







Comparison of Acute Health Care Utilization Between Patients Receiving In-Center Hemodialysis and the General Population: A Population-Based Matched Cohort Study From Ontario, Canada

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Abstract

Background: Patients receiving maintenance hemodialysis have multiple comorbidities and are at high risk of presenting to the hospital. However, the incidence and cost of acute health care utilization in the in-center hemodialysis population and how this compares with other populations is poorly understood.

Objective: To determine the rate, pattern, and cost of emergency department visits and hospitalizations in patients receiving in-center hemodialysis compared with a matched general population.

Design: Population-based matched cohort study.

Setting: We used linked administrative health care databases from Ontario, Canada.

Patients: We included 25 379 patients (incident and prevalent) receiving in-center hemodialysis between January 1, 2010, and December 31, 2018. Patients were matched on birth date (± 2 years), sex, and cohort entry date using a 1:4 ratio to 101 516 individuals from the general population.

Measurements: Our primary outcomes were emergency department visits (allowing for multiple visits per individual) and hospital admissions from the emergency department. We also assessed all-cause hospitalizations, all-cause readmissions within 30 days of discharge from the original hospitalization, length of stay for hospital admissions (including multiple visits per individual), and the financial cost of these admissions.

Methods: We presented the rate, percentage, median (25th, 75th percentiles), and incidence rate per 1000 person-years for emergency department visits and hospitalizations. Individual-level health care costs for emergency department visits and all-cause hospitalization were estimated using resource intensity weights multiplied by the cost per weighted case.

Results: Patients receiving in-center hemodialysis had substantially more comorbidities (eg, diabetes) than the matched general population. Eighty percent ($n = 20\,309$) of patients receiving in-center hemodialysis had at least 1 emergency department visit compared with 56% ($n = 56\,452$) of individuals in the matched general population, over a median follow-up of 1.8 years (25th, 75th percentiles: 0.7, 3.6) and 5.2 (2.5, 8.4) years, respectively. The incidence rate of emergency department visits, allowing for multiple visits per individual, was 2274 per 1000 person-years (95% confidence interval [CI]: 2263, 2286)

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for patients receiving in-center hemodialysis, which was almost 5 times as high as the matched general population (471 per 1000 person-years; 95% CI: 469, 473). The rate of hospital admissions from the emergency department and the rate of all-cause hospital admissions in the in-center hemodialysis population was more than 7 times as high as the matched general population (hospital admissions from the emergency department: 786 vs 101 per 1000 person-years; all-cause hospital admissions: 1056 vs 139 per 1000 person-years). The median number of all-cause hospitalization days per patient year was 4.0 (0, 16.5) in the in-center hemodialysis population compared with 0 (0, 0.5) in the matched general population. The cost per patient-year for emergency department visits in the in-center hemodialysis population was approximately 5.5 times as high as the matched general population while the cost of hospitalizations in the in-center hemodialysis population was approximately 11 times as high as the matched general population (emergency department visits: CAN\$ 1153 vs CAN\$ 209; hospitalizations: CAN\$ 21 151 vs CAN\$ 1873 [all costs in 2023 CAN\$]).

Limitations: External generalizability and we could not determine whether emergency department visits and hospitalizations were preventable.

Conclusions: Patients receiving in-center hemodialysis have high acute health care utilization. These results improve our understanding of the burden of disease and the associated costs in the in-center hemodialysis population, highlight the need to improve acute outcomes, and can aid health care capacity planning. Additional research is needed to address the risk of hospitalization after controlling for patient comorbidities.

Trial registration: This is not applicable as this is a population-based matched cohort study and not a clinical trial.

Abrégé

Contexte: Les patients qui suivent des traitements d'hémodialyse d'entretien présentent de multiples comorbidités et sont hautement susceptibles de se présenter à l'hôpital. On en sait toutefois peu sur l'incidence de l'utilisation des soins de santé aigus chez les patients hémodialysés en center, sur les coûts qui y sont associés, ainsi que sur la manière dont cela se compare à d'autres populations.

Objectif: Déterminer, dans une population de patients hémodialysés en center, les taux d'hospitalisations et de visites aux urgences, leurs schémas et les coûts qui y sont associés, puis comparer ces résultats à ceux d'une population générale appariée.

Type d'étude: Étude de cohorte populationnelle rétrospective.

Cadre: Nous avons utilisé les bases de données couplées du système de santé de l'Ontario (Canada).

Sujets: Nous avons inclus 25 379 patients (incidents et prévalents) qui recevaient des traitements d'hémodialyse en center entre le 1^{er} janvier 2010 et le 31 décembre 2018. Les patients inclus ont été appariés, en fonction de leur date de naissance (± 2 ans), de leur sexe et de leur date d'entrée dans la cohorte, à 101 516 individus de la population générale dans un rapport de 1:4.

Mesures: Nos principaux critères de jugement étaient les visites aux urgences (en permettant plusieurs visites par personne) et les admissions à l'hôpital à partir de l'urgence. Nous avons également évalué les hospitalisations toutes causes confondues, les réadmissions toutes causes confondues dans les 30 jours suivant le congé initial, la durée du séjour (en comptant les visites multiples par personne) et les coûts associés à ces admissions.

Méthodologie: Nous avons présenté le nombre, le pourcentage, la médiane (25^e et 75^e percentile) et le taux d'incidence par 1000 années-personnes pour les visites aux urgences et les hospitalisations. Les coûts de santé par individu associés aux visites à l'urgence et aux hospitalisations toutes causes confondues ont été estimés en multipliant la pondération du volume des ressources par le coût pondéré par cas.

Résultats: Les patients hémodialysés en center présentaient beaucoup plus de comorbidités (p. Ex. diabète) que la population générale appariée. Au cours d'un suivi médian respectif de 1,8 an (25^e et 75^e percentile: 0,7 et 3,6 ans) et de 5,2 ans (2,5 et 8,4 ans), 80 % (n=20 309) des patients hémodialysés en center ont visité l'urgence au moins une fois, contre 56 % (n= 56 452) des patients de la population générale appariée. Le taux d'incidence des visites aux urgences, en permettant plusieurs visites par personne, était de 2274 pour 1000 années-personnes (intervalle de confiance à 95% [IC 95%]: 2 263 à 2 286) chez les patients hémodialysés en center, soit presque cinq fois plus élevé que la population générale appariée (471 pour 1000 années-personnes; IC95 %: 469 à 473). Les taux d'admissions à partir de l'urgence et d'hospitalisations toutes causes confondues dans la population de patients hémodialysés en center étaient plus de sept fois plus élevés que dans la population générale appariée (admissions à partir de l'urgence: 786 contre 101 pour 1000 années-personnes; hospitalisations toutes causes confondues: 1056 contre 139 pour 1000 années-personnes). La durée médiane des hospitalisations toutes causes confondues par année-patient était de 4,0 jours (0 et 16,5 jours) chez les patients hémodialysés en center et de 0 jour (0 et 0,5 jour) dans la population générale appariée. Le coût par année-patient des visites à l'urgence chez les patients hémodialysés en center était environ 5,5 fois plus élevé que dans la population générale appariée, tandis que celui des hospitalisations était environ 11 fois plus élevé (visites à l'urgence: 1153 CAD contre 209 CAD; hospitalisations: 21 151 CAD contre 1873 CAD [coûts en dollars canadiens de 2023]).

Limites: Généralisabilité externe; impossible de déterminer si les visites aux urgences et les hospitalisations étaient évitables.
Conclusion: Les patients hémodialysés en center sont de grands utilisateurs des soins de santé aigus. Ces résultats améliorent notre compréhension du fardeau de la maladie et des coûts associés à cette utilisation dans cette population. Ces résultats soulignent également la nécessité d'améliorer les résultats des soins aigus et peuvent aider à la planification des capacités en matière de soins de santé. D'autres études sont nécessaires pour examiner le risque d'hospitalisation après la gestion des comorbidités des patients.

Keywords

in-center hemodialysis, emergency department visits, hospitalizations

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Introduction

Over the last 20 years, the number of Canadians receiving maintenance dialysis nearly doubled with more than 29 000 individuals receiving dialysis in 2021.¹ Worldwide this number is expected to increase to 5.4 million by the year 2030, up from 2 million in 2010.² Nearly, three quarters of patients in Canada receiving maintenance dialysis do so at a hospital or at a community or satellite hemodialysis unit (ie, in-center hemodialysis).³ Patients receiving in-center hemodialysis are generally older (average age 65 years), have more comorbidities, and have higher health care resource utilization (CAN\$100 000 per patient per year) compared with other dialysis types (eg, peritoneal dialysis).³⁻⁵

There are an increasing number of studies examining health care utilization in patients receiving maintenance dialysis. These studies have consistently found that individuals receiving maintenance dialysis frequently visit the emergency department or require hospitalization.^{4,6-14} For example, Komenda et al⁶ found the rate of emergency department visits in patients receiving dialysis was 8.5 times as high as the general population. However, these previous studies had limitations, including a lack of detailed information on multiple aspects of health care utilization (eg, emergency department visits, in-patient hospitalizations, and costs).

Understanding health care utilization in patients receiving in-center hemodialysis and their associated costs could be used to guide resource planning, impact future funding decisions, and encourage the development of approaches that might improve patient care while reducing costs. Therefore, we conducted this study to examine acute health care utilization, including emergency department visits, hospitalizations, and costs among patients receiving in-center hemodialysis in Ontario, Canada compared with a matched general population.

Methods

Design and Setting

We conducted a population-based matched cohort study using administrative health care databases in Ontario,

Canada. These data sets were linked using unique encoded identifiers and analyzed at ICES Western (ices.on.ca). ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement. The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board. We followed the reporting of studies conducted using observational routinely collected health data guidelines (RECORD) (Supplementary Table S1).¹⁵

Data Sources

We used several databases to obtain information on patient demographics, comorbidities, and outcomes. To identify patients receiving in-center hemodialysis we used the Ontario Renal Reporting System (ORRS) database, a provincial reporting system in which reporting by the hospital-based Regional Renal Programs is mandatory to receive financial reimbursement for their activities.¹⁶ Vital status (mortality can be accurately ascertained in our data sources)¹⁷ and demographic information were obtained from the Registered Persons Database. We used the Canadian Institute for Health Information (CIHI) Discharge Abstract Database to identify hospital admissions, and procedural and diagnostic codes associated with hospitalizations; submission of data is mandated by the provincial ministry of health.¹⁸ The CIHI Same Day Surgery Database was used to identify day surgeries. The CIHI National Ambulatory Care Reporting System database was used to identify emergency department visits. Reasons for emergency department visits and hospitalizations could not be accurately determined from our administrative health care databases. The Ontario Health Insurance Plan contains information on inpatient and outpatient physician submitted diagnostic and billing codes. Supplementary Table S2 contains further information on the databases and coding definitions.

Cohort

In-center hemodialysis. We included patients receiving in-center hemodialysis between January 1, 2010 and December 31, 2018. We excluded individuals aged < 18 years. To ensure we were not capturing patients receiving acute dialysis, we required all patients to remain on in-center hemodialysis for at least 90 days. To ensure continuity of care, we required that patients received care at the same Regional Renal Program for at least 28 days; there are 27 Regional Renal Programs in Ontario that oversee 97 hemodialysis units with over 10 000 patients receiving in-center hemodialysis.¹⁹ Patients already receiving in-center hemodialysis at the beginning of the accrual period had an index date (ie, cohort entry date) of January 1, 2010, while individuals initiating in-center hemodialysis between January 2, 2010 and December 31, 2018 had an index date of 90 days after dialysis initiation. If a patient's index date overlapped with an emergency department visit or hospital admission, the index date was reassigned to the day after hospital discharge.

General population. Since the general population is very large (more than 14 000 000 residents in Ontario), we randomly selected 200 individuals from the general population that were matched (on sex and birth date within 2 years) with each individual from the in-center hemodialysis population. We assigned the general population the same index date as the matched individuals receiving in-center hemodialysis. If the index date overlapped with an emergency department visit or hospital admission, we reassigned the index date to the day after hospital discharge. We excluded individuals aged < 18 years and anyone who previously received maintenance dialysis (including home hemodialysis and peritoneal dialysis) prior to the index date. Finally, we randomly selected 4 unique individuals from the general population for each individual receiving in-center hemodialysis.

Outcomes

Our primary outcomes included the rate of emergency department visits (allowing for multiple visits per individual) and the rate of all-cause hospitalizations from the emergency department visits (allowing for multiple visits per individual).

Our secondary outcomes included all-cause hospital admissions (including admissions for elective procedures and admissions that are from the emergency department or bypass the emergency department), all-cause hospitalizations that bypassed the emergency department, and all-cause readmission within 30 days of being discharged from the original hospitalization. We also reported the method of entry into hospital (ie, the last entry point prior to being admitted as an inpatient)²⁰ as well as whether admissions were elective. Methods of entry into the hospital, included direct admission to the hospital (ie, patient admitted through

the admitting department or admitted directly to the unit), day procedure (ie, patient admitted through the day surgery department), patient admitted directly from a hemodialysis unit or medical clinic (eg, cardiac clinic), or patient admitted through the emergency department.²⁰

We used the ICES case-costing macro to compute individual-level health care costs for emergency department visits (allowing for multiple visits per individual) and all-cause hospitalization (including admissions for elective procedures and allowing for multiple hospitalizations per individual). The macro calculates costs using resource intensity weights multiplied by the cost per weighted case (ie, cost of a hypothetical average patient in Ontario).²¹ Resource intensity weights do not provide a direct cost estimate, rather it is an average of over 20 Ontario organizations (and 2 in Alberta) that submits data to CIHI's costing group. Costs related to physician services provided in hospital are not included in the cost per weighted case.²¹ Costs that are paid by private insurers, out-of-pocket costs, indirect costs (eg, lost productivity), and costs related to public health services are also not included. Costs were presented as CAD 2023.

Statistical Analysis

We reported categorical variables as proportions, while continuous variables were reported as medians (25th, 75th percentiles) or means (\pm standardized deviation). We used standardized differences to compare baseline characteristics between the in-center hemodialysis population and the matched general population. Standardized differences allow for comparisons between groups independent of sample size with a standardized difference of $\geq 10\%$ between groups considered substantially different.²²

For all outcomes, we reported the rate and percentage of events, the total person-years of follow-up, and the event rate per 1000 person-years (95% confidence interval [CI]),²³ allowing for multiple events per person. The 95% CIs are not adjusted for multiplicity. We followed the in-center hemodialysis population until death, emigration from the province (defined as no evidence of a health care interaction in the last 7 years), receipt of a kidney transplant, dialysis modality switch (eg, switch to home dialysis), or no longer receiving hemodialysis (ie, recovered kidney function, withdrew from dialysis or loss to follow-up). We followed individuals in the matched general population until death, initiation of maintenance dialysis, or receipt of a kidney transplant. The maximum follow-up date was March 31, 2019 (maximum follow-up 9.25 years). All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Additional Analyses

We stratified all outcomes in patients receiving in-center hemodialysis by prevalent (ie, entered the cohort on January 1, 2010) and incident status (ie, entered the cohort [started

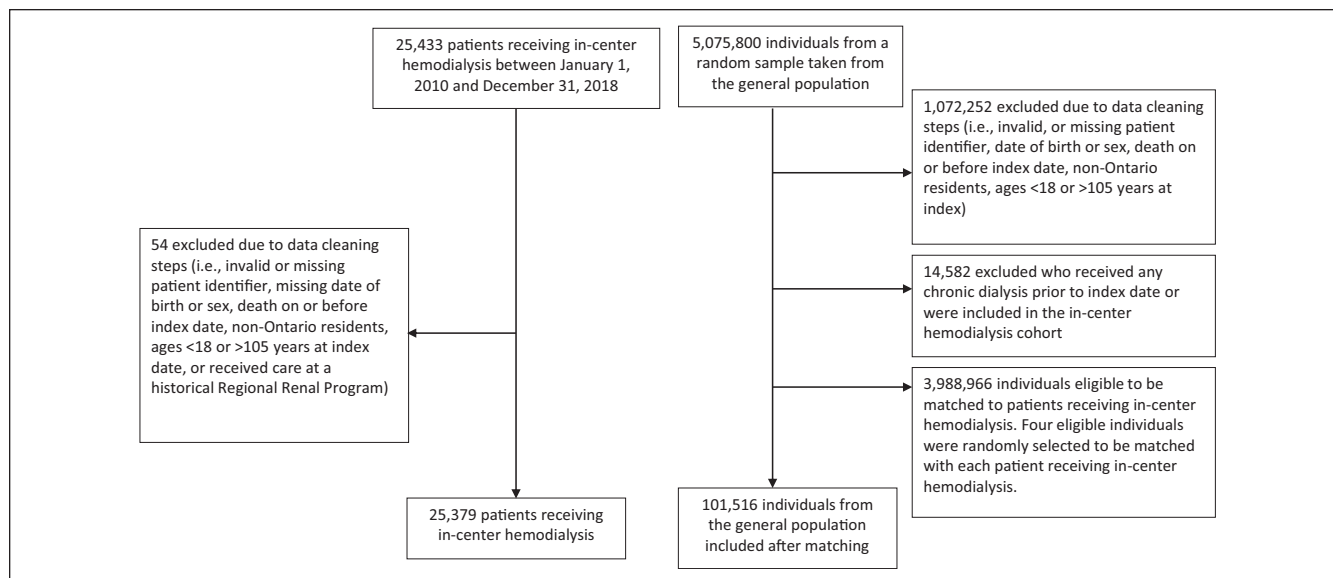


Figure 1. Flow diagram of the in-center hemodialysis cohort and matched general population.

dialysis] between January 2, 2010 and December 31, 2018); the risk of being hospitalized is highest in the initial period after dialysis initiation.²⁴ Post hoc, among those with a hospital admission from the emergency department, we calculated the median in-hospital length of stay (days). This was calculated by subtracting the day of hospital admission from the day of discharge or the day of a censoring event, if the event occurred in the hospital (eg, death). Individuals who entered and left the hospital on the same day had a length of stay of 1 day. We did not count transfers from 1 acute care hospital to another as being discharged from the hospital. We reported this allowing for multiple admissions during follow-up (ie, adding the length of stay for each separate hospital admission) and we also calculated this restricting to the first hospital admission.

Post hoc, we examined the proportion of individuals who had high acute health care utilization during the study period. Specifically, we examined the proportion of individuals who had more than 5 emergency department visits per person-year and more than 4 all-cause hospital admissions (including elective procedures) per person-year. These cutoffs were selected as they were considered to represent substantial health care resource consumption by clinical experts.

Results

Baseline Characteristics

We included 25 379 individuals receiving in-center hemodialysis and 101 516 individuals in the general population, matching 4 individuals from the general population to each patient receiving dialysis (Figure 1).

Baseline characteristics for the in-center hemodialysis and the matched general population are presented in Table 1. Compared with the matched general population, patients receiving in-center hemodialysis were more likely to live in the lowest neighborhood income quintile (28.3% vs 19.6%) and more likely to live in long-term care (6.8% vs 2.0%). Patients receiving in-center hemodialysis also had substantially higher previous health care utilization and substantially more comorbidities compared with the matched general population. The most common cause of end-stage kidney disease in the in-center dialysis population was diabetes (38%) (Table 2).

Over a median follow-up of 1.8 years, 11 452 (45%) patients receiving in-center hemodialysis died, 2729 (10.8%) received a kidney transplant, 392 (1.5%) left the province, 479 (1.9%) were alive but no longer receiving dialysis, and 3921 (15.5%) switched dialysis modalities. In the matched general population (median follow-up 5.2 years), 14 420 (14.2%) died, and 67 (0.07%) received a kidney transplant or initiated maintenance dialysis during follow-up.

Emergency Department Visits

Eighty percent ($n = 20\,309$) of patients receiving in-center hemodialysis had at least 1 emergency department visit with a median of 3 (1, 7) visits per person and an incidence rate of 2274 visits per 1000 person-years (95% CI: 2263, 2286) (allowing for multiple visits per individual). In comparison, 56% ($n = 56\,452$) in the matched general population had at least 1 emergency department visit with a median of 1 (0, 3) visit per person and an incidence rate of 471 visits per 1000 person-years (95% CI: 469, 473) (Table 3). When examining the incidence rate of emergency

Table 1. Baseline Characteristics of Individuals Receiving In-Center Hemodialysis Compared With the Matched General Population.

Characteristics	In-center hemodialysis (N = 25 379)	Matched general population (N = 101 516)	Standardized difference ^a (%)
Demographics			
Age (years)	67 (56, 77)	67 (56, 77)	1
Age categories (years)			
18-39	1660 (6.5)	6638 (6.5)	0
40-59	6325 (24.9)	25 562 (25.2)	1
60-79	12 823 (50.5)	51 118 (50.4)	0
≥ 80	4571 (18.0)	18 198 (17.9)	0
Sex, female	10 082 (39.7)	40 328 (39.7)	0
Year of cohort entry			
2010-2014	16 748 (66.0)	66 992 (66.0)	0
2015-2018	8631 (34.0)	34 524 (34.0)	0
Urban residence ^b	22 627 (89.2)	89 441 (88.1)	3
Neighborhood income quintile ^c			
Quintile 1, low	7188 (28.3)	19 932 (19.6)	20
Quintile 2	5652 (22.3)	20 471 (20.2)	5
Quintile 3, middle	4720 (18.6)	19 932 (19.6)	3
Quintile 4	4234 (16.7)	19 757 (19.5)	7
Quintile 5, high	3423 (13.5)	20 946 (20.6)	19
Missing	162 (0.6)	478 (0.5)	2
Residential instability ^c			
1—Lowest	3861 (15.5)	18 173 (18.1)	7
2	3832 (15.4)	18 345 (18.2)	7
3	4331 (17.4)	19 114 (19.0)	4
4	5294 (21.3)	19 671 (19.5)	4
5—Highest	7526 (30.3)	25 378 (25.2)	11
Material deprivation ^c			
1—Lowest	3218 (13.0)	19 584 (19.5)	18
2	3886 (15.6)	19 693 (19.6)	10
3	4463 (18.0)	19 637 (19.5)	4
4	5584 (22.5)	20 477 (20.3)	5
5—Highest	7693 (31.0)	21 290 (21.1)	23
Dependency ^c			
1—Lowest	4609 (18.6)	18 937 (18.8)	1
2	4244 (17.1)	17 928 (17.8)	2
3	4505 (18.1)	18 439 (18.3)	0
4	4582 (18.4)	19 368 (19.2)	2
5—Highest	6904 (27.8)	26 009 (25.8)	4
Previous health care utilization			
Number of emergency department visits in the previous year	2 (1.4)	0 (0.0)	156
0	4925 (19.4)	79 709 (78.5)	147
1	5875 (23.1)	13 144 (12.9)	27
2	4573 (18.0)	4564 (4.5)	44
≥ 3	10 006 (39.4)	4099 (4.0)	95
Number of emergency department visits in the previous 90 days	0 (0-1)	0 (0-0)	75
0	16 168 (63.7)	94 081 (92.7)	75
1	5629 (22.2)	5604 (5.5)	50
2	2083 (8.2)	1174 (1.2)	34
≥ 3	1499 (5.9)	657 (0.6)	30

(continued)

Table 1. (Continued)

Characteristics	In-center hemodialysis (N = 25379)	Matched general population (N = 101516)	Standardized difference ^a (%)
Number of hospitalizations in the previous year	1 (0-2)	0 (0-0)	172
0	7363 (29.0)	93645 (92.2)	170
1	6875 (27.1)	5772 (5.7)	60
2	4806 (18.9)	1362 (1.3)	61
≥3	6335 (25.0)	737 (0.7)	78
Number of hospitalizations in the previous 90 days	0 (0-1)	0 (0-0)	126
0	12789 (50.4)	98838 (97.4)	127
1	8833 (34.8)	2253 (2.2)	92
2	2722 (10.7)	343 (0.3)	47
≥ 3	1035 (4.1)	82 (0.1)	28
Long-term care facility resident	1735 (6.8)	1981 (2.0)	24
Comorbidities^d			
Charlson comorbidity index ^e	4 (2-5)	0 (0-0)	278
Diabetes ^f	15883 (62.6)	20515 (20.2)	95
Hyperkalemia	5436 (21.4)	432 (0.4)	71
Hypertension ^g	23530 (92.7)	48752 (48.0)	112
Coronary artery disease	14228 (56.1)	18515 (18.2)	85
Congestive heart failure	10621 (41.8)	4062 (4.0)	101
Atrial fibrillation/flutter	5464 (21.5)	5422 (5.3)	49
Cardiovascular disease	5644 (22.2)	4,266 (4.2)	55
Myocardial infarction	3953 (15.6)	2087 (2.1)	49
Peripheral vascular disease	3311 (13.0)	870 (0.9)	49
Stroke/transient ischemic attack	3110 (12.3)	3682 (3.6)	32
Major cancers ^h	10138 (39.9)	22699 (22.4)	39
Dementia	2137 (8.4)	4257 (4.2)	17

Note. Data are presented as n (%) or median (25th, 75th percentiles).

^aStandardized differences are used as an index to measure the discrepancy between 2 groups and is independent of sample size. Bold font indicates a difference of >10%, which was considered to be a meaningful difference.

^bMissing imputed as urban for urban residence.

^cNeighborhood income and marginalization subscale indices categorized into quintiles. For the marginalization indices, there were 535 individuals in the in-center hemodialysis population with missing data and 835 individuals in the matched general population; these individuals were not included in the marginalization indices. The Ontario Community Health Profiles Partnership is the source of the marginalization indices.

^dAll baseline comorbidities were assessed 5 years prior to index date unless otherwise indicated.

^eThe Charlson comorbidity index is a method of predicting mortality and resource use based on categories of patient comorbidities identified in administrative data. This index was assessed in the 3 years prior to index date.

^fA diagnosis of diabetes could occur at any time prior to the index date and was defined as 2 Ontario Health Insurance Plan (OHIP) codes, 1 medication drug claim for diabetes, or 1 hospital admission for diabetes within 1 year.

^gA diagnosis of hypertension could occur at any time prior to the index date and was defined as 1 hospital admission with a hypertension diagnosis or an OHIP claim for a hypertension diagnosis followed by another OHIP claim or a hospital admission with evidence of a hypertension diagnosis within the 2 years of an OHIP diagnosis code for hypertension.

^hMajor cancers included: skin, mouth (lip, tonsils, etc), throat, stomach, small/large intestine, liver, gall bladder, pancreas, breast, reproductive organs, heart, lung, bone, urinary system (kidney, bladder, etc), endocrine glands, leukemias, and lymphomas.

department visits in patients receiving in-center hemodialysis stratified by incident versus prevalent status at cohort entry, incident patients had a higher rate of visits per 1000 person-years (2373; 95% CI: 2358, 2388) compared with prevalent patients (2102; 95% CI 2083, 2121) (Supplementary Table S3). When examining the proportion of individuals who had more than 5 emergency department visits per person-year, we found 17.7% (n=4483) of individuals receiving in-center hemodialysis met this criterion

compared with 1.6% (n=1648) of matched individuals from the general population.

All-Cause Hospitalizations From the Emergency Department

Sixty-two percent of individuals receiving in-center hemodialysis had at least 1 all-cause hospital admission from the emergency department compared with 25% in the matched

Table 2. Additional Baseline Characteristics for the In-Center Hemodialysis Cohort.

Characteristics	In-center hemodialysis (N = 25 379)
Incident cohort	18 719 (73.8)
Prevalent cohort	6660 (26.2)
Previous receipt of a kidney transplant	189 (0.7)
Cause of end-stage kidney disease	
Diabetes	9650 (38.0)
Glomerulonephritis/autoimmune diseases	3294 (13.0)
Nephropathy, drug-induced	405 (1.6)
Other	4960 (19.5)
Polycystic kidney disease	908 (3.6)
Renal vascular disease	4189 (16.5)
Unknown	1973 (7.8)
Number of visits to a nephrologist in the 1 year prior to cohort entry ^a	9 (3,19)

Note. Data are presented as n (%) or median (25th, 75th percentiles).

^aIncludes both inpatient and outpatient nephrology visits.

general population. The rate of hospital admissions from the emergency department in the in-center hemodialysis population was more than 7 times as high as the matched general population (786 [95% CI: 779, 793] vs 101 per 1000 person-years [95% CI: 101, 102]) (Table 3). In the in-center hemodialysis population, 36.3% of all emergency department visits ended up with a transfer to an inpatient hospital admission compared with 22.2% of visits in the matched general population. The median length of stay when including all-cause hospital admissions from the emergency department was 18 days (7, 44) in the in-center hemodialysis population versus 10 days (4, 26) in the matched general population. When restricting to the first hospitalization episode the median length of stay was similar in both groups with a median stay of 5 days (2, 12) in the in-center hemodialysis population and 5 days (2, 10) in the matched general population.

All-Cause Hospitalization (Including Admissions for Elective Procedures and Admissions That Are From the Emergency Department or Bypass the Emergency Department)

Seventy-four percent of individuals receiving in-center hemodialysis had at least 1 all-cause hospital admission compared with 32% of the matched general population with the rate of hospital admissions in the hemodialysis population more than 7 times as high as the general population. When examining the proportion of individuals who had more than 4 all-cause hospitalizations per person-year, we found 11.0% (n=2801) of individuals receiving in-center hemodialysis met this criterion compared with 0.8% (n=823)

matched individuals from the general population. The median and mean number of all-cause hospitalization days per patient year was 4.0 (0, 16.5) and 16.3 ± 33.9 in the in-center hemodialysis population, respectively, compared with 0 (0, 0.5) and 2.2 ± 11.1 in the matched general population.

All-Cause Hospitalizations That Bypass the Emergency Department

During follow-up, 39% of the in-center hemodialysis population had at least one hospitalization that bypassed the emergency department (Table 3) compared with 14% in the matched general population group with an incidence rate in the in-center hemodialysis population more than 7 times as high as the matched general population (276 vs 38 per 1000 person-years).

Method of Entry Into the Hospital

When examining method of entry (allowing for multiple visits per individual), in the in-center hemodialysis population, the greatest proportion of all-cause hospital admissions came from the emergency department (74.0%), followed by directly from the admitting department (20.1%), directly from a hemodialysis unit or medical clinic (4.5%), and day surgery (1.4%) (Figure 2A). Similarly, in the general population the greatest proportion of all-cause hospital admissions came from the emergency department (72.7%), with a smaller degree coming directly from a medical clinic (1.3%) (Figure 2B).

Other Outcomes

In the in-center hemodialysis population 22.1% had at least one elective admission compared with 11.6% in the general population. Over one quarter (27%) of the in-center hemodialysis group had at least 1 all-cause readmission (ie, readmission within 30 days of being discharged from the original hospitalization) in follow-up with an incidence rate of 225 per 1000 person-years (95% CI: 221, 229), which is roughly 12 times that observed in the matched general population (Table 3).

Costs

For all-cause hospitalization (including hospitalization for elective procedures) the total cost over follow-up was over CAN\$ 1 billion (CAN\$ 1357347438) for the in-center hemodialysis population. The cost per person-year in the dialysis population was approximately 11 times as high as the general population (CAN\$ 21151 per person-year vs CAN\$ 1873 per person-year). For emergency department visits the total cost for the in-center hemodialysis population was CAN\$ 73909686, while the cost per person-year was

Table 3. Emergency Department Visits and All-Cause Hospitalizations in the In-Center Hemodialysis population Compared With the General Population Matched on Birth Date, Sex, and Index Date.

Outcome	Population ^a	Number of unique patients with ≥ 1 event N (%)	Incidence rate per 1000 person-years (95% CI) ^b	Median (25th, 75th percentiles)
Emergency department visits	Hemodialysis	20 309 (80.0)	2274 (2263, 2286)	3 (1, 7)
	General population	56 452 (55.6)	471 (469, 473)	1 (0, 3)
All-cause hospital admissions from emergency department	Hemodialysis	15 774 (62.2)	786 (779, 793)	1 (0, 3)
	General population	25 074 (24.7)	101 (101, 102)	0 (0, 0)
All-cause hospital admissions (including admissions for elective procedures and admissions that are from the emergency department or bypass the emergency department)	Hemodialysis	18 657 (73.5)	1056 (1048, 1064)	2 (0, 4)
	General population	32 645 (32.2)	139 (138, 140)	0 (0, 1)
Total all-cause hospitalizations that bypass the emergency department	Hemodialysis	9916 (39.1)	276 (272, 280)	0 (0, 1)
	General population	14 607 (14.4)	38 (38, 39)	0 (0, 0)
All-cause hospital admission with entry through an admitting department or directly to the unit	Hemodialysis	8370 (33.0)	213 (209, 217)	0 (0, 1)
	General population	13 492 (13.3)	34 (34, 35)	0 (0, 0)
All-cause hospital admission with entry through a clinic	Hemodialysis	2277 (9.0)	47 (46, 49)	0 (0, 0)
	General population	896 (0.9)	1.9 (1.8, 2.0)	0 (0, 0)
All-cause hospital admission with entry through a day surgery department	Hemodialysis	885 (3.5)	15 (14, 16)	0 (0, 0)
	General population	1020 (1.0)	2.0 (1.9, 2.1)	0 (0, 0)
Elective hospital admission	Hemodialysis	5597 (22.1)	127 (124, 130)	0 (0, 0)
	General population	11 776 (11.6)	29 (29, 30)	0 (0, 0)
All-cause hospital readmission (ie, readmissions within 30 days of hospital discharge)	Hemodialysis	6765 (26.7)	225 (221, 229)	0 (0, 1)
	General population	6552 (6.5)	19 (19, 19)	0 (0, 0)

Note. CI = confidence interval.

^aIncluded 25 379 individuals from the in-center hemodialysis population and 101 516 individuals from the general population.

^bIncidence rates are unadjusted and allow for multiple events per person.

CAN\$ 1153 in the in-center hemodialysis population compared with CAN\$ 209 per person-year in the general population.

Discussion

In this study, we found that patients receiving in-center hemodialysis had high acute health care utilization with a substantially higher incidence and cost of emergency department visits and hospitalizations compared with a matched general population. These findings highlight the high burden of disease in the in-center hemodialysis population and the need to test and develop strategies to reduce acute health care utilization.

Our findings are consistent with previous studies.^{4,6-10} For example, a study conducted in Manitoba, Canada found patients receiving maintenance dialysis (ie, in-center hemodialysis, peritoneal, and home dialysis) visited the emergency department more than eight-times as frequently compared with the general population, a statistically significant difference after adjusting for age and sex.⁶ This was slightly higher than our Ontario patients receiving in-center hemodialysis where the rate of emergency department visits was almost 5 times as high as the general population. Unlike

previous publications, our study provided detailed information on multiple aspects of acute health care utilization (eg, categorizing hospitalizations by method of entry). We found that patients receiving in-center hemodialysis had substantially higher rates of all hospitalization types, including elective hospitalizations and hospital readmissions. This allowed for a more complete understanding of acute health care use in patients receiving in-center hemodialysis.

Our rate of all-cause hospitalization was lower than what has been found in the United States. For example, we found a rate of all-cause hospitalization in the in-center hemodialysis population of 1.06 hospitalizations per person-year while the United States found a rate of 1.6 per person-year.²⁴ It is important to note that the US rate only included acute hospitalizations, while we also included hospitalizations for elective surgeries. The US hospitalization rate also only included patients covered by Medicare, which may represent a slightly different patient population.

The large number of emergency department visits and hospitalizations in the in-center hemodialysis population are concerning. In 2014, patients receiving dialysis accounted for more than 1.1% of the total health expenditures in Canada (approximately \$2.28 billion per year [value updated to 2021 CAN\$] excluding Quebec) despite only making up 0.08% of

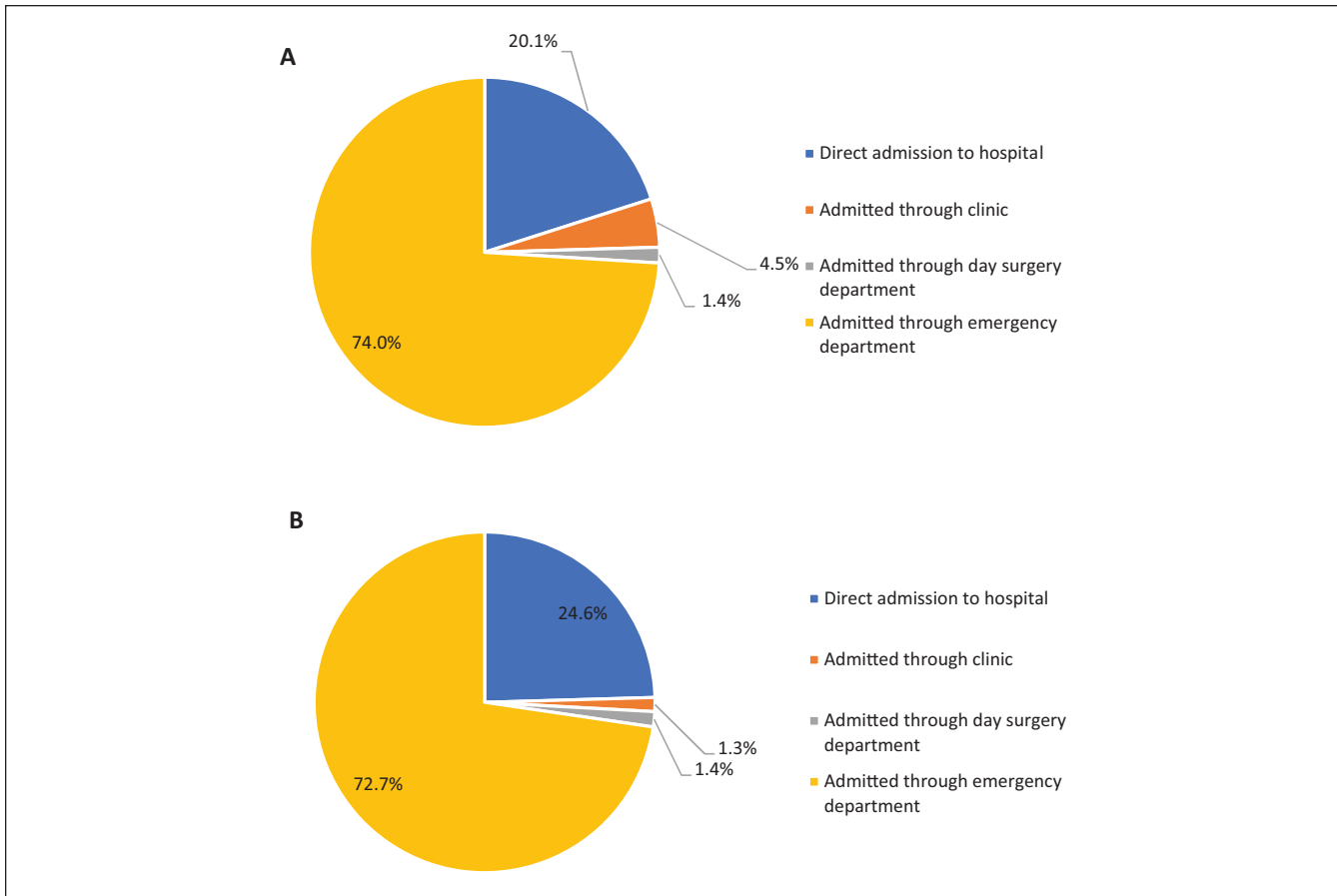


Figure 2. Method of entry into the hospital (ie, the last entry point prior to being admitted as an inpatient). Note. (A) In-center hemodialysis population and (B) matched general population.

the Canadian population; these costs have undoubtedly increased, with more Canadians requiring dialysis.⁴ Similarly, in the United States, Medicare expenditures are over \$35.9 billion per year and account for over 7% of all Medicare spending.²⁵ In our study, we found that the cost of hospitalization per person-year in the in-center hemodialysis population was approximately 11 times as high as the general population (CAN\$ 21 151 vs CAN\$ 1873). The total cost of hospitalizations in the 25 379 in-center hemodialysis patients in our study (median follow-up, 1.8 years) was over CAN\$ 1.3 billion. It is important to note that these costs do not include many of the other dialysis costs, including the cost of in-center hemodialysis itself (eg, equipment, overhead, staff) and the cost of medications and physician services. It has been estimated that dialysis costs the health care system close to \$100 000 per patient year,²⁶ with hospital admissions often the second-largest cost for these patients after the dialysis treatment itself.²⁷ In Ontario, there are approximately 12 000 individuals currently receiving maintenance dialysis²⁸ (representing one-third of patients receiving hemodialysis in Canada), resulting in over CAN\$ 1.2 billion in total

health care costs for dialysis per year in Ontario. This highlights the need for capacity planning to anticipate the increased number of hospitalizations in this growing population and the urgent need for strategies to decrease acute health care utilization.

Several strategies have been proposed to reduce acute health care utilization in the dialysis population. Of note, before many of these strategies can be implemented an understanding of the most common causes of admissions is required. First, similar to what was done in the United States, Canadian provinces and territories could form a task force responsible for monitoring, reporting and reducing hospitalizations among patients receiving maintenance dialysis with a focus on preventable visits (ie, infection, vascular access-related).²⁹ Second, in the general population numerous interventions (eg, home visits and telephone follow-up) have been found to be effective in reducing the risk of early hospital readmission³⁰; interventions applied to the general population could be adopted, and validated in the dialysis population.³¹ In the chronic obstructive pulmonary disease population, a program that provides patients and their

families with supports to improve the management of their disease at home resulted in a reduction in hospital admissions by 80%.³² Third, there needs to be a continued focus on increasing the number of patients receiving home dialysis. A previous report found that patients who received home dialysis treatments had a significantly lower risk of all-cause hospitalization compared with patients who received dialysis at a facility; however, results should be interpreted cautiously, as patients receiving home hemodialysis are often healthier, potentially resulting in fewer hospitalizations.⁴ Fourth, for patients who are transplant eligible, reducing the amount of time it takes to get a transplant may reduce dialysis-associated hospitalizations. Fifth, other components of dialysis care may need to be further examined, such as interdialytic time,^{6,8} dialysis schedule,⁸ early pre-dialysis care access,^{7,33} increased monitoring by health care professionals, infection control strategies related to dialysis access,^{34,35} remote patient monitoring,¹⁰ and multispecialty care coordination.³⁶ Sixth, predictive analytics (eg, machine learning) could be used to identify patients at high risk for hospitalization, allowing physicians to preemptively intervene to prevent these patients from being hospitalized.^{37,38} Seventh, patients receiving in-center hemodialysis commonly require urgent hemodialysis treatments due to fluid overload or high potassium levels and are subsequently sent to the emergency department if the hemodialysis clinic is not open (eg, weekend closures). The development of methods for these patients to receive care without having to go to the emergency department might reduce the number of visits. Finally, a focus on strategies to prevent or delay the progression to kidney failure is needed (eg, lifestyle modifications, medications).^{39,40}

There are several limitations that should be considered. First, we only matched the in-center hemodialysis population to the general population on age, sex and cohort entry date. There are many other factors that drive differences in emergency department visits and hospital admissions that were not measured. For example, in our study the prevalence of several comorbidities (eg, diabetes) were substantially higher in the in-center hemodialysis population compared with the general population. However, controlling for differences in comorbidities would diminish the magnitude of disparity between the 2 groups making it appear that the rate of acute health care utilization is more similar between the 2 populations, potentially leading to the incorrect conclusion that equivalent resources are needed for both populations.⁴¹ Nonetheless, future research to address the risk of hospitalization after controlling for patient comorbidities would be beneficial. Second, our results may not be generalizable outside of Ontario or to different dialysis modalities (eg, home hemodialysis or peritoneal dialysis). Finally, we could not accurately determine the reasons for emergency department visits and hospitalizations, including whether they were preventable, as detailed clinical data would be required. Future work may benefit from examining ambulatory care sensitive

conditions (ie, conditions, such as diabetes, where appropriate ambulatory care avoids or decreases hospital admission) in the dialysis population.⁴²

This population-based study highlights the high rate and cost of acute health care utilization in patients receiving in-center hemodialysis, with substantially more use compared with the general population. The results of this study are a call to develop and test interventions to reduce acute health care use in the in-center hemodialysis population. These results also highlight the need for health care capacity planning to fund this growing population.

Ethics Approval and Consent to Participate

ICES is a designated prescribed entity under Section 45 of the Personal Health Information Protection Act (PHIPA). Section 45 authorizes ICES to collect personal health information, without consent, for the purpose of analysis or compiling statistical information with respect to the management, evaluation, or monitoring of the allocation of resources to or planning for all or part of the health system. Projects conducted under section 45, by definition, do not require review by a Research Ethics Board. This project was conducted under section 45 and approved by ICES' Privacy and Compliance Office. Participant informed consent was not required for this study.

Consent for Publication

All authors consent to the publication of this study.

Availability of Data and Materials

The data set from this study is held securely in coded form at ICES. While legal data sharing agreements between ICES and data providers (eg, health care organizations and government) prohibit ICES from making the data set publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS (email: das@ices.on.ca). The full data set creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

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Author Contributions

Research idea and study design: A.X.G., P.M., and P.G.B.; data acquisition: B.L. and S.B.; data analysis/interpretation: B.L., S.B., K.L.N., P.G.B, P.M., and M.V.; statistical analysis: B.L.; drafting of initial manuscript: K.L.N and M.V. Each author contributed important intellectual content during manuscript drafting or revision, accepts personal accountability for the author's own contributions, and agrees to ensure that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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