Feasibility of infection control measures in hemodialysis units to prevent outbreaks of COVID-19: An empiric province-wide study from Quebec

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Abstract:	Background: In-center hemodialysis units pose the perfect conditions for COVID-19 transmission yet limited space and resources are obstacles to infection prevention and control (IPAC) measures. We aimed to describe IPAC measures implemented in Quebec and document the infection rates within hemodialysis units during the first year of the COVID-19 pandemic. Methods: We invited leaders of Quebec's hemodialysis units to collect information on IPAC measures from March 1st to June 30th 2020 and dialysis unit characteristics. Participating units were contacted again in March 2021 to collect information about the total number of COVID-19 cases. The cumulative infection rate of each unit was compared to the regional cumulative infection rate using standardized infection ratio (SIR). Results: Data was obtained from 38 units, representing 90% of Quebec's hemodialysis patients. 30% of units were perceived as crowded, and this was associated with objective distance measures between stations. IPAC measures regarding general prevention,

	screening procedures, physical distancing, and PPE use were implemented in 50% of units by 3 weeks and the remainder by 6 weeks. Data on cumulative infection rate was obtained in 26 units providing care to 3942 patients. The cumulative infection rate was disproportionally elevated in hemodialysis units compared to regional rates (Median SIR: 2.68 IQR: 1.58; 4.45). No difference was noted in the SIR related to specific IPAC measures or to physical characteristics of the units. Interpretation: Hemodialysis units throughout Quebec were able to rapidly implement modified IPAC measures. Despite this, cumulative infection rates were disproportionally elevated compared to the general population.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	p.1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	p.2
Introduction			p. 3
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	
Methods			
Study design	4	Present key elements of study design early in the paper	p. 3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	p.3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	units, p.3
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	p.4, appendix
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	p.4
Study size	10	Explain how the study size was arrived at	p.5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	p.4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	
		(*b*) Describe any methods used to examine subgroups and interactions	p.4
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	p.5
		(b) Give reasons for non-participation at each stage	p.5
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	Figure 2, p7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Figure 2

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	All analysis reported
Discussion			
Key results	18	Summarise key results with reference to study objectives	
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	p.7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	p.8
Generalisability	21	Discuss the generalisability (external validity) of the study results	p.8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	p.9

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Feasibility of infection control measures in hemodialysis units to prevent outbreaks of COVID-19: An empiric province-wide study from Quebec

Short title: Infection control measures in hemodialysis units

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Relevant Conflicts of Interest: None

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Word Count: 2410

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Abstract:

Background: In-center hemodialysis units pose the perfect conditions for COVID-19 transmission yet limited space and resources are obstacles to infection prevention and control (IPAC) measures. We aimed to describe IPAC measures implemented in Quebec and document the infection rates within hemodialysis units during the first year of the COVID-19 pandemic.

Methods: We invited leaders of Quebec's hemodialysis units to collect information on IPAC measures from March 1st to June 30th 2020 and dialysis unit characteristics. Participating units were contacted again in March 2021 to collect information about the total number of COVID-19 cases. The cumulative infection rate of each unit was compared to the regional cumulative infection rate using standardized infection ratio (SIR).

Results: Data was obtained from 38 units, representing 90% of Quebec's hemodialysis patients. 30% of units were perceived as crowded, and this was associated with objective distance measures between stations. IPAC measures regarding general prevention, screening procedures, physical distancing, and PPE use were implemented in 50% of units by 3 weeks and the remainder by 6 weeks. Data on cumulative infection rate was obtained in 26 units providing care to 3942 patients. The cumulative infection rate was disproportionally elevated in hemodialysis units compared to regional rates (Median SIR: 2.68 IQR: 1.58; 4.45). No difference was noted in the SIR related to specific IPAC measures or to physical characteristics of the units.

Interpretation: Hemodialysis units throughout Quebec were able to rapidly implement modified IPAC measures. Despite this, cumulative infection rates were disproportionally elevated compared to the general population.

Introduction:

Since March 2020, the COVID-19 pandemic has completely disrupted the lives of Canadians, but for the 24,000 vulnerable Canadians receiving in-center hemodialysis[1], its effects are especially grave. Case-fatality rates from COVID-19 are reported at 20 to 30% in hemodialysis patients – ten times the general population[2-8]. Yet self-isolation to avoid exposure is impossible. Most patients must leave their homes 3 times a week to receive their life-saving treatments. Each treatment is typically performed for 3-5 hours in an open space shared with several other patients, and involves frequent health-care worker contact. Exposure to COVID-19 may also occur during transport, and in the waiting area before and after dialysis. Outbreaks of COVID-19 within hemodialysis units can have disastrous consequences[9],[10]. While the risk of outbreaks in dialysis was recognized early on during the pandemic[9], implementation of strict infection prevention and control (IPAC) measures in hemodialysis units is challenging. Most North American installations were not originally designed with the objective of preventing respiratory virus transmission. Many are crowded with minimal distance between treatment stations, poor ventilation, and few, if any, single patient rooms.

Quebec was the first Canadian province to experience intense community transmission of COVID-19. While several experts' panels had issued recommendations on outbreak prevention strategies for hemodialysis units[11-14], to what extent and how rapidly these could be rapidly implemented was unclear. We empirically assessed the type, timing, and feasibility of IPAC measures implemented in hemodialysis units in Quebec. We hypothesized that IPAC measures were implemented rapidly but that the ability of local leaders to implement physical distancing measures would be dependent on the crowdedness of each unit, and that standardized infection rates would be higher in more crowded units with less single patient rooms.

Methods:

Data Collection Strategy:

On July 15th 2020, we invited nurse managers and/or dialysis unit directors from all of Quebec's 54 hemodialysis units to complete an electronic questionnaire regarding specific IPAC measures deployed at their institutions. Nephrologists and nursing managers from these units had been keeping documentation on this since early May at our request. Up to two email reminders were sent to centers who did not initially respond. Clarifications were sought in cases of incomplete answers or major data discrepancies. Data collection was considered complete by August 31, 2020. As no personal or patient-related information was collected, ethics review was waived.

Data Collection Tool:

A questionnaire was designed by 4 nephrologists directly involved in outbreak prevention efforts at their institutions. We asked questions about the physical characteristics of each unit, which IPAC measures were implemented from March 1 – June 30 2020, provider perception of crowdedness and adherence to IPAC measures. We divided IPAC measures into 4 themes: screening procedures, physical distancing measures, personal protective equipment (PPE) use, and other general measures. We asked which measures were applied to: all patients; high-risk patients (residents of long-term care facilities, returning travelers, recently hospitalised patients); and patients with suspected/confirmed COVID-19. The questionnaire was tested for clarity and face validity iteratively by its creators and two research coordinators. Items considered unclear by ≥1 reviewer were revised and the questionnaire re-tested until all reviewers agreed it was adequate. Study data were collected and managed using REDCap) electronic data capture tools hosted at the coordinating centre[15,16].

Follow-up data collection of infection rates:

In April 2021, units were individually contacted to collect information about the total number of infections documented from March 1st 2020 to March 31st 2021 and the current number of patients undergoing in-center hemodialysis in their unit. At least two contact attempts were made. Cumulative infection rates up to March 31st 2021 in each of Quebec Health regions were collected from publicly available data produced by *the Institut de Santé Publique du Québec* (INSPQ).

Statistics:

The primary objective was descriptive in nature. No sample size calculation were performed since we aimed to include all of Quebec HD units. Categorical variables are presented as number (%) and continuous variables are presented as medan (SD) or median [interquartile range (IQR)].

Dialysis unit characteristics and IPAC measures were compared between units reported as overcrowded vs. not crowded using Chi squared or Fisher's exact (if cell count were <5) for categorical variables, and Student's t- or Mann U Whitney-test (in case of non-normal distribution after examination of Q-Q plot) for continuous variables.

Expected infection rates in each unit were calculated by multiplying the regional infection rate to the number of patients in each unit. The ratio of the actual infection rate to the expected infection rate, the standardized infection ratio (SIR), is presented with 95% confidence intervals. Differences in SIR according to unit characteristics and deployed IPAC measures were assessed using Mann U Whitney-test. Spearman correlation were used to assess the relationship between SIR and both the unit size defined as the number of patients receiving HD treatment at the studied units and the number of isolation rooms available at the units. A significance level of p=0.05 was used for all tests. All statistics were performed in SPSS version 25 (IBM, Armonk, New York).

Results

Dialysis Unit Characteristics:

Of Quebec's 54 dialysis units with almost 4800 patients, the managers of 38 (70%) completed surveys representing >4300 patients (~90%). There was wide variation in the number of treated patients (range 8-380, median 86) and treatment stations (range 4-70, median 20) (**Table 1**). Thirteen units (34%) were operating at ≥90% of their capacity, and this correlated with unit size (r=0.61 p<0.001) (Supplemental **Figure S1**).

Over 30% and 40% of respondents reported their treatment area or waiting room was crowded, respectively. Importantly, the perception of crowdedness correlated with an objective measurement of <2 m between dialysis stations or waiting room chairs (**Table 1**). There was no relationship between crowdedness and % filled capacity. While 92% of units had at least one regular isolation room (median 3), in only 32% were any of these rooms equipped with negative pressure ventilation (range 0-4).

Frequency of Specific IPAC Measures:

The frequency of specific IPAC measures in Quebec's hemodialysis units are given in **Table 2**. Strict screening procedures including a symptoms questionnaire and taking patients' temperature on arrival were implemented almost universally. Most units (74%) had set up a separate triage post for this purpose. While most units (82%) encouraged patients to inform the dialysis unit in advance if they were experiencing symptoms, few units (37%) routinely called patients the day before. Very few units (<10%) performed regular surveillance testing for SARS-CoV-2 by nasopharyngeal swab for all patients, but 64% of units did so for high-risk patients from long-term care facilities and other group living situations.

Most (71%) units installed plexiglass, or other physical barriers between dialysis stations, while 55% reorganized the dialysis chairs to create more space between them; notably only 40% of units with <2 m between dialysis chairs were able to do so. All units reported that patients with suspected or confirmed COVID-19 would be isolated in some manner. Most (92%) units dialyzed these patients in single patient rooms, while smaller satellite centers would transfer them to the main center that was better equipped. Only 18% of units reported having to decrease dialysis frequency to ensure adequate physical distancing was maintained between patients during treatments.

Interestingly, PPE use was not universal during the first phase of the pandemic. Procedure masks were worn at all times by staff in 100% of units, but staff visors were worn only when caring for suspected, positive, or high-risk patients in most units. In contrast, patients were not required to wear masks except if they were suspected or proven to have COVID-19.

Compared to other regions, more dialysis units located in the Greater Montreal Region (GMR) implemented specific IPAC measures for high-risk groups (Table 2). These measures included dialyzing high-risk patients in a dedicated zone or shift (100% vs 46%, p=0.001) and using full droplet and contact precautions (100% vs 65.4% p=0.036). The rate of systematic PCR testing for COVID-19 in high-risk patients did not differ between units in the GMR vs. outside of it (35% vs 29.1%, p=0.73).

Feasibility of IPAC Measures and Impact of Crowdedness

Only 8% of units reported that physical distancing measures could not be easily maintained in their units; 69% and 23% reported that measures were easily implemented all or part of the time, respectively. Almost 90% of reported that their access to PPE use was adequate. There were no significant differences between the rate of adoption of IPAC measures between units with "crowded" vs "non-crowded" treatment areas (**Table 2**).

Timing of IPAC Measures and Outbreaks

By July 15th, 2020, ~5% of Quebec's almost 5000 hemodialysis patients had tested positive for COVID-19 (*personal communications with 98% of Quebec's dialysis unit directors*). The majority of these were from the GMR, mirroring the provincial experience during the first phase (**Figure 1A**). The most common IPAC measures (>85% of units) were implemented in all hemodialysis units within 6 weeks of the first documented case in Quebec province (**Figure 1B**); 50% of these units had implemented these measures by 3 weeks, at the time where a rapid increase in COVID-19 cases in the GMR was observed.

Cumulative infection rate during the first year of the pandemic

Follow-up data was obtained in 26 centers providing care to 3942 hemodialysis patients as of March 31st 2021 in 8 different health regions. Documented infection rate varied from 0% to 50% (Median: 10.4% IQR: 5.1%; 20.5%) (Figure 2A). When compared to regional cumulative infection rate, 22/26 (84.6%) units showed standardized infection ratio >1 (Median SIR: 2.68, IQR: 1.58; 4.45) (Figure 2B).

No statistical difference in SIR was observed according to physical distance between HD chairs (<2m: Median: 4.40 [IQR: 2.98; 4.86] vs ≥2m: Median: 2.25 [IQR: 1.31; 3.48] p=0.07) or reported unit crowdedness (Crowded: Median: 3.70 [IQR: 2.27; 4.86] vs Not crowded: 2.48 [IQR: 1.31; 4.17] p=0.28). Similarly, no difference in SIR was seen according to specific IPAC measures (Supplementary table 1),

and no association were observed between SIR and the number of patients treated at each center (r=0.21, p=0.32) or number of isolation rooms per centre (r=0.16, p=0.45).

Interpretation

In this study, we found that local leaders in Quebec's hemodialysis unit were able to rapidly and successfully implement recommended IPAC measures in the spring of 2020, whether they were crowded or not. Most measures were implemented within 3 weeks of the World Health Organization's pandemic declaration[17]; the remaining measures were implemented by 6 weeks. Despite rapid and universal adoption of IPAC measures, we observed that the infection rate in most hemodialysis units remained elevated compared to regional infection rates.

Hemodialysis units pose the perfect opportunity for transmission of airborne and droplet infections, with potentially disastrous consequences. There is often limited space for large numbers of patients who must spend 3-4 hours in close proximity[12], often in spaces with poor ventilation[18]. Early during the pandemic, expert groups published multiple recommendations on how to avoid outbreaks in hemodialysis units[11-14]. However, whether these strict screening, physical distancing, and isolation measures could feasibly be implemented in crowded units at full capacity with limited space and resources was highly uncertain and the fear of outbreaks high.

In terms of specific IPAC measures, we found that implementation of hand hygiene, disinfection of surfaces, and mask use was universal. During the first wave, the use of visors was restricted in some units perhaps due to perceived lack of importance or shortages, but now practices have evolved such that anyone directly caring for patients wears ocular protection in addition to masks[19]. Contrary to our original hypothesis, physical distancing IPAC measures were feasibly implemented, whether the dialysis unit was perceived as crowded or not. Space restrictions and other limitations may have prompted the use of alternative solutions such as the installation of plexiglass barriers, or modification to the dialysis schedule. Similar adaptations have been reported in centres outside Quebec[20]. Fortunately, major changes in the model of care such as by reducing dialysis frequency, a strategy reported in other countries[21], were rarely needed in Quebec. It is also important to note that confirmed COVID-19 patients were rarely dialyzed in negative pressure isolation rooms as some have recommended[18], as only 32% of units were equipped with them.

Screening and triage measures were universally deployed to identify infected patients, and most units in the GMR area where community prevalence was high implemented special measures for high-risk patients including those living in long-term care facilities or other group living situations. Conversely, regular nasopharyngeal testing for SARS-CoV-2 in all asymptomatic high-risk patients was not commonly implemented during the first months of the pandemic, although it may have been more frequent following a recommendation from *Institut national de santé et services sociaux* (INESSS) in

September 2020. Notably, this "surveillance" testing approach may be important to curb spread during outreaks[10].

It remains unknown if the high observed SIRs are related to transmission occurring in the unit, or in the living environment of the patient. A recent paper documenting outcomes of SARS-CoV-2 infection in long-term dialysis recipients in Ontario up to August 20th 2020 reported that individual risk factor for infection included residence in long-term care facilities, residence in the greater Toronto region and non-white ethnicities and lower income quartiles[8]. In this work, a cumulative infection rate of 1.5%[8] was reported at a time when the cumulative infection in Ontario rate was approximately 0.28%. However, there was no comparison between specific unit infection rate and regional infection rate. In our work, we confirm that infection rate in HD unit remain disproportionally high when compared to regional infection rate.

To our knowledge, this is the first comprehensive empiric study of IPAC strategies implemented in Canada in multiple centers from a single provincial health care jurisdiction. Data was obtained from units representing ~90% of dialysis patients in Canada's 2nd largest province. All types of dialysis units are represented, including academic and community, urban and rural, large and small. In comparison with prior work[8], we compared center infection rate to regional infection rate enabling a better appreciation of the heightened risk of infection in HD patients compared to the general population. We also recognize our study's limitations. First, data collection relied on administrative records and testimony of local leaders responsible for IPAC measures at their respective units. Secondly, cumulative infection rates were only collected in a subset of participating centers and compared to the general population, which is likely to have a different age distribution. Finally, because the units of observation were dialysis centers and not individual patients, it was not possible to determine risk factors for infection.

Conclusion

We conclude that hemodialysis units throughout Quebec were able to rapidly implement IPAC measures during the first months of the pandemic. Despite these measures, the infection rate within dialysis unit remain high compared to the general population. Our study also suggests IPAC measures should continue until the hemodialysis population develops acquired immunity to COVID-19, and may also be relevant during future epidemics of viral respiratory illnesses.

Data-Sharing Statement: Data available on request from the authors

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Figure legend

Figure 1: Implementation of general preventive measures in the province of Quebec during the first phase of the COVID-19 pandemic. A) Location of participating hemodialysis units and number of confirmed cases per capita in each Quebec Health Regions as of June 1st 2020 according to data from the *Institut National de Santé Publique du Québec*[22]) B) Timing of implementation of the most common infection prevention measures in hemodialysis units in relationship to important COVID-19 events in Quebec. As shown, the most common preventive measures were largely implemented before May 1st 2020.

Figure 2: Cumulative infection rate in 26 hemodialysis units until March 31st 2021. A) Cumulative incidence rate in each unit (black bars) compared to cumulative incidence rate in corresponding Quebec health region (red line) according to data from the *Institut National de Santé Publique du Québec*[22]. B) Standardized infection ratio (SIR) in each hemodialysis unit with 95% confidence intervals. A SIR higher than 1 (blue line) indicates that the observed infection rate in the unit is higher than expected based of the infection rate observed in the respective Quebec health region.

Table 1: Hemodialysis Unit Characteristics

	All (N=38)	"Crowded" (N=12)*	"Not Crowded" (N=26)*	p-value
Type of unit				
University-based	7 (18%)	1 (8.3%)	6 (23.1%)	0.40
Community-based	31 (82%)	11 (91.7%)	20 (76.9%)	
No. patients treated per week	86 (32; 138)	58 (38; 138)	88 (24; 150)	0.89
No. dialysis treatment stations	19 (10; 27)	16 (11; 25)	21 (8; 40)	0.63
No. separate sectors in the unit	1 (1; 3)	1 (1; 2)	2 (1; 4)	0.51
No. patients per sector	43 (7; 257)	44 (30; 61)	40 (19; 71)	0.65
At >90% filled capacity	13 (34%)	4 (33.3%)	9 (34.6%)	0.94
Patient to nurse ratio	3 (3; 4)	3 (3; 3)	4 (3; 4)	**0.02**
Patient to PSW ratio	9 (7; 10)	9 (6; 11)	9 (7; 10)	0.82
No. isolation rooms	2 (1; 4)	2 (2; 3)	2 (1; 4)	0.63
Ratio of all dialysis stations to isolation rooms	8 (5; 10)	9 (6; 10)	8 (5; 10)	0.93
No. negative pressure ventilation rooms	0 (0;2)	0 (0; 2)	0 (0; 1)	0.57
Distance between treatment stations (N, %)				
<1 meter	1 (2.6%)	1 (8.3%)	0 (0%)	
1-2 meters	14 (36.8%)	9 (75.0%)	5 (19.2%)	<0.001
>2 meters	23 (60.5%)	2 (16.7%)	21 (80.8%)	
Nursing stations >2m from dialysis stations (N, %)	34 (89.5%)	9 (75.0%)	25 (96.2%)	0.08
Number of computers per sector	4 (2; 8)	3 (3; 7)	6 (2; 9)	0.45
No. units with >1 waiting area	6 (14.6%)	2 (16.7%)	4 (15.4%)	1.00
Distance between waiting room chairs (N, %)**				
<1 meter	10 (26.3%)	7 (50.0%)	3 (13.0%)	
1-2 meters	14 (36.8%)	5 (35.7%)	9 (43.5%)	0.049
>2 meters	11 (28.9%)	2 (14.3%)	9 (43.5%)	

Data are presented as median (interquartile range) or number (percentage).

Filled capacity was calculated as number of patients over 6 times the number of stations, as each dialysis station can accommodate 6 patients per week on a 3 times weekly schedule.

**"Crowdedness" was as perceived by person completing the survey.*

***Waiting room crowdedness was assessed separately from dialysis unit crowdedness, resulting in slightly different totals (n=14 crowded waiting rooms, 21 non-crowded waiting rooms).*

PSW: Personal support workers

Table 2: IPAC measures implemented in Quebec dialysis units by May 31, 2020

Measures for ALL Patients	N (%) of Units N=38	Crowded N=12	Not crowded N=26	p-value
GENERAL MEASURES				
Restriction of visitors	38 (100%)	12 (100%)	26 (100%)	*
Mandatory hand hygiene for patients at entrance	35 (92%)	11 (92%)	24 (92%)	1.00
Signs for hand hygiene	32 (84%)	10 (83%)	22 (85%)	1.00
Disinfection of all surfaces	32 (84%)	11 (92%)	21 (81%)	0.64
Masks for all patients	30 (80%)	10 (83%)	20 (77%)	1.00
SCREENING and TRIAGE				
Screening questionnaire administered to all patients	37 (97%)	12 (100%)	25 (96%)	1.00
Patient temperature taken on arrival	36 (95%)	12 (100%)	24 (92%)	1.00
All symptomatic patients tested with nasopharyngeal swab	36 (95%)	12 (100%)	24 (92%)	1.00
Patients requested to call ahead if symptoms	31 (82%)	10 (83%)	21 (81%)	1.00
Separate triage post	28 (74%)	10 (83%)	18 (69%)	0.45
Surveillance testing for all high-risk patients*	24 (63%)	7 (58%)	17 (65%)	0.68
Called patients routinely the day before	12 (37%)	3 (25%)	11 (42%)	0.47
Surveillance testing of all patients with nasopharyngeal swab	3 (8%)	1 (8%)	2 (8%)	1.00
Surveillance testing of all staff with nasopharyngeal swab	3 (8%)	2 (17%)	1 (4%)	0.23
PHYSICAL DISTANCING MEASURES				
Plexiglass or other barriers	27 (71%)	11 (92%)	16 (62%)	0.12
Separate schedule or location for high-risk patients*	24 (63%)	6 (50%)	18 (69%)	0.25
Reorganization of chairs in hemodialysis unit**	21 (55%)	4 (33%)	17 (65%)	0.09
Decrease in HD Frequency	7 (18%)	2 (17%)	5 (19%)	1.00
PPE				
Masks for all staff	38 (100%)	12 (100%)	26 (100%)	*
PPE teaching sessions	31 (82%)	10 (83%)	21 (81%)	1.00
Visors for staff at all times with high risk patients*	29 (76%)	10 (83%)	19 (73%)	0.69
Visors for all staff at all times	13 (34%)	5 (42%)	8 (31%)	0.71
Measures for COVID-19 Suspect or Positive Patients				
PHYSICAL DISTANCING MEASURES				
Physical distancing in waiting room	36 (95%)	12 (100%)	24 (92%)	1.00
Creation of red or warm zones in the dialysis unit	34 (89%)	11 (92%)	23 (88%)	1.00
Isolated transportation	31 (82%)	10 (83%)	21 (81%)	1.00
Plexiglass or other barriers	31 (82%)	12 (100%)	19 (73%)	0.07
Dialysis in an isolation room	32 (84%)	8 (67%)	24 (92%)	0.07
Dialysis in a separate area of the unit	20 (53%)	7 (58%)	13 (50%)	0.73
Separate dialysis schedule	23 (53%)	10 (83%)	13 (50%)	0.08
Transfer to another unit for dialysis	14 (37%)	4 (33%)	10 (38%)	1.00
Change of personnel to patient ratios	14 (37%)	3 (25%)	11 (42%)	0.47
Dialysis in a negative pressure ventilation room	12 (32%)	6 (50%)	6 (23%)	0.10
PPE				
Masks for all patients	38 (100%)	12 (100%)	26 (100%)	*
Visors for staff at all times	37 (97%)	11 (92%)	26 (100%)	0.32

Color indicates the rate of implementation within included HD units (green >=80%, blue 50-79%, red <50%)

**Residents of long-term facilities, those in group living situations, or hospitalized in the last 14 days.*

***For units with <2 m between chairs, 40% were able to reorganize the chairs.*

Trends with p-values <0.10 are bolded. P-values of 1.00 not shown.

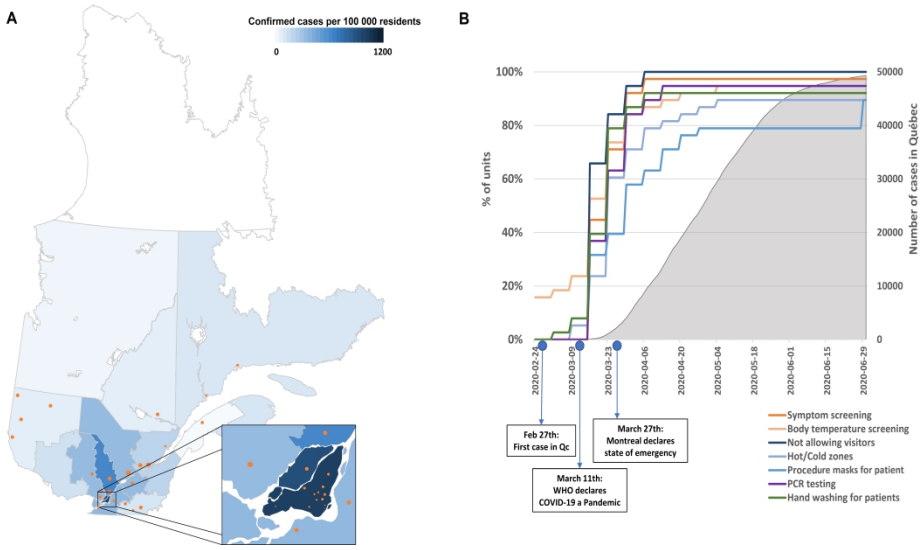

Figure 1: Implementation of general preventive measures in the province of Quebec during the first four months of the COVID-19 pandemic. A) Location of participating hemodialysis units and number of confirmed cases per capita in each Quebec Health Regions as of June 1st 2020 according to data from the Institut National de Santé Publique du Québec17) B) Timing of implementation of the most common infection prevention measures in hemodialysis units in relationship to important COVID-19 events in Quebec. As shown, the most common preventive measures were largely implemented before May 1st 2020.

719x390mm (300 x 300 DPI)

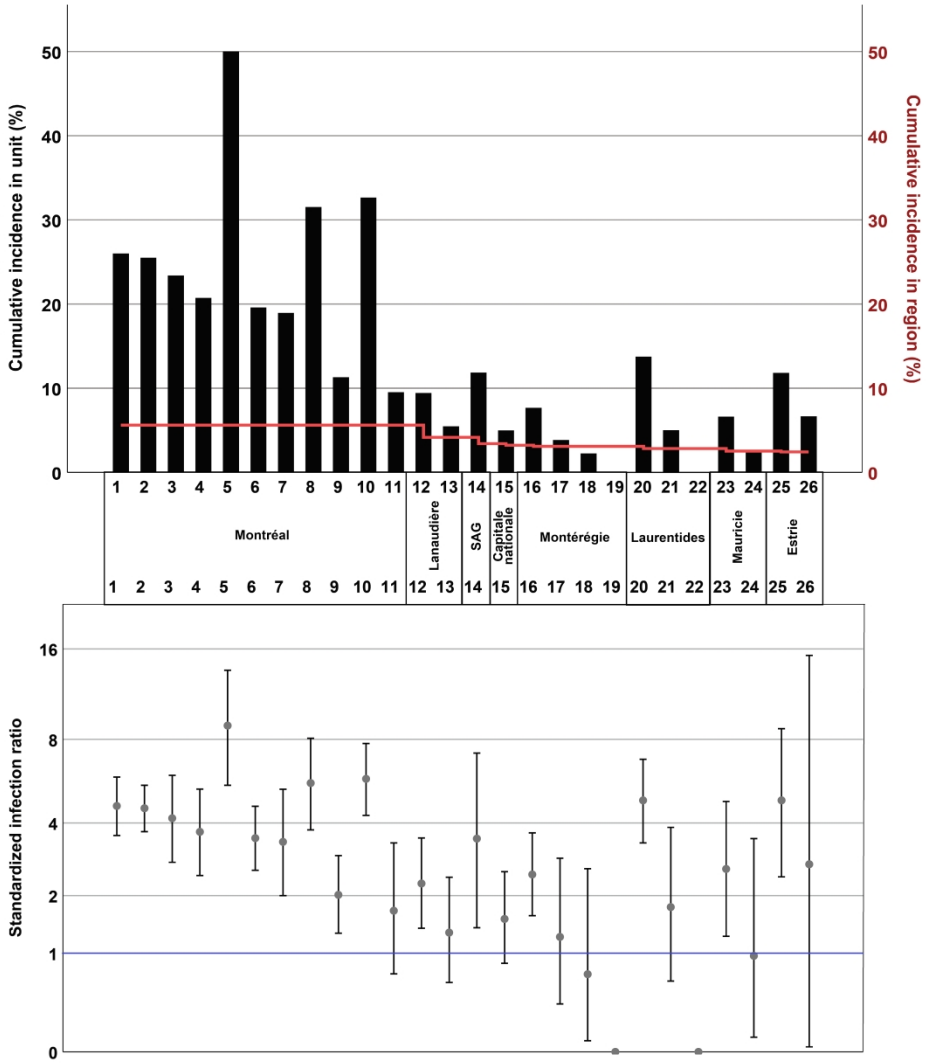

Figure 2: Cumulative infection rate in 26 hemodialysis units until March 31st 2021. A) Cumulative incidence rate in each unit (black bars) compared to cumulative incidence rate in corresponding Quebec health region (red line) according to data from the Institut National de Santé Publique du Québec22. B) Standardized infection ratio (SIR) in each hemodialysis unit with 95% confidence intervals. A SIR higher than 1 (blue line) indicates that the observed infection rate in the unit is higher than expected based of the infection rate observed in the respective Quebec health region.

Supplementary material: Feasibility of infection control measures in hemodialysis units to prevent outbreaks of COVID-19: An empiric province-wide study from Quebec

Supplemental Figure S1: Relationship between the number of patients per hemodialysis unit and % filled capacity of hemodialysis units in Quebec (r=0.607, p<0.001).

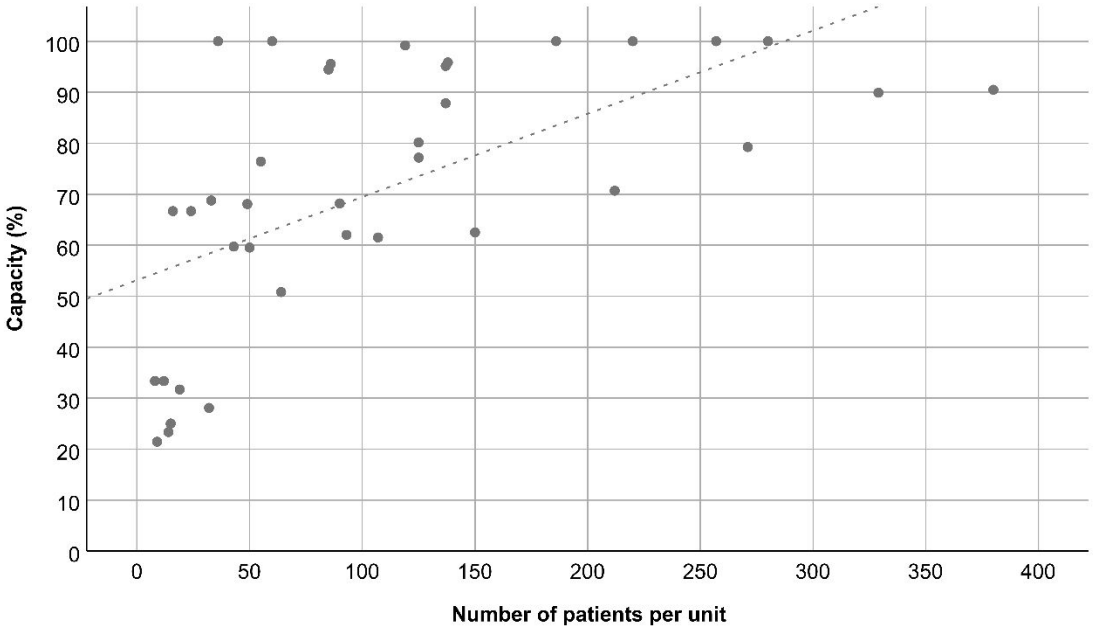

Table S1: Standardized infection ratio (SIR) in participating hemodialysis unit (n=22) according to specific infection prevention and contro (IPAC)l measures deployed in the first phase of the pandemic.

IPAC measure		SIR (Median [IQR])	p-value
Separate trialge post at the entrance of HD unit	Yes	2.48 [1.54; 4.54]	0.96
	No	2.74 [0.96; 4.86]	
Use of physical barriers within the units	Yes	2.93 [1.62; 4.75]	0.46
	No	2.68 [0.96; 3.48]	
Creating cohorts of high-risk patients	Yes	3.49 [1.70; 4.86]	0.09
	No	2.27 [0.96; 2.74	
Re-arrangement of the unit to maintain social distancing	Yes	2.68 [1.55; 4.17]	0.89
	No	2.98 [1.25; 4.70]	
Systematic PCR screening of high-risk patients (up to June 30th)	Yes	2.48 [1.55; 4.55]	0.96
	No	2.74 [0.96; 4.86]	

Appendix 1: Investigators and collaborators of the COVID-19 Quebec Renal Network:

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