Optimizing Ambulance Transport of Hemodialysis Patients to the Emergency Department: A Cohort Study

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Abstract
Background: Dialysis patients who require ambulance transport to the emergency department (“ambulance-ED”) may subsequently require timely dialysis in a monitored setting (“urgent dialysis”).
Objective: The purpose of this study was to develop and internally validate a risk prediction model for urgent dialysis based on patient characteristics at the time of paramedic assessment before ambulance-ED.
Design: Cohort Study
Setting: Region of Nova Scotia, Canada, covered by a single emergency medical services provider
Patients: Thrice-weekly hemodialysis patients who initiated dialysis between 2009 and 2013 (follow-up to 2015) and experienced one or more ambulance-ED events.
Measurements: The primary outcome (“urgent dialysis”) was defined as dialysis within 24 hours of an ambulance-ED in a monitored setting or dialysis within 24 hours of an ambulance-ED with an initial ED potassium of >6.5 mmol/L. Predictors of urgent dialysis based on paramedic assessment before ambulance-ED included presenting complaint, vital signs and time from last dialysis to ambulance dispatch.
Methods: Associations with urgent dialysis were analyzed using logistic regression from which a risk prediction model was created. The model was internally validated using bootstrapping and model performance was assessed by discrimination and calibration.
Results: Among 197 patients, there were 624 ambulance-ED events and 87 episodes of urgent dialysis. Weakness as a presenting complaint (odds ratio [OR]: 4.62, 95% confidence interval [CI]: 1.23-17.29), >24 hours since last dialysis (OR: 2.09, 95% CI: 1.15-3.81), and vital signs, including heart rate <60 beats/minute (OR: 3.06, 95% CI: 1.09-8.61), oxygen saturation <90% (OR: 3.04, 95% CI: 1.55-5.94), elevated respiratory rate (≥20 breaths/min), and systolic blood pressure >160 mmHg, were associated with urgent dialysis after ambulance-ED. A risk prediction model incorporating these variables had very good discrimination (C-statistic: 0.81, 95% CI: 0.76-0.86). The negative predictive value was 93.6% using the optimal cut point. Of patients who were predicted to need urgent dialysis but were transported to a facility incapable of providing it, 31% were re-transported for urgent dialysis.
Limitations: Findings of our study may not be generalizable to other centers where the practice of ambulance transfer and availability of monitored dialysis may differ, and data were lacking for potential missed dialysis sessions or changes in routine dialysis scheduling.
Conclusions: Patient characteristics at the time of paramedic assessment are associated with urgent dialysis after ambulance-ED. This risk prediction model has the potential to guide dialysis patient transport to dialysis-capable facilities when needed.

Abrégé
Contexte: Les patients dialysés transportés à l’urgence en ambulance (« transports en ambulance ») pourraient par la suite nécessiter une dialyse urgente dans un environnement monitoré (« dialyse d’urgence »).
Objectifs: On visait à élaborer et à valider à l’interne un modèle de prédiction du risque pour une dialyse d’urgence basé sur les caractéristiques des patients recueillies par les ambulanciers pendant le transport.
Type d’étude: Étude de cohorte
Cadre: Une région de la Nouvelle-Écosse (Canada) desservie par un seul établissement fournissant des soins médicaux d’urgence.
Sujets: Des patients hémodialysés trois fois par semaine ayant amorcé leur traitement entre 2009 et 2013 (suivi jusqu’en 2015) et ayant été transportés au moins une fois à l’urgence en ambulance.
Mesures: Le critère de jugement principal (« dialyse d’urgence ») a été défini par une dialyse amorcée dans un environnement monitré dans les 24 heures suivant l’arrivée en ambulance, ou par une dialyse amorcée dans les 24 heures suivant l’arrivée en ambulance et en présence d’un taux de potassium supérieur à 6,5 mmol/L. Les plaintes formulées par le patient, les signes vitaux et le temps entre la dernière dialyse et l’envoi de l’ambulance ont constitué les facteurs prédictifs d’une dialyse d’urgence s’appuyant sur l’évaluation des ambulanciers.
Méthodologie: La régression logistique a été utilisée pour analyser les associations avec une dialyse urgente et cette analyse a servi à la création d’un modèle de prédiction du risque. Ce dernier a été validé à l’interne par la méthode du bootstrapping, et sa performance a été confirmée par discrimination et calibration.
Résultats: Parmi les 197 patients recrutés, 624 transports en ambulance et 87 épisodes de dialyse urgente ont été répertoriés. Une dialyse urgente après un transport en ambulance a été justifiée par les facteurs suivants: des plaintes de faiblesse générale (RC: 4,62; IC 95 %: 1,23-17,29), une période de plus de 24 heures depuis la dernière dialyse (RC: 2,09; IC 95 %: 1,15-3,81) et les signes vitaux (notamment une fréquence cardiaque <60 battements/minute [RC: 3,06; IC 95 %: 1,09-8,61], une saturation en oxygène <90 % [RC: 3,04; IC 95 %: 1,55-5,94], une fréquence respiratoire élevée [≥20 respirations/min] et une pression artérielle systolique >160 mmHg). Un modèle de prédiction du risque incorporant ces variables a montré une bonne discrimination (statistique c: 0,81; IC 95 %: 0,76-0,86). Le coefficient de prévision d’un test négatif s’est établi à 93,6 % en utilisant un seuil optimal. Parmi les patients pour qui on avait prévu qu’ils nécessiteraient une dialyse urgente, mais qui avaient été transportés dans un établissement n’étant pas en mesure de la fournir, 31 % ont dû être transportés à nouveau pour une dialyse urgente.
Limites: Ces résultats pourraient ne pas être généralisables aux établissements où diffèrent les pratiques de transfert par ambulance et la disponibilité de la dialyse urgente en environnement monitré. De plus, des données quant aux séances de dialyse manquées ou aux changements apportés dans la routine de la dialyse étaient non disponibles.
Conclusion: Certaines caractéristiques des patients, recueillies par les ambulanciers pendant le transport à l’hôpital, ont été associées au besoin de procéder à une dialyse urgente après un transport en ambulance. Ce modèle de prédiction du risque pourrait, lorsque nécessaire, guider le transport en ambulance des patients dialysés vers des établissements en mesure de les prendre en charge.

Keywords
ambulance, transport, hemodialysis, acute dialysis, emergency medical services

What was known before
Dialysis patients frequently utilize emergency medical services and often require transport to the emergency department for medical care. Many of these patients may require timely dialysis in a closely monitored setting (urgent dialysis), but it is unknown how their characteristics at the time of transport by paramedics associate with the need for subsequent urgent dialysis.
What this adds

In this study, we identified patient characteristics at the time of paramedic assessment prior to transport to the emergency department that were associated with a subsequent need for urgent dialysis. Using these characteristics, we were able to develop a risk prediction model for urgent dialysis that may help to better direct ambulance services to transport dialysis patients to the appropriate hospital location when needed.

Introduction

Dialysis patients commonly utilize emergency medical services and have frequent emergency department (ED) presentations due to multiple factors. In more urgent or medically serious situations, dialysis patients require ambulance transport to the ED (ambulance-ED) after a 911 call prompting emergency dispatch and assessment by paramedics. The need for ambulance-ED is not a rare occurrence; we recently identified that >50% of incident dialysis patients in a large cohort from a quaternary care facility experienced one or more ambulance-ED events despite a relatively short period of follow-up (median follow-up time of 2.5 years).

Despite the fact that ambulance-ED is common, little is known about predictors of outcomes subsequent to ambulance-ED based on patient characteristics at the time of assessment by paramedics. One of the most important outcomes is the need for urgent dialysis (timely dialysis with the need for monitoring). Being aware of who needs urgent dialysis based on their characteristics prior to ED transport has implications for ambulance destination planning to optimize patient outcomes after transfer to the ED. One study suggested that the most common ED presentations for hemodialysis patients were shortness of breath (69%) and weakness (15%), with 32% requiring hospital admission following ED hemodialysis. After presentation to an ED, a prior study suggested the most common indications for “interventional dialysis” (defined as urgent dialysis required to treat a patient’s presenting complaint) were shortness of breath, weakness, and chest pain, with only shortness of breath predominating in need for dialysis (positive predictive value 0.63).

While valuable, this study did not define urgent dialysis on the basis of patient clinical stability (ie, requirement for dialysis in a monitored setting). Irrespective of the indication for dialysis, this is a more practical consideration when determining where a patient should be transported to be supported with dialysis in a timely fashion (ie, not all facilities have dialysis facilities and even those that do may not be capable of providing monitored dialysis). Finally, to our knowledge, it is not known if vital sign parameters or patient chief complaint at the time of assessment by paramedics or the time from a patient’s last dialysis session relative to contact with paramedics (acknowledging the well-established increased mortality rate after the long-dialysis break) is associated with a need for urgent dialysis after ED transport.

Therefore, in a cohort of chronic dialysis patients who subsequently required ambulance-ED, the primary objective of this study was to identify factors associated with urgent dialysis based on patient characteristics at the time of paramedic assessment and to create a risk prediction model for urgent dialysis based on these factors. A secondary objective was to assess the actual disposition of patients, including whether they were transported to a dialysis capable versus incapable ED and whether they subsequently required urgent dialysis.

Methods

Study Population

We conducted a cohort study of all incident, adult (≥18 years old) chronic dialysis patients (from January 1, 2009 to June 30, 2013) who were receiving three times/week in-center hemodialysis. All patients in the cohort experienced one or more ambulance-ED events, with a last follow-up date of June 30, 2015. We chose this follow-up to ensure there was enough time to capture ambulance-ED events for those entering the cohort in 2013 (minimum of 2 years from the last possible date of cohort entry). Patients <18 years of age and those with acute kidney injury requiring dialysis were excluded.

Data Sources and Linkage

Data pertaining to ambulance dispatch and patient characteristics at the time of paramedic assessment were collected from Emergency Health Services (EHS), Nova Scotia. EHS is the sole provincial provider of emergency and transfer services in the province of Nova Scotia, Canada, responding to over 155,000 annual calls. EHS serves a provincial population of >900,000 individuals and an area of 55,000 square kilometers. All responses that lead to a patient encounter generate an electronic patient care record. For the purposes of this study, information collected from this record included paramedic contact date and time, urgency of care presentation (based on the Canadian Triage and Acuity Scale, CTAS), primary patient complaint, vital signs at the time of transport (including blood pressure, heart rate [HR], temperature, respiratory rate, and oxygen saturation) and the destination ED location. Vital sign parameters were categorized a priori using thresholds to define marked systolic hypertension or hypotension (>160 or <100 mmHg, respectively) tachycardia or bradycardia (>100 beats/min or <60 beats/min, respectively), elevated respiratory rate (≥20 breaths/min) and hypoxemia (oxygen saturation <90%). In a sensitivity analysis, we used restricted cubic splines to define cutpoints for these vital sign parameters. Dialysis cohort data were collected using an electronic database at the Nova Scotia Health Authority (NSHA) Central Zone. The renal program at the NSHA Central Zone cares for 70% (N=500

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individuals) of the chronic dialysis population in the province. Use of this database for data collection has been previously described\(^{10,11}\) and the database includes information on all chronic dialysis patients (defined as those who start dialysis without anticipated recovery of kidney function) at the time of dialysis initiation including demographic variables (age, sex, race), comorbidities (diabetes, coronary artery disease, peripheral vascular disease, congestive heart failure, chronic liver disease, failed prior transplant, clinical frailty scale score [CFS]),\(^{10,12}\) cause of end-stage renal disease (ESRD), and dialysis access (defined as arteriovenous fistula or central venous catheter). In addition, we captured information on the timing of a patients’ dialysis shift (morning, afternoon, evening) from which we were able to identify a time from last dialysis as \(\leq 24\) or \(>24\) hours. Time from last dialysis was defined based on the start of the patient’s last dialysis shift (morning: 8 am; afternoon: 1 pm; evening: 6 pm) to ambulance dispatch. We subsequently determined the proportion of patients with time from last dialysis \(\leq 24\), 24 to 48, and \(>48\) hours.

**Outcome**

The primary outcome was receipt of urgent dialysis which was defined as (1) dialysis within 24 hours of presentation to the ED in a monitored setting (intensive care unit [ICU], intermediate care unit or ED itself) or (2) dialysis within 24 hours of presentation with an ED potassium \(>6.5\) mmol/L irrespective of whether or not a patient was monitored. Acknowledging that only one dialysis center is capable of supporting monitored dialysis among all facilities in the NSHA Central Zone, we felt that this definition would be the most pragmatic and would help to identify those patients that would benefit from direct transfer to this center on the basis of requiring urgent dialysis. We included a criterion based on serum potassium to identify those patients at high risk of an arrhythmia without urgent dialysis. Secondary outcomes included the actual destination ED where a patient was transported, and the need for admission after ambulance-ED (vs same-day discharge).

**Analysis**

Descriptive statistics were used to report baseline patient characteristics for all patients with an ambulance-ED and outcomes after ED transport. We also described characteristics of patients at the time of assessment by paramedics and ambulance transport characteristics for each ambulance-ED episode. Multivariable logistic regression was used to determine if patient characteristics at paramedic assessment were associated with an increased risk for urgent dialysis. Analyses were clustered on the individual, using standard errors allowing for intragroup, but not between group, correlation. These characteristics included categorized respiratory rate, oxygen saturation, HR, systolic blood pressure, time from last dialysis (\(\leq 24\) or \(>24\) hours) and patient primary complaint.

We built a parsimonious predictive model using logistic regression for the outcome of need for urgent dialysis after ambulance-ED, incorporating each variable noted above. This model was internally validated using bootstrapping with replacement, 1000 iterations. Model calibration was determined using the Hosmer-Lemeshow goodness of fit test and observed versus predicted risk was plotted. The C-statistic was used to assess model discrimination in the original and bootstrapped cohort. Positive and negative predictive values, sensitivity, specificity and overall correct predictions for the optimal prediction cut point were calculated using a classification matrix. This was repeated using pre-specified thresholds of 5% to 25% predicted probability.

The proportion of patients predicted to need urgent dialysis who were transferred to a dialysis versus non-dialysis capable facility and whether or not they subsequently required urgent dialysis after ambulance-ED was displayed in a flowchart stratified by the optimal predicted cut point.

**Sensitivity Analyses**

In pre-specified sensitivity analyses, we varied the included population, model variables and outcome of interest to test the robustness of our risk prediction model for the outcome of urgent dialysis in the following fashion:

A. We recreated the risk prediction model to include both paramedic assessment variables and baseline patient characteristics at the time of dialysis initiation (as summarized in Dialysis cohort data)

B. We excluded non-monitored patients with hyperkalemia from our definition of urgent dialysis.

C. We recreated the risk prediction model to include only first EMS events.

D. We included age in the risk prediction model given that age is a patient variable that is readily available at each EMS encounter.

E. We repeated the primary analysis using cut-points identified using restricted cubic splines for vital sign parameters.

F. We determined the proportion of patients with more granular time from last dialysis (\(\leq 24\), 24-48, and \(>48\) hours) and how this associated with EMS events and need for urgent dialysis. We repeated our primary analysis using these intervals for time from last dialysis.

**Missing data.** Data were assumed to be missing at random and missing predictors were treated with case wise deletion.

All statistical analyses were performed using Stata version 13.1 (Stata Corp., College Station, TX). Institutional ethics approval for this study was provided by the NSHA research ethics board. The manuscript follows reporting standards outlined within the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) statement.\(^{13}\)
Results

There were 674 ambulance-ED events among 207 in-center hemodialysis patients (1-38 ambulance-ED events per person) and 624 ambulance-ED events among 197 patients on a thrice weekly hemodialysis schedule. Of the 624 ambulance-ED events, 269 (43.1%) resulted in hospital admission and 50 individuals (8.0%) were admitted to an ICU. A total of 91 and 87 ambulance-ED events resulted in urgent dialysis for the overall cohort and those on thrice weekly dialysis, respectively. Five ambulance-ED events had data missing regarding need for urgent dialysis. Of those 87 ambulance-ED events requiring urgent dialysis, 68 (78.2%) resulted in hospital admission and 22 (25.3%) were admitted to an ICU. Of those with data on presenting ED potassium, 18 out of 85 ambulance-ED events (21.2%) requiring subsequent urgent dialysis had a potassium > 6.5; 14/18 also received monitored dialysis. Of the 532 ambulance-ED events not requiring urgent dialysis, 201 (37.8%) were admitted and 28 (5.3%) required an ICU admission. Baseline patient characteristics at the time of dialysis initiation for those on thrice weekly hemodialysis are noted in Table 1. The mean age of patients starting dialysis was 67.2 ± 14.9 years, the majority of whom were Caucasian (88.4%) and male (66.2%). Characteristics of patients at the time of assessment by paramedics for each ambulance-ED episode are noted in Table 2. Overall, 50.6% of patients were transported to a dialysis capable facility at the time of their EMS event and 54.7% had dialysis >24
hours earlier. Abnormal vital signs were common; 15.5% of patients were hypoxemic at the time of paramedic assessment and approximately 5 and 22% of patients were bradycardic (HR < 60) and had a blood pressure of > 160, respectively.

Weakness as a presenting complaint (odds ratio [OR]: 4.62, 95% confidence interval [CI]: 1.23-17.29), > 24 hours since last dialysis (OR: 2.09, 95% CI: 1.15-3.81), and triage vitals (HR < 60 beats/minute [OR: 3.06, 95% CI: 1.09-8.61], systolic blood pressure > 160 mmHg [OR: 2.76, 95% CI: 1.32-4.25], respiratory rate ≥ 20 breaths/minute [OR: 2.00, 95% CI: 1.06-3.75] and oxygen saturation < 90% [OR: 3.04, 95% CI: 1.55-5.94]) were associated with urgent dialysis (Table 3). Weakness was significantly associated with hyperkalemia (serum potassium > 6.5 mmol/L) at ED presentation (P < 0.001 by chi-square testing).

The C-statistic for the risk prediction model including those factors noted in Table 3 was 0.81 (95% CI: 0.76-0.86), corresponding to very good discrimination (Figure 1a). The model was well calibrated (Hosmer-Lemeshow goodness-of-fit P = 0.71). A plot of observed versus expected probability of needing dialysis is noted in Supplemental Figure 1. Discrimination remained very good in the bootstrapped model (C-statistic 0.79, 95% CI: 0.72-0.88). Sensitivity and specificity versus the model predictive probability is shown in Figure 1b. The optimal cutoff predictive probability was ≥ 14.8% from Figure 1b. Using an optimal cutoff of ≥ 15%, patients were correctly classified 74.0% of the time, with a positive predictive value of 33.3%, negative predictive value of 93.6%, sensitivity of 71.6%, and specificity of 74.4%.

Sensitivities, specificities, negative and positive predictive values using different thresholds are noted in Table 4. A total of 175 patients (32.6%) had a predicted probability of needing urgent dialysis of ≥ 15%; 58 (33.1%) actually received it. Of those predicted to need urgent dialysis, 90 (51.4%) were transported to a site that did not have dialysis capabilities and 28 (31.1%) subsequently needed urgent dialysis, requiring a second transport (Figure 2).

**Sensitivity Analyses**

The risk prediction model was performed in a similar fashion when using the restricted definition of urgent dialysis (Supplemental Table 1), after inclusion of baseline characteristics at
the time of dialysis initiation (Supplemental Table 2). For first EMS-ED event only (Supplemental Table 3) point estimates were comparable (unadjusted and adjusted) but no longer statistically significant in the multivariable model. Of note, only 93 ambulance-ED events and 19 urgent dialysis outcomes were included in the multivariable analysis as some factors perfectly predicted urgent dialysis leading to the exclusion of these ambulance-ED events from the adjusted model. When age at EMS event was included in the model (Supplemental Table 4) and finally after using restricted cubic splines to define cut-points for continuous variables at the time of EMS encounter (Supplemental Table 5), the model performed similar to the primary analysis. Discrimination and calibration results for all risk prediction models are shown in Supplemental Table 6. The discrimination and calibration did not significantly change with this new model (C-statistic 0.81, 95% CI: 0.76-0.86, and Hosmer-Lemeshow goodness-of-fit \( P = 0.77 \)).

**Discussion**

In this study, we identified predictors of urgent dialysis for those patients who required ambulance transport to the ED, based on patient characteristics at the time of assessment by paramedics. We used this information to develop a risk prediction model for urgent dialysis and identified that a sizeable proportion of patients predicted to require urgent dialysis are transported to a facility that is incapable of providing it.

Importantly, this study identified patient vital sign parameters at paramedic assessment associated with an increased risk for needing urgent dialysis at the time of ambulance-ED. We hypothesize that many of these vital signs (including elevated blood pressure, respiratory rate and hypoxemia) were a reflection of extracellular fluid overload; a situation in which urgent dialysis is required for fluid removal. In contrast, bradycardia and weakness are commonly observed manifestations of hyperkalemia, and weakness appeared to be a surrogate marker for a critically elevated potassium necessitating urgent dialysis. It is likely that the associations we observed were underestimates because of our a priori decision to exclude the indication for dialysis from our definition of urgent dialysis. Many of the situations in which dialysis was undertaken in a monitored setting may not have been due to an urgent indication but rather, supportive dialysis for a patient requiring monitoring for another reason. Therefore, the association between abnormal vital signs and need for urgent dialysis would have been stronger if we excluded those events. However, our choice of definition is more pragmatic for paramedics deciding on where to transport a patient; a decision that should be guided by the need for monitored dialysis irrespective of the underlying reasons.

Overall, our risk prediction model had very good discrimination and calibration and a high negative predictive value using the optimal cut-off of \( \geq 15\% \). Similar to most clinical prediction rules, where a better negative predictive value is of higher utility than the positive predictive value, the risk to a patient from incorrectly classifying them as not needing urgent dialysis when they do (false negative) is far greater than the risk to them if they are incorrectly classified as needing urgent dialysis when they do not (false positive). With our model, a predicted probability of \(< 15\% \) means there is only a 7% chance the patient will require urgent dialysis. While our primary risk prediction model was strong (suggested by a C-statistic of \( > 0.8 \)), the model incorporating baseline patient characteristics performed even better than this parsimonious model. However, many of these characteristics were collected using detailed electronic records; information that would not be available to paramedics in a rapid fashion at the time of patient assessment.
The value of our clinical prediction model is evident. Not all facilities are capable of providing monitored dialysis and many peripheral hospitals do not have dialysis capabilities at all. Accurately identifying patients who are likely to require urgent dialysis could have implications for ambulance trip destination policies. If a patient who requires urgent dialysis is transferred to a center without dialysis capabilities, the time until that patient can receive potentially life-saving therapy is prolonged and the patient would likely require a second transport to a dialysis-capable facility. In Nova Scotia, the patient cost of an ambulance varies from 146.55-1099.35 CAD and intuitively, the overall health care system costs would increase further if a patient becomes hemodynamically unstable due to long waits for dialysis requiring higher level care. Importantly, this model also has the potential to reduce ED crowding by ensuring patients not likely to require urgent dialysis are assessed first in their local hospital instead of being unnecessarily transferred to a dialysis-capable tertiary center, based on their presentation characteristics.

The utility of our model is supported by the comparison of our predicted result to what actually occurred for patients in the emergency medical services region of interest. Using a conservative predictive probability of ≥15%, 51.4% of patients predicted to require urgent dialysis were transported to a facility without dialysis capabilities and of these, 31.1% needed subsequent transfer for urgent dialysis. We speculate that dialysis patients were transported on the basis of proximity (ie, closest ED in many circumstances) or potentially under the impression that they could still receive outpatient dialysis at the facility to which they were transported (as many Nova Scotia facilities support outpatient but not monitored dialysis). Using this prediction model to better stratify patients based on projected risk of requiring dialysis would have reduced cost, alleviated strain on ambulance utilization, and most importantly, expedited time to definitive, life-sustaining therapy for these patients.

This study has a number of strengths, most importantly the investigation of a novel question (predictors of urgent dialysis subsequent to ambulance-ED, based on assessment

| Probability cut-off, % | Correctly classified, % | Sensitivity, % | Specificity, % | PPV, % | NPV, % |
|-----------------------|-------------------------|---------------|---------------|--------|--------|
| 5                     | 43.82                   | 97.53         | 34.22         | 20.95  | 98.73  |
| 10                    | 61.42                   | 85.19         | 57.17         | 26.24  | 95.57  |
| 15                    | 73.97                   | 71.60         | 74.39         | 33.33  | 93.61  |
| 20                    | 77.72                   | 61.73         | 80.57         | 36.23  | 92.17  |
| 25                    | 81.27                   | 50.62         | 86.75         | 40.59  | 90.76  |

Note. PPV = positive predictive value; NPV = negative predictive value.
at initial contact by paramedics) that to our knowledge has not been rigorously evaluated in prior study. Furthermore, the linkage of EMS ambulance transport with a cohort of chronic dialysis patients including outcomes after ED presentation (eg, need for urgent dialysis) is also novel. Finally, we were able to develop and internally validate a prediction model that has the potential to change current practice in terms of guiding ambulance destination transport decisions. A future study that will aim to validate the model in a more contemporary cohort of incident and prevalent dialysis patients from Nova Scotia is planned. This study will also address ways to translate the findings into practical change including incorporation of point of care tool or systematic algorithms to help guide destination planning for dialysis patients.

There are limitations to our study, however. There is the potential for misclassification, but any coding error would be expected to be distributed evenly among individuals and would be unlikely to significantly bias results. Although our model would not apply to those who were not receiving thrice weekly in-center hemodialysis, this represented only a small minority of patients receiving in-center hemodialysis in our cohort (N = 10), and we felt that the time from last dialysis to ambulance dispatch (which was difficult to ascertain for those receiving inconsistent dialysis schedules) was a clinically relevant predictor. We did not have data regarding potential missed dialysis sessions which could certainly lead to an increased need for ambulance-ED. Finally, we acknowledge that the study findings pertaining to need for urgent dialysis are not generalizable to other centers where the availability of dialysis or practice of ambulance transport may differ and that our model requires external validation. Many non-tertiary care centers may be able to support urgent dialysis (as we defined it). Nonetheless, our study demonstrates that in systems where there are one or few EMS providers (similar to Nova Scotia), the linkage of EMS data with dialysis cohorts to best predict the need for urgent dialysis is feasible. External validation in regions or provinces that have a similar model or the ability to collate provincial EMS data would be an important future initiative. However, identifying clinical factors that would predict urgent dialysis is potentially valuable for resource planning irrespective of whether or not it would alter regional ambulance transport practice.

The burden of ambulance-ED is high among dialysis patients. Predicting the need for urgent dialysis after ambulance-ED based on patient characteristics at the time of paramedic assessment has the potential to improve the outcomes for dialysis patients and optimize the use of ambulance resources.

**Ethics Approval and Consent to Participate**

Ethics approval to conduct this research was provided by the Nova Scotia Health Authority Research Ethics Board (#1020092). Consent for access to clinical records for data collection is provided by dialysis patients at the time of dialysis initiation. In those for whom it was not possible, a waiver of consent was authorized.

**Consent for Publication**

Consent for publication was obtained from all authors.

**Availability of Data and Materials**

Data is available from the authors on request provided it is approved by the REB with appropriate data agreements in place.

**Declaration of Conflicting Interests**

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: KT has no direct conflicts of interest relevant to the current area of research. KT has done advisory work for AstraZeneca and Otsuka, Canada. All other authors have no conflicts of interest to declare.

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**Supplemental Material**

Supplemental material for this article is available online.

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