.3%	6,194,203	47,424	0.8%	4.3 (4, 4.7)
	2nd	18,086	719	4%	6,217,063	94,375	1.5%	2.6 (2.4, 2.8)
	3rd	18,036	470	2.6%	6,239,923	74,961	1.2%	2.2 (2, 2.4)

Supplemental Table 3 : Relative risks (95% credible intervals) of severe infection in dialysis patients, predicted from model M_3, between April 2 and April 8, 2021 in Paris.

	Vaccine exposure	
Age class (years)	**No**	**Yes**
25-35	0.74 (0.50, 1.09)	0.00 (0.00, 12.4)
35-45	1.01 (0.76, 1.35)	0.02 (0.00, 0.21)
45-55	0.98 (0.77, 1.26)	0.20 (0.07, 0.54)
55-65	1 (reference)	0.37 (0.20, 0.69)
65-75	0.89 (0.72, 1.11)	0.31 (0.19, 0.52)
75-85	0.70 (0.56, 0.87)	0.45 (0.27, 0.73)
> 85	0.67 (0.53, 0.84)	0.57 (0.30, 1.06)

These relative risks of severe infection depend on the considered week and department, as their estimations use data on local vaccination coverage in dialysis patients and the general population. For this example, we chose the week and department with the highest number of cases during the third wave.

Supplemental Table 4 : Coefficients from the Poisson regression (exponentiated and reported as incidence rate ratios with their 95% credible intervals): model M3 (3- and 5-week lags between first dose and expected protection in the general population and in dialysis patients, respectively) and additional model with 3-week lags for all.

Variable	Model M_3 (3- and 5-week lags)	Sensitivity analysis (3-week-lags)
Age class (years)		
- 25-35	2.92 (2.03, 4.09)	2.85 (1.97, 4.02)
- 35-45	2.19 (1.74, 2.73)	2.20 (1.75, 2.74)
- 45-55	1.32 (1.11, 1.56)	1.35 (1.14, 1.60)
- 55-65	1 (reference)	1 (reference)
- 65-75	0.88 (0.78, 0.98)	0.87 (0.78, 0.98)
- 75-85	0.78 (0.70, 0.88)	0.77 (0.69, 0.87)
- > 85	0.86 (0.76, 0.97)	0.84 (0.74, 0.96)
Epidemic wave ≥ 2	0.70 (0.64, 0.76)	0.69 (0.64, 0.75)
Vaccination coverage in the general population (per 10% increase)	0.50 (0.40, 0.61)	0.47 (0.38, 0.58)
Vaccine exposure in dialysis patients	0.37 (0.18, 0.71)	0.46 (0.26, 0.78)
Age class–vaccine interaction (years)		
- 25-35	0.00 (0.00, 4.66)	0.12 (0.00, 1.59)
- 35-45	0.04 (0.00, 0.46)	0.13 (0.02, 1.56)
- 45-55	0.55 (0.16, 1.72)	0.38 (0.13, 1.04)
- 55-65	1 (reference)	1 (reference)
- 65-75	0.94 (0.43, 2.11)	0.99 (0.53, 1.87)
- 75-85	1.74 (0.80, 3.86)	1.80 (0.98, 3.37)
- > 85	2.30 (0.95, 5.56)	2.48 (1.25, 4.92)

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