Emergency Department Utilization Among Maintenance Hemodialysis Patients: A Systematic Review

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Complete author and article information provided before references.
Abstract

**Rational and Objective:** Evaluate predictors of Emergency Department (ED) utilization by adult patients receiving hemodialysis (HD) and interventions to reduce ED utilization by HD patients.

**Study Design:** We searched Ovid MEDLINE, Ovid EMBASE, and The Cochrane Library for randomized controlled trials and observational studies up until April 2020.

**Selection Criteria for Studies:** We included studies that investigated predictors of ED utilization and/or interventions to reduce ED utilization in HD patients.

**Data Extraction:** We extracted data regarding study design, study population, and results regarding ED utilization from 38 studies using Excel software.

**Analytical Approach:** We performed narrative synthesis to group articles that investigated similar themes.

**Results:** 1060 titles and abstracts were screened, of which 98 were selected for full-text review. 38 studies met inclusion criteria and underwent data extraction. Quality was high according to the Downs and Black tool, with 11 rated as good, 22 as fair, and 5 as poor. 34 studies described predictors of ED utilization, while 4 studies investigated interventions where ED utilization was studied. Our narrative synthesis produced 8 concept subgroups in the core concepts of access to care, comorbidity burden, and new healthcare models. Poor access to care and high comorbidity burden are associated with increased ED use. No ED-based interventions designed to reduce ED utilization were identified, but recent changes in healthcare systems like the formation of ESRD Seamless Care Organizations (ESCOs) and greater involvement of palliative care services are associated with improved outcomes.
**Limitations:** Clinical heterogeneity and variability in the included studies precluded a meta-analysis.

**Conclusions:** HD patients’ high ED use is multifactorial. Further research is required to understand and predict ED utilization in this vulnerable population, which will facilitate the development of interventions to reduce avoidable ED use.

**Keywords:** Emergency Department, End-Stage Renal Disease, end-stage kidney disease, kidney failure, Hemodialysis, Care Transitions, Healthcare Utilization

**PROSPERO registration #:** CRD42020196569

**Plain Language Summary:**

Patients with kidney failure, especially those on hemodialysis, visit the emergency department much more frequently than the general population. This contributes to hemodialysis patients’ increasingly high healthcare utilization over the last twenty years. In this article, we propose a conceptual framework that summarizes the existing literature on emergency department use in the hemodialysis patient population and associated interventions. Many variables have been shown to predict emergency department use by hemodialysis patients, including access to care, comorbidity burden, and evolving healthcare models. However, few interventions demonstrated an impact on emergency department use by this vulnerable population.
Introduction

The United States end-stage kidney disease (ESKD) population has increased 91% since 2000, totaling 746,557 in 2017.\textsuperscript{1} Current Medicare expenditures for these patients reaches $35.9 billion a year, accounting for 7.2% of all Medicare spending.\textsuperscript{1} This evolving burden of kidney failure is largely due to the combination of an aging population, the increasing prevalence of obesity and diabetes mellitus, and the improving survival of ESKD patients.\textsuperscript{1} Increased survival likely reflects improvements in ESKD care during the past 20 years, which are associated with a concomitant decline in hospitalization rates.\textsuperscript{1-3} Despite this, ESKD patients continue to have the highest risk for hospitalization amongst other chronic medical conditions like heart failure, pulmonary disease, and cancer, and are at higher risk of adverse safety events.\textsuperscript{4,5}

While hospitalization rates for ESKD patients are declining, ED visits are increasing.\textsuperscript{1-3} This reduction in admissions may be in part due to the rise of observational stays in lieu of admission,\textsuperscript{6} but hemodialysis (HD) patients are still presenting to the ED 8.5 times more frequently than the general population.\textsuperscript{2,7} In-center HD patients use the ED more than those on home HD or peritoneal dialysis, emphasizing the particular challenges that in-center HD patients face as compared to the overall ESKD population.\textsuperscript{8} However, many ED visits by patients with ESKD are for complaints seemingly unrelated to kidney disease, suggesting that comorbidities and other healthcare needs contribute to their high ED utilization.\textsuperscript{3,9,10}

To reduce ESKD patients’ healthcare utilization, the Centers for Medicare and Medicaid Services (CMS) launched the Comprehensive ESRD Care Model in 2015, under which nephrologists, dialysis facilities, and other providers formed ESRD
Seamless Care Organizations (ESCOs). Similarly, the CMS-supported ESRD Network programs have recently designated the reduction of ED utilization as a priority for quality improvement. Since HD patients appear to be the greatest ED utilizers amongst ESKD patients, and are the largest subset of the ESKD patient population, understanding ED utilization by HD patients is a critical step towards these initiatives’ goals.

This study is a systematic review designed to identify predictors and interventions for ED utilization in HD patients. While a narrative review was performed in the early 2000s, our systematic review is of much greater scope and includes many papers from the past 15 years. We also produced a conceptual framework through narrative synthesis to codify how these predictors and interventions impact ED use.

Methods

This systematic review was constructed using Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. A protocol titled “The Need for Accessible Emergency Care for Patients with End-Stage Renal Disease” was registered in PROSPERO, an international prospective register of systematic reviews (URL: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=196569). The PRISMA checklist can also be found in Items S1-2.

Search Strategy

Comprehensive literature searches were performed to identify predictors of ED utilization and interventions with ED utilization as a measured outcome among adult HD patients. All searches were developed and performed by experienced medical librarians [KM, CJ], upon consultation with the lead investigators [GH, PS].
The search was run on April 15, 2020 using OVID MEDLINE® ALL (1946 – April 14, 2020), OVID EMBASE (1974 – April 14, 2020), and The Cochrane Library (Cochrane Reviews, Cochrane Protocols, Cochrane Trials, Cochrane Editorials). Search terms in each database included all appropriate subject headings and/or keywords associated with our research question, including the following: Renal Dialysis; Renal Insufficiency/therapy; Chronic Kidney Failure/therapy; Hospital Emergency Service; Emergency Medical Services; Emergency Medicine; Utilization Review; Facilities and Services Utilization; Patient Acceptance of Health Care.

Search terms were joined using Boolean operators ‘OR’ and ‘AND’, as appropriate. There were no language, publication date, or article-type restrictions implemented. Our search strategies can be found in Items S3-5.

**Study Selection**

After excluding duplicates, GH and HS independently screened the titles and abstracts using Covidence, a systematic review screening tool. Discrepancies were resolved via consensus, with PS serving as tiebreaker. All citations were reviewed against pre-defined inclusion/exclusion criteria:

- **Inclusion criteria** were: described ED utilization by HD patients; patient age >18 years; identification of ED utilization predictors or testing of interventions with ED utilization as an outcome measure.

- **Exclusion criteria** were: HD patients not stratified from other dialysis modalities; ED utilization not reported; no quantitative data for analysis; systematic reviews; scoping reviews; meta-analyses; duplicate publications.
Full-text review followed the initial title and abstract screening phase. Studies were selected for inclusion using the criteria outlined above. GH, HS, and PS extracted data using a pre-determined extraction tool. (Table S1) A meta-analysis was precluded by heterogeneity in the reporting of outcomes. A narrative synthesis approach, as described by Snilstveit et al. was utilized to group articles with similar ED utilization-associated factors thematically.\textsuperscript{14}

\textit{Quality Assessment}

Included studies were assessed for quality using the Downs and Black checklist.\textsuperscript{16} This checklist consists of 27 questions designed to evaluate both randomized and non-randomized studies for overall quality of reporting, and for internal and external validity. Quality levels were assigned to each included study, using the categories proposed by Hooper et al. (2008): \textit{excellent} (Downs and Black score $\geq 26$), \textit{good} (20-25), \textit{fair} (15-19), and \textit{poor} ($\leq 14$).\textsuperscript{17} GH, HS, KM, and PS scored each included study individually, with quality levels assigned after consensus was reached (Table S2).

\textbf{Results}

The initial electronic database search yielded 1060 unique titles and abstracts. 98 appeared to meet inclusion criteria and were imported for full text review. 21 of the excluded texts were potentially relevant abstracts without an associated manuscript (Figure 1). 38 articles were included. They were published between 2007-2020, 74\% were published in US cohorts, and the majority were retrospective cohort studies (71\%). 34 papers investigated predictors of ED utilization, while 4 evaluated an intervention’s effect on ED utilization. The study populations ranged from 12 to 9,672,413. (Table S1)
With respect to quality assessment, 10 were rated as good, 22 as fair, and 5 as poor using the Downs and Black tool. While none achieved an excellent score, the Downs and Black tool is designed to only award RCTs such a score. Only one RCT met inclusion criteria, so our included studies achieved a high level of quality for our chosen quality assessment tool.

Using narrative synthesis as described by Snilstveit et al. (2012), we summarized ED utilization themes amongst the included papers to form eight concept subgroups by consensus [GH, AB, HS, PS]. The subgroups are as follows: dialysis, social determinants of health, undocumented immigrant populations, medications and adverse drug events, lab values and scoring forms, psychiatric illness, palliative care, and new financial models (Table 1). The main characteristics of these studies are provided in separate tables for each concept subgroup (Tables 2-9). These concept subgroups were subsequently organized into three core concepts by consensus [GH, PS]: access to care, comorbidity burden, and new healthcare models (Figure 2). The number of studies in each concept subgroup is shown in Figure 3.

The Access to Care core concept included 20 papers. Higher ED utilization was predicted by missed dialysis, longer interdialytic intervals, dialysis through catheters instead of arteriovenous fistulas, dialysis initiation, frequent postdialysis weights above target, prior hospitalization for dialysis, and infrequent pre-dialysis care. Higher ED utilization was also predicted by the following social determinants of health: racial segregation, lower community income, female sex, black race, reliance on public transport, and lower health literacy. The undocumented and social determinants of health concept subgroups were treated separately to reflect the unique
barriers to care undocumented persons face in the United States, such as their ineligibility for Medicare. Several studies demonstrated an association between undocumented status and higher rates of ED visits. The use of loop diuretics in appropriate undocumented patients has been associated with reduced ED visits while another study demonstrated that implementing strict laboratory cutoffs to determine the need for emergency HD reduced subsequent ED utilization.

The Comorbidity Burden core concept included 15 studies. Depression and pain predicted increased ED utilization but no association was found with antidepressant use or measured psychosocial distress. Medications whose use predicts ED utilization include psychoactive anticholinergics, gabapentin and pregabalin, muscle relaxants, anticoagulants, and latent tuberculosis treatment. Finally, several lab values predicted ED utilization: high serum potassium, high serum-dialysate potassium gradients, and N-terminal pro b-type natriuretic peptide (NT-proBNP). Lab values were also integrated into a frailty score and a remote telemonitoring platform, which predicted and reduced ED utilization respectively.

The New Healthcare Models core concept included 3 studies. Of note, several excluded studies were related to its constituent subgroups. Receiving care at an ESCO-organized dialysis center and the use of home palliative care both predicted lower ED utilization. Another study found that establishing a payer-provider relationship at a dialysis center reduced ED utilization by its HD patients.

The four studies that tested interventions are summarized in Table 10. The average population sizes for these intervention studies was ~90, which is much smaller
than the overall average for our included studies (334,556). Furthermore, no studies tested an intervention in the ED.

Discussion

Our thematic framework highlights key areas that impact ED utilization by HD patients; we identified diverse predictors of ED utilization across our three core concepts.

Access to care is key to the management of chronic diseases and is our first core concept. Since most patients on dialysis are unemployed, access to health insurance is of paramount importance for this population. Nephrology experts have recently highlighted the need for research on the effects of improving access to nephrology care through health insurance expansion. As of 2021, certain HD patients in the US remain excluded from Medicare, including undocumented persons. Dialysis patients with Medicaid have higher ED utilization compared to those with Medicare. Access to care is also modulated by other social determinants of health, such as race and residential segregation.

HD patients require regularly scheduled dialysis, one of the greatest burdens of their disease experience. Missed dialysis is associated with ED visits, hospitalizations, and mortality. Furthermore, the US had the highest proportion of patients with missed treatments (24%) amongst the 40 countries in the 3-year international DOPPS study. These findings suggest that reducing rates of missed dialysis may help reduce ED visits, although predictors of both missed dialysis and increased ED visits warrant further investigation. While we did not identify any interventions in this subgroup, Chen et al. (2019) found that more frequent pre-dialysis care by a nephrologist was associated with lower ED visit rates following HD initiation, suggesting that optimized pre-dialysis care
may help HD patients avoid the ED. Furthermore, Harel et al. (2015) observed that dialysis centers in Canada frequently share records systems with hospitals and have lower hospitalization rates for their patients than American dialysis centers. It is possible that improving access to dialysis center medical records may facilitate better care management, which could subsequently reduce hospitalizations and their antecedent ED visits.

Undocumented persons on HD have higher rates of hospitalization, increased hospitalization days, and higher mortality. In a Texas cohort, individuals receiving emergency-only dialysis had a 5-fold higher mortality rate as compared to those on scheduled dialysis. Undocumented persons on HD do not qualify for Medicare insurance, so many rely on the ED for dialysis, which contributes to their higher rate of ED utilization. To address this gap in care, some states are using emergency Medicaid to pay for outpatient dialysis treatments. In the absence of regularly scheduled dialysis, alternate approaches to care may help reduce these patients’ ED visit rates.

Finally, several other social determinants of health also predict increased ED utilization. Given the strong association between social determinants and poor health outcomes, it follows that HD patients experiencing barriers to longitudinal care, such as poor community income and lack of health literacy, are more likely to require emergency, or “safety net” care.

Healthcare access is critical for HD patients, and many studies identified predictors of ED utilization that stemmed from suboptimal access to care. The one intervention identified in this core concept used laboratory cutoffs and vital signs to decide whether emergency HD was required, which reduced subsequent ED utilization.
The success of this novel study could inform comparable protocols for patients who frequently miss dialysis, which are a cohort at increased risk for ED visits, hospitalizations, and mortality.\textsuperscript{18,19,62} However, healthcare nonadherence like missed dialysis is influenced by complex social factors that warrants further clarification to guide interventions.\textsuperscript{29,68,69} Furthermore, we did not identify published work describing an intervention that directly improved access to HD care.

Comorbidity burden is an independent risk factor for ED utilization by HD patients, and serves as our second core concept.\textsuperscript{2} Understanding what comorbidities are most associated with increased ED utilization has the potential to inform future interventions.

Depression is the most common psychiatric comorbidity in HD patients,\textsuperscript{70} and was linked with ED utilization in Iranian and US cohorts.\textsuperscript{37,38} However, research on other psychiatric measures produced equivocal results.\textsuperscript{39,40} While psychiatric comorbidity is a prevalent and morbid concern for the HD population, research to date has not elucidated what psychiatric measures best predict ED utilization in this population.

HD patients are at high risk of adverse drug events. Polypharmacy is common in HD patients, with daily pill intake often >20.\textsuperscript{71} Moreover, elevated creatinine levels have been associated with a higher risk of ED visits due to adverse drug events.\textsuperscript{72} Many medications require renal dosing adjustments due to nephrotoxicity and renal excretion, compounding risks for adverse drug events in HD patients. National data reflects this vulnerability, as there is a ten-fold higher incidence of ED encounters for adverse drug events in the maintenance dialysis patients compared to non-dialysis patients.\textsuperscript{44} Our included studies corroborate this; several medications are associated with higher ED use.
Some studies specifically investigated the association between medications and ED visits by older HD patients due to fall, fracture, or altered mental status, limiting their generalizability to all-cause ED utilization. Regardless, the use of medications with significant side effect profiles, especially those renally dosed for patients with decreased kidney function, are consistently associated with increased ED utilization. Interventions to reduce risks of adverse events due to polypharmacy should be developed, such as robust medication reconciliation processes that could reduce accidental over- or under-dosing of medications and subsequent ED utilization.

The relationship between elevated creatinine and ED visits underlies the potential utility in lab values of predicting and managing ED utilization by HD patients. Loss of kidney function results in electrolyte dysregulation, pathophysiologic changes, and poor clearance resulting in abnormal lab values. Even modest elevations in serum potassium are associated with death, hospitalization, and cardiovascular events in HD patients. BNP is also an independent marker of mortality. While several included studies highlighted both potassium and BNP as predictors of ED utilization, none demonstrated that a reduction of potassium values or volume status management reduced ED utilization. Further investigation on laboratory test markers like BNP and their association with HD patients’ clinical volume status would help translate these findings to clinical practice, such as risk stratification using BNP and clinical volume status in parallel.

Understanding comorbidity burden is important to understanding ED utilization by HD patients. Various diagnoses, scoring measures, and medications are associated with increased ED use in this population, but we did not find investigations of comorbid
chronic diseases like congestive heart failure or chronic obstructive pulmonary disease. Similarly, no studies investigating the role of opioid use in ED utilization by HD patients were identified, despite the prevalence of pain and high rate of opioid prescription in this population.\textsuperscript{76,77} These gaps in the literature underscore the lack of research on causal factors driving HD patient ED utilization and any associated interventions.

Finally, the rising cost of HD patient care has generated momentum to reimagine healthcare delivery for these patients.\textsuperscript{78} Our third core concept, healthcare models, seeks to capture the results of these efforts.

The high cost of HD care has driven federal initiatives to introduce new financial models, such as ESCOs.\textsuperscript{11,12} Two included studies demonstrated that changing financial structures for dialysis centers can impact ED utilization by HD patients.\textsuperscript{53,55} More research is needed to further explore causality, as well as the effects of these changes on total healthcare costs. Although articles on home HD were excluded from our review, home HD is another way dialysis providers may reduce cost and improve quality of life for in-center HD patients.\textsuperscript{79} The literature on the benefits of care at home is growing,\textsuperscript{80,81} and we expect further developments to emerge in the coming years. In a similar vein, the only clinical intervention described to reduce HD patients’ ED utilization was remote patient monitoring. Telehealth has been rapidly expanding in the US, accelerated most recently by the COVID-19 pandemic.\textsuperscript{82} It has potential in telemonitoring HD patients and reducing rates of missed dialysis, which may subsequently reduce ED encounters.\textsuperscript{51,52} However, given the social vulnerability of the ESRD population, telehealth-based interventions will need to circumvent technical and social barriers to implementation, as has been seen in telehealth expansions for other patient populations.\textsuperscript{83,84}
As of 2015, over 80% of all dialysis patients were admitted to the hospital in the last 90 days of life, considerably higher than the 62.5% reported for other Medicare beneficiaries.85 Since the majority of unscheduled hospitalizations arise from ED encounters, this represents a significant ED use by HD patients in the last 90 days of life.86 Recent studies have explored this high rate of ED visits by patients with end-of-life conditions like kidney failure and highlighted the need to develop ways to better serve terminally ill patients and provide cost-effective and meaningful care.87 Although only one study met criteria for inclusion in this review,54 we reviewed many articles describing palliative care for kidney disease in the US and abroad.88-90 Results are promising, with reduced ED utilization demonstrated following the initiation of palliative care plans for kidney failure patients declining dialysis.88 The high mortality of maintenance HD and the paucity of transplants makes establishing end-of-life goals of care an important consideration for all HD patients.1

This systematic review is subject to several limitations. Most included studies were retrospective chart reviews and only one was an RCT. Therefore, most of the reviewed findings were associations with ED utilization rather than proven causality. While the quality of our included studies was high, we found significant heterogeneity (dialysis population, country of study, etc.) among the data, which precluded the ability to perform a meta-analysis. During our full text review, we could not find associated full texts for 21 of the abstracts. If full texts for some of these articles do exist, it is possible that some would have met criteria for inclusion.

As systemic reviews are limited by random and human error, we minimized chances for error by developing a protocol (submitted to PROSPERO), clearly
articulating inclusion and exclusion criteria, developing a peer-reviewed comprehensive search-strategy, and performed title and abstract screening and full-text screening. Quality assessment of the screening process was achieved with at least two independent reviewers working in parallel, adjudicating disagreements first via consensus, and if necessary, via a third reviewer.

We limited the scope of our systematic review to HD patients due to the higher rate of ED utilization in this population compared to other forms of dialysis. However, this limits our ability to compare different dialysis populations in this study. We also excluded studies whose study populations included adolescents (<18 years old), even if adults were also included. We decided to exclude pediatric populations because adolescents are a non-representative minority of HD patients; in 2019 only 1% of all ESKD patients were under 21 years old. The characteristics of the pediatric ESKD population are significantly different from those of the overall ESKD population, as illustrated by the 20.8% transplant rate in this subgroup, vs. 2.9% overall.

In summary, our systematic review uncovers a broad range of studies describing predictors of ED utilization by HD patients, as well as four studies that test interventions to reduce ED use (Table 10). Our concept subgroups spanned the core concepts of access to care, comorbidity burden, and new healthcare models, which underscores the complex causality behind HD patients’ ED utilization. The predictors we have compiled in this review provide rich ground for the development of a risk stratification tool to predict future all-cause ED visits by HD patients. An ED screening tool could be used to direct limited ED case management resources to the highest risk patients, providing interventions to potentially improve post-ED outcomes. The next step for developing
such a tool would be to perform a multivariate analysis on the predictors identified in this study to further our understanding of which predictors best predict increased ED utilization by HD patients.

We identified only four studies measuring the impact of interventions on ED utilization, with none performed in the ED. These include investigations on the efficacy of home telemonitoring, which had equivocal results.\textsuperscript{51,52} There is a great deal of room for further research, since care at home like telemedicine and home HD has the potential to improve access and overcome barriers to in-person care.\textsuperscript{51,52,80,81} While the lower rates of ED utilization by patients on peritoneal dialysis and home HD were not covered in this review, they also merit further investigation.\textsuperscript{1} Palliative and hospice care may also provide alternative modes of care at the end of life,\textsuperscript{54,88} and payment models incentivizing these various modes of care may reduce ED use for this vulnerable and often poorly understood population.

**Supplementary Material:**

**Item S1:** PRISMA 2020 Checklist for Systematic Reviews.

**Item S2:** PRISMA 2020 Abstract Checklist for Systematic Reviews.

**Item S3:** Final database search strategy for The Cochrane Library.

**Item S4:** Final database search strategy for Ovid Medline.

**Item S5:** Final database search strategy for Ovid EMBASE.

**Table S1:** Categories for the full data extraction form.

**Table S2:** Additional extracted information from the 38 included articles not included in Tables 2-9.

*Descriptive Text for Online Delivery*
Supplementary File (PDF)
Items S1-S5, Table S1-S2

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and accepts accountability for the overall work by ensuring that questions pertaining to
the accuracy or integrity of any portion of the work are appropriately investigated and
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47. Brunelli SM, Spiegel DM, Du Mond C, Oestreicher N, Winkelmayer WC, Kovesdy CP. Serum-to-dialysate potassium gradient and its association with


85. Chapter 12: End-of-life Care for Patients with End-Stage Renal Disease, 2000-2015.


Table 1: Summary of concept subgroups. Identified predictors and interventions are outlined per subgroup.

<table>
<thead>
<tr>
<th>Concept Subgroups</th>
<th>Identified factors</th>
<th>Targeted Intervention(s)</th>
<th>Included Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialysis</td>
<td>Interdialytic interval; Missed dialysis; Frequency of nephrologic care; Dialysis access type; History of hospitalization for dialysis; Dialysis initiation; Postdialysis weights above target</td>
<td>None identified</td>
<td>Assimon 2018&lt;sup&gt;24&lt;/sup&gt;; Bartolacci 2018&lt;sup&gt;20&lt;/sup&gt;; Chan 2014&lt;sup&gt;16&lt;/sup&gt;; Chen 2019&lt;sup&gt;25&lt;/sup&gt;; Coentrão 2012&lt;sup&gt;22&lt;/sup&gt;; Cohen 2020&lt;sup&gt;19&lt;/sup&gt;; Harel 2015&lt;sup&gt;5&lt;/sup&gt;; Komenda 2018&lt;sup&gt;7&lt;/sup&gt;; Siracuse 2017&lt;sup&gt;23&lt;/sup&gt;; Zhang 2019&lt;sup&gt;21&lt;/sup&gt;</td>
</tr>
<tr>
<td>Social Determinants of Health</td>
<td>Transportation; Racial segregation; Female sex; Health Literacy; Black race; Community income</td>
<td>None identified</td>
<td>Balhara 2020&lt;sup&gt;29&lt;/sup&gt;; Golestaneh 2019&lt;sup&gt;27&lt;/sup&gt;; Golestaneh 2018&lt;sup&gt;28&lt;/sup&gt;; Green 2013&lt;sup&gt;30&lt;/sup&gt;; Thomas-Hawkins 2019&lt;sup&gt;26&lt;/sup&gt;</td>
</tr>
<tr>
<td>Undocumented Immigrant Populations</td>
<td>Reliance on emergency-only HD; Use of furosemide</td>
<td>Initiating emergency dialysis based on strict clinical and laboratory cutoffs</td>
<td>Ahmed 2016&lt;sup&gt;35&lt;/sup&gt;; Cervantes 2018&lt;sup&gt;32&lt;/sup&gt;; Nguyen 2019&lt;sup&gt;33&lt;/sup&gt;; Sheikh-Hamad 2007&lt;sup&gt;34&lt;/sup&gt;; Sher 2017&lt;sup&gt;36&lt;/sup&gt;</td>
</tr>
<tr>
<td>Medications and Adverse Drug Events</td>
<td>Anticoagulant use; Initiation of LTBI treatment; Anticholinergic medication use; Gabapentin/pregabalin use; Muscle relaxant use</td>
<td>None identified</td>
<td>Chan 2018&lt;sup&gt;44&lt;/sup&gt;; Hamadah 2016&lt;sup&gt;45&lt;/sup&gt;; Ishida 2019&lt;sup&gt;41&lt;/sup&gt;; Ishida 2018&lt;sup&gt;42&lt;/sup&gt;; Mina 2019&lt;sup&gt;43&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lab Values and Scoring Forms</td>
<td>Serum potassium level; Serum-dialysate potassium gradient; Serum NT-proBNP level; Severe frailty score (Edmonton Frail Score)</td>
<td>-Home telemonitoring</td>
<td>Berman 2011&lt;sup&gt;51&lt;/sup&gt;; Brunelli 2017&lt;sup&gt;46&lt;/sup&gt;; Brunelli 2018&lt;sup&gt;47&lt;/sup&gt;; Chen Yi-Hsin 2019&lt;sup&gt;48&lt;/sup&gt;; Garcia-Canton 2019&lt;sup&gt;50&lt;/sup&gt;; Minatodani 2013&lt;sup&gt;52&lt;/sup&gt;</td>
</tr>
<tr>
<td>Psychiatric Illness</td>
<td>Depression (HADS scale); Depression (PHQ-9); Pain (SF-MPQ)</td>
<td>None identified</td>
<td>Abbas Tavallai 2009&lt;sup&gt;37&lt;/sup&gt;; El-Majzoub 2019&lt;sup&gt;40&lt;/sup&gt;; Vork 2018&lt;sup&gt;39&lt;/sup&gt;; Weisbord 2014&lt;sup&gt;38&lt;/sup&gt;</td>
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<tr>
<td>Palliative Care</td>
<td>Home palliative care utilization</td>
<td>None identified</td>
<td>Nesrallah 2018&lt;sup&gt;54&lt;/sup&gt;</td>
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<tr>
<td>New Financial Models</td>
<td>ACO-governed healthcare delivery</td>
<td>Initiating a payer-provider partnership</td>
<td>Kindy 2018&lt;sup&gt;55&lt;/sup&gt;; Marrufo 2020&lt;sup&gt;53&lt;/sup&gt;</td>
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Table 2: Abbreviated data extraction table with main characteristics of studies in the Dialysis concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>1st Author (pub. year)</th>
<th>Study Design</th>
<th>Study Measures</th>
<th>Country</th>
<th>Population Included</th>
<th>Dialysis Modalities Included</th>
<th>Key ED Utilization Findings</th>
<th>Downs and Black Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assimon, 2018&lt;sup&gt;24&lt;/sup&gt;</td>
<td>RCS</td>
<td>7, 14, 30-day ED visits; 7, 14, 30-day; hospitalizations (all-cause, cardiovascular, volume-related); Short-term all-cause mortality; Short-term cardiovascular mortality</td>
<td>USA</td>
<td>Medicare primary payer; At least one eKt/V measurement during study interval</td>
<td>Maintenance HD</td>
<td>Frequent postdialysis weight &gt;1 kg above target was associated with increased risk of ED visit across 7-30 day follow-up (ARR 1.13-1.14) - ARR for 30-day all-cause ED visits is higher at higher &quot;kilogram thresholds.&quot;</td>
<td>Good</td>
</tr>
<tr>
<td>Bartolacci, 2018&lt;sup&gt;20&lt;/sup&gt;</td>
<td>RCS</td>
<td>EMS event rate by day of the week; EMS response type; EMS transport event on dialysis day vs. off-day</td>
<td>Canada</td>
<td>Age 18 or older - &gt;2 years of dialysis treatment for analysis; 3x weekly HD</td>
<td>Maintenance HD</td>
<td>EMS transports to the ED occurred most frequently on M/T, the days after the long interdialytic interval (p&lt;0.001)</td>
<td>Fair</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Year</td>
<td>RCS</td>
<td>Outcome Measures</td>
<td>Country</td>
<td>Diagnosis</td>
<td>Payer</td>
<td>Risk Factors</td>
</tr>
<tr>
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</tr>
<tr>
<td>Chan, 2014&lt;sup&gt;18&lt;/sup&gt;</td>
<td>2014</td>
<td>RCS</td>
<td>Admission rate after treatment; ER visit rate after treatment; ICU-CCU admission rate after treatment; Total visit rate after treatment</td>
<td>USA</td>
<td>Diagnosis of ESRD; Primary payer: Medicare</td>
<td>Maintenance HD</td>
<td>Risk of ED visit increased significantly after missed treatment (OR 2.00); Various barriers to attending dialysis associated with increased ER visit rate (+1.1 visits per patient-year) and missed dialysis (+5.6 missed sessions per patient-year)</td>
</tr>
<tr>
<td>Chen, 2019&lt;sup&gt;25&lt;/sup&gt;</td>
<td>2019</td>
<td>RCS</td>
<td>No. of ED visits; Infection-related ED visits; Potentially avoidable ED visits (prevention quality indicators)</td>
<td>Taiwan</td>
<td>Diagnosis of ESRD; Dialysis treatment &gt;90 days; Interval between dialysis treatments &lt;60 days</td>
<td>Chronic dialysis</td>
<td>Patients with early referral to nephrologist with frequent care had lower risk of all-cause ED visit (HR 0.92), lower risk of infection-related ED visit (HR 0.76), and lower risk of avoidable ED visit (HR 0.76)</td>
</tr>
<tr>
<td>Coentrão, 2012&lt;sup&gt;22&lt;/sup&gt;</td>
<td>2012</td>
<td>RCS</td>
<td>1 year mortality; 1 year dialysis access-related complication rate; No. of admissions; No. of ED visits</td>
<td>Portugal</td>
<td>Diagnosis of end-stage CKD; Received outpatient chronic dialysis</td>
<td>Chronic Dialysis (initiating)</td>
<td>Initiating HD-TCC was associated with higher ED visits and admissions than HD-AVF and PD</td>
</tr>
<tr>
<td>Cohen, 2020&lt;sup&gt;19&lt;/sup&gt;</td>
<td>2020</td>
<td>RCS</td>
<td>No. of hospitalizations; No. of ED visits; Mortality</td>
<td>USA</td>
<td>All dialysis sessions scheduled on 12 index days (MWF schedule); Age 18 or older; Medicare primary payer</td>
<td>Maintenance HD</td>
<td>Missed dialysis associated with an IRR of 2.00 for 5-day ED visit rate vs. attended dialysis; Rescheduled dialysis associated with an IRR of 1.33 for 5-day ED visit vs. attended dialysis</td>
</tr>
<tr>
<td>Harel, 2015&lt;sup&gt;3&lt;/sup&gt;</td>
<td>2015</td>
<td>RCS</td>
<td>30-day all-cause rehospitalization; 30-day ED visit; 30-day death</td>
<td>Canada</td>
<td>Discharged alive from an index medical hospitalization; Age 18-105</td>
<td>Maintenance HD</td>
<td>Positive history of hospitalizations 6 mos. prior to index hospitalization associated with increased ED visit (3.0 vs. 1.6)</td>
</tr>
<tr>
<td>Komenda, 2018&lt;sup&gt;7&lt;/sup&gt;</td>
<td>RCS</td>
<td>ED visit rate</td>
<td>Canada</td>
<td>All ED visits in Winnipeg Regional Health Authority (WRHA) database</td>
<td>Chronic dialysis</td>
<td>Dialysis patients presented to ED 8.5x as often as the general population (p&lt;0.001); ED utilization significantly higher after long interdialytic interval (on M/T; p&lt;0.001); In the 7 days before dialysis initiation, ED presentation rate 9x higher (p&lt;0.001) than general prevalent kidney disease patients; In the 7 days after dialysis initiation, ED presentation rate 4x higher than general prevalent kidney disease patients (p&lt;0.001)</td>
<td>Poor</td>
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</tr>
<tr>
<td>Siracuse, 2017&lt;sup&gt;23&lt;/sup&gt;</td>
<td>RCS</td>
<td>30 day readmission; 90 day readmission; Cause for readmission (access-related, catheter related, other); 90 day ED visits w/o hospitalization</td>
<td>USA</td>
<td>Initiated new AVF for maintenance HD</td>
<td>Maintenance HD</td>
<td>Dialysis access creation associated with increased 30 and 90 day readmissions (25.5% and 47.7% vs. general Medicare rates of 17% and 27%); Prosthetic grafts associated with procedure-related readmissions</td>
<td>Fair</td>
</tr>
<tr>
<td>Zhang, 2019&lt;sup&gt;21&lt;/sup&gt;</td>
<td>RCS</td>
<td>No. of ED visits; No. of hospitalizations; No. of ED visits w/o hospitalization; No. of hospitalizations w/o preceding ED visit</td>
<td>USA</td>
<td>Medicare primary payer; 3x weekly dialysis</td>
<td>Maintenance HD</td>
<td>A &quot;sawtooth&quot; pattern for ED visits observed, where ED visits were higher on dialysis days vs. off-dialysis days (F1); IRR for ED visits rose most from Sunday-Monday, illustrating a weekend effect; For MWF patients, IRR for ED visits were highest on Monday, while for TThS patients it was highest on T, demonstrating an interdialytic gap effect</td>
<td>Fair</td>
</tr>
</tbody>
</table>
Table 3: Abbreviated data extraction table with main characteristics of studies in the Social Determinants of Health concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>1st Author (pub. year)</th>
<th>Study Design</th>
<th>Study Measures</th>
<th>Country</th>
<th>Population Included</th>
<th>Dialysis Modalities Included</th>
<th>Key ED Utilization Findings</th>
<th>Downs and Black Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balhara, 2020&lt;sup&gt;29&lt;/sup&gt;</td>
<td>Pilot Study</td>
<td>Comorbidities (CCI); Degree of disability (KD-QOL); Depression (PHQ-9); Economic stability (DCI); Neighborhood and built environment (DCI and distance to HD center); Education (highest level of formal education); Healthcare access (REALM-SF); Social and community context (Choices for Healthy Outcomes survey)</td>
<td>USA</td>
<td>Cases: presenting to ED after missed HD; Age 18 or older; English-speaking</td>
<td>Maintenance HD</td>
<td>Cases were more dependent on public transport to reach dialysis (p=0.024) and less likely to drive themselves (p=0.002)</td>
<td>Poor</td>
</tr>
<tr>
<td>Golestaneh, 2019&lt;sup&gt;27&lt;/sup&gt;</td>
<td>RCS</td>
<td>ED visits without hospitalization</td>
<td>USA</td>
<td>Diagnosis of ESKD; 1+ index ED visit</td>
<td>Maintenance HD</td>
<td>Top two quintiles of black resident proportion associated with increased risk for ED revisit (IRR 1.15, 1.15); When stratified by sex and adjusted for covariates, males in Q3-5 had significantly increased risk for ED visit (IRR 1.19, 1.28, 1.21)</td>
<td>Good</td>
</tr>
<tr>
<td>Golestaneh, 2018&lt;sup&gt;28&lt;/sup&gt;</td>
<td>RCS</td>
<td>No. of avoidable ED visits before index visit; No. of avoidable ED visits after index visit</td>
<td>USA</td>
<td>Patients with at least 1 avoidable ED visit</td>
<td>Maintenance HD</td>
<td>Female sex associated with more avoidable ED visits in non-Hispanic whites (IRR 1.30); Female sex associated with more avoidable ED visits in patients &lt;44 yo (IRR 1.17)</td>
<td>Good</td>
</tr>
<tr>
<td>Study</td>
<td>Method</td>
<td>Measures</td>
<td>Country</td>
<td>Logistic Factors</td>
<td>Risk Factors</td>
<td></td>
<td></td>
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<td>--------------------------------------------</td>
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<td></td>
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</tr>
<tr>
<td>Green, 2013³⁰</td>
<td>PCS</td>
<td>Dialysis adherence; No. of ED visits; No. of Hospitalizations related to ESRD</td>
<td>USA</td>
<td>Age 18 or older</td>
<td>Maintenance HD; Limited literacy associated with increased ED visits and hospitalizations related to ESRD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thomas-Hawkins, 2019²⁶</td>
<td>RCS</td>
<td>No. of ED revisit</td>
<td>USA</td>
<td>Treat and release HD visits (to/from home w/o hospitalization); White/Black race (95% of sample)</td>
<td>Maintenance HD; Living in communities with lower median income associated with higher risk for ED revisit (ARR 5.83); Living in communities with higher racial segregation associated with higher risk for ED revisit (ARR 3.13); Black race potentiated the above effects</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4: Abbreviated data extraction table with main characteristics of studies in the Undocumented Immigrant Populations concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Study Population</th>
<th>Results</th>
<th>Key ED Utilization Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ahmed, 2016</strong>&lt;sup&gt;35&lt;/sup&gt;</td>
<td>RCS</td>
<td>No. of ED visits; No. of Emergent HD sessions; Potassium values</td>
<td>USA</td>
</tr>
<tr>
<td><strong>Cervantes, 2018</strong>&lt;sup&gt;32&lt;/sup&gt;</td>
<td>RCS</td>
<td>Death; Acute care days; Ambulatory care visits; Bacteremia rate</td>
<td>USA</td>
</tr>
<tr>
<td><strong>Nguyen, 2019</strong>&lt;sup&gt;33&lt;/sup&gt;</td>
<td>RCS</td>
<td>Death; ED visits; Hospitalizations; No. of Hospital days; total cost of care per person per month</td>
<td>USA</td>
</tr>
<tr>
<td><strong>Sheikh-Hamad, 2007</strong>&lt;sup&gt;34&lt;/sup&gt;</td>
<td>RCS</td>
<td>ED visits; No. of admissions; Length of stay; No. of dialysis treatments; Total cost of care</td>
<td>USA</td>
</tr>
<tr>
<td>Sher, 2017&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Case series</td>
<td>No. of ED visits; Hospital nights; ICU days</td>
<td>USA</td>
</tr>
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</tr>
</tbody>
</table>
Table 5: Abbreviated data extraction table with main characteristics of studies in the Medications and Adverse Drug Events concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>1st Author (pub. year)</th>
<th>Study Design</th>
<th>Study Measures</th>
<th>Country</th>
<th>Population Included</th>
<th>Dialysis Modalities Included</th>
<th>Key ED Utilization Findings</th>
<th>Downs and Black Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chan, 2018⁴⁴</td>
<td>RCS</td>
<td>ED visit rate; ED visit for adverse drug event rate</td>
<td>USA</td>
<td>ED visits in 33 states (NEDS 2008-2013)</td>
<td>Chronic dialysis</td>
<td>ED visit for adverse drug event rate per year was more than 10x higher in the dialysis group (65.8-88.5 per 1000 patients vs. 4.6-5.4, p&lt;0.001); In the dialysis group, hematologically active medications (94% anticoagulants) associated with adverse drug events resulting in ED visits</td>
<td>Good</td>
</tr>
<tr>
<td>Hamadah, 2016⁴⁵</td>
<td>Case series</td>
<td>ED visit without hospitalization rate; Hospitalization rate; Symptoms of tuberculosis therapy</td>
<td>USA</td>
<td>Diagnosis for tuberculosis or other mycobacterial infection</td>
<td>Maintenance HD</td>
<td>In the LTBI group, increased hospitalizations and ED visit w/o admission were associated initiation of treatment (0→6, 0→4)</td>
<td>Fair</td>
</tr>
<tr>
<td>Ishida, 2019⁴¹</td>
<td>RCS</td>
<td>First episode of AMS, fall, fracture resulting in ED visit +/- hospitalization</td>
<td>USA</td>
<td>Age 65 or older; Medicare D coverage</td>
<td>Maintenance HD</td>
<td>Anticholinergic antidepressants associated with higher hazard of AMS, fall, and fracture ED visit/hospitalization (HR 1.25, 1.27, 1.39)</td>
<td>Good</td>
</tr>
<tr>
<td>Ishida, 2018⁴²</td>
<td>RCS</td>
<td>First episode of AMS, fall, fracture resulting in ED visit +/- hospitalization</td>
<td>USA</td>
<td>Medicare D coverage</td>
<td>Maintenance HD</td>
<td>Gabapentin associated with increased ED visits in study categories across all dosage ranges; Pregabalin associated with increased ED visits</td>
<td>Good</td>
</tr>
<tr>
<td>Mina, 2019\textsuperscript{43}</td>
<td>RCS</td>
<td>First episode of AMS, fall, fracture resulting in ED visit +/- hospitalization</td>
<td>USA</td>
<td>Age 18-100; Medicare coverage</td>
<td>Maintenance HD</td>
<td>Muscle relaxant use was associated with higher risk for ED visit/hospitalization for AMS (HR 1.39) and fall (HR 1.18)</td>
<td>Good</td>
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</tbody>
</table>


Table 6: Abbreviated data extraction table with main characteristics of studies in the Lab Value/Scoring Form concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Study Population</th>
<th>Results</th>
<th>Downs and Black Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study Design</strong></td>
<td><strong>Study Population</strong></td>
<td><strong>Results</strong></td>
<td><strong>Downs and Black Quality Score</strong></td>
</tr>
<tr>
<td>Berman, 2011</td>
<td>Pilot Study</td>
<td>No. of admissions; No. of ED visits; No. of admission days; ED/admission cost; SF-36 quality of life measure</td>
<td>USA</td>
</tr>
<tr>
<td>Brunelli, 2017</td>
<td>RCS</td>
<td>4-day death; 4-day hospitalization; 4-day ED visit; 4-day hospital costs</td>
<td>USA</td>
</tr>
<tr>
<td>Brunelli, 2018</td>
<td>RCS</td>
<td>Same/next day death; Same/next day hospitalizations; Same/next day ED visit</td>
<td>USA</td>
</tr>
<tr>
<td>Chen Yi-Hsin, 2019</td>
<td>PCS</td>
<td>No. of ED visits; No. of ICU admissions; No. of Cardiovascular events</td>
<td>Taiwan</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Country</td>
<td>Outcome Measures</td>
</tr>
<tr>
<td>-------</td>
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<td>------------------</td>
</tr>
<tr>
<td>Garcia-Canton, 2019&lt;sup&gt;50&lt;/sup&gt;</td>
<td>PCS</td>
<td>Spain</td>
<td>Number of admissions; number of ED visits</td>
</tr>
<tr>
<td>Minatodani, 2013&lt;sup&gt;52&lt;/sup&gt;</td>
<td>RCT</td>
<td>USA</td>
<td>Number of admissions; number of ED visits; number of admission days; ED/admission cost</td>
</tr>
</tbody>
</table>
Table 7: Abbreviated data extraction table with main characteristics of studies in the Psychiatric Illness concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Study Population</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbas Tavallaii, 2009</td>
<td>PCS</td>
<td>Depression associated with increased risk for visiting the ED (14/19 vs. 20/49, p=0.015) and with increased median #ED visits (p=0.279)</td>
</tr>
<tr>
<td>El-Majzoub, 2019</td>
<td>PCS</td>
<td>Psychosocial distress associated with faster time to first hospitalization, but not to ED visit</td>
</tr>
<tr>
<td>Vork, 2018</td>
<td>RCS</td>
<td>-There was no significant difference in ED visit rate between the treated and untreated groups</td>
</tr>
<tr>
<td>Weisbord, 2014</td>
<td>PCS</td>
<td>Increasing PHQ-9 score correlated with increased ED visits (IRR 1.24); Increasing SF-MPQ score correlated with increased ED visits (IRR 1.58)</td>
</tr>
</tbody>
</table>
**Table 8:** Abbreviated data extraction table with main characteristics of studies in the Palliative Care concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>1st Author (pub. year)</th>
<th>Study Design</th>
<th>Study Measures</th>
<th>Country</th>
<th>Population Included</th>
<th>Dialysis Modalities Included</th>
<th>Key ED Utilization Findings</th>
<th>Downs and Black Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nesrallah, 2018\textsuperscript{54}</td>
<td>RCS</td>
<td>ACG comorbidity estimate; ED visits; ICU visits; Time from dialysis initiation to death; Place of death</td>
<td>Canada</td>
<td>Deceased chronic dialysis patients</td>
<td>Chronic dialysis</td>
<td>Patients receiving home palliative care had less ED visits</td>
<td>Fair</td>
</tr>
</tbody>
</table>
Table 9: Abbreviated data extraction table with main characteristics of studies in the New Healthcare Models concept subgroup. The full data extraction table is available in Supplemental Table 2. Abbreviations: RCS = retrospective cohort study, PCS = prospective cohort study, RCT = randomized controlled trial.

<table>
<thead>
<tr>
<th>1st Author (pub. year)</th>
<th>Study Design</th>
<th>Study Measures</th>
<th>Country</th>
<th>Population Included</th>
<th>Dialysis Modalities Included</th>
<th>Key ED Utilization Findings</th>
<th>Downs and Black Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindy, 2018&lt;sup&gt;55&lt;/sup&gt;</td>
<td>RCS</td>
<td>Vascular access type; Vaccination rates; Readmission rate; Healthcare cost; Hospitalization rate; ED visit rate; Length of stay; No. of hospitalized days</td>
<td>USA</td>
<td>Receiving dialysis from one provider</td>
<td>Chronic dialysis</td>
<td>ED visit rate significantly reduced after beginning the payer-provider partnership (Y1 and Y2) as compared to the baseline year for both commercial and Medicare Advantage members</td>
<td>Poor</td>
</tr>
<tr>
<td>Marrufo, 2020&lt;sup&gt;53&lt;/sup&gt;</td>
<td>RCS</td>
<td>Hospitalizations per month; ED visits per month; 30 readmissions per month; Rate of poor quality of care (HD-catheter for 90-days, emergency dialysis, etc.)</td>
<td>USA</td>
<td>Medicare A/B primary payer; US residence; Age 18 or older</td>
<td>Chronic dialysis</td>
<td>Change to ACOs reduced ED use, with effect significant by year 2 (p=0.03)</td>
<td>Fair</td>
</tr>
</tbody>
</table>
Table 10: Summary of intervention studies. The full data extraction table is available in Supplemental Table 2.

<table>
<thead>
<tr>
<th>1st Author (pub. year)</th>
<th>Study Design</th>
<th>N=</th>
<th>Demographics</th>
<th>Study Measures</th>
<th>Intervention</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berman, 2011&lt;sup&gt;51&lt;/sup&gt;</td>
<td>Pilot Study</td>
<td>44</td>
<td>Remote Telemonitoring: 7 F, 12 M. Mean age 57; Usual Care: 11 F, 14 M. Mean age 62</td>
<td>No. of admissions; No. of ED visits; No. of admission days; ED/admission cost; SF-36 QOL measure</td>
<td>Remote home telemonitoring</td>
<td>Home-based remote telemonitoring reduced ED visits</td>
</tr>
<tr>
<td>Kindy, 2018&lt;sup&gt;55&lt;/sup&gt;</td>
<td>RCS</td>
<td>197</td>
<td>Year 1: 99; Year 2: 101; Baseline: 197</td>
<td>Vascular access type; Vaccination rates; Readmission rate; Healthcare cost; Hospitalization rate; ED visit rate; Length of stay; No. of hospitalized days</td>
<td>Initiation of a payer-provider relationship at the study dialysis center</td>
<td>ED visit rate was significantly reduced after beginning the payer-provider partnership (Y1 and Y2) as compared to the baseline year for both commercial and Medicare Advantage members</td>
</tr>
<tr>
<td>Minatodani, 2013&lt;sup&gt;52&lt;/sup&gt;</td>
<td>Pilot Study</td>
<td>99</td>
<td>Remote Telemonitoring: 18 F, 25 M, mean age 58.6; Usual Care: 26 F, 30 M, mean age 63.1</td>
<td>No. of admissions; No. of ED visits; No. of admission days; ED/admission cost</td>
<td>Remote home telemonitoring</td>
<td>Home-based remote telemonitoring reduced hospitalizations, but reduction of ED utilization was not statistically significant (p=0.229)</td>
</tr>
<tr>
<td>Sher, 2017&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Case Series</td>
<td>19</td>
<td>Overall: 6 F, 13 M, mean age 36.6</td>
<td>No. of ED visits; Hospital nights; ICU days</td>
<td>Criterion-based emergent dialysis</td>
<td>ED visits decreased after transition to criterion-based emergent dialysis (early transition vs. baseline, late transition baseline both p&lt;0.001)</td>
</tr>
</tbody>
</table>
**Figure Legend:**

**Figure 1:** Preferred reporting items for systematic reviews and meta-analyses (PRISMA) workflow: study selection.

**Figure 2:** Conceptual framework for organizing ED utilization-associated factors in HD patients. Eight concept subgroups each correspond to one of three core concepts: Access to Care, Comorbidity Burden, and New Healthcare Models.

**Figure 3:** Distribution of included papers per concept subgroup. The majority of included articles described predictors of emergency department utilization (34/38 articles), with most subgroups lacking an associated intervention. Blue: predictor studies. Orange: intervention studies.

- [ ] Predictor Studies
- [ ] Intervention Studies
Titles and abstracts identified through database searches: n = 1387

Titles and abstracts screened n = 1060

Excluded: n = 962
Titles and abstracts did not contain key terms and were deemed irrelevant

Full-text articles assessed for eligibility n = 98

Excluded: n = 60
- No full text for analysis (abstract only): 21
- Wrong patient population: 13
- Wrong study design: 5
- Wrong setting: 1
- Wrong comparator: 2
- Wrong outcomes: 9
- No quantitative data for analysis: 8
- Wrong intervention: 1

Studies included n = 38
Access to Care
- Dialysis
- Social Determinants of Health
- Undocumented Immigrant Populations

Comorbidity Burden
- Medications and Adverse Drug Events
- Lab Values and Scoring Forms
- Psychiatric Illness

Healthcare Models
- New Financial Models
- Palliative Care