Management of Hypertension in the End-Stage Renal Disease Patient

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Abstract

- **Objective:** To discuss mechanisms involved in blood pressure dysregulation in patients on hemodialysis and present strategies to improve blood pressure control in end-stage renal disease (ESRD) patients.
- **Methods:** Review of the literature.
- **Results:** Blood pressure control is not adequate in a vast majority of hemodialysis patients, which in turn translates into an elevated rate of cardiovascular disease. Although ambulatory blood pressure monitoring provides a superior assessment of blood pressure, its utilization is limited. Home blood pressure measurements are a reliable and inexpensive method to help diagnose occult hypertension in chronic hemodialysis patients. Aiming for a blood pressure of less than 140/90 mm Hg or the lowest possible value as tolerated by the patient should be the target. Achievement of dry weight is a key factor in obtaining optimal blood pressure control. Salt restriction to less than 2 g per day should be reinforced. Adequate blood pressure control usually will require pharmacologic therapy and it should be tailored according to the physiology of the patient as well as to the presence of other end-organ damage and disease comorbidities.
- **Conclusion:** To reduce the disease burden in patients with ESRD, vigorous control of hypertension is recommended.

Hypertension is a strong (particularly the systolic component) and independent risk factor for cardiovascular disease in the general population [1]. It occurs in an estimated 72 million people in the United States [2]. Hypertension is the second leading cause of end-stage renal disease (ESRD) in the United States and accounts for 30% of the ESRD population [3]. Over the past 2 decades, the prevalence and incidence of ESRD have been increasing [4]. Hypertension is both a cause and consequence of kidney disease, as the prevalence of hypertension in patients on dialysis is as high as 90% [5–8]. It is associated with an annual mortality of 23% [6], mainly from cardiovascular disease [9]. Interestingly, only a minority of patients on hemodialysis have satisfactory blood pressure control [10]; there is better control in the peritoneal dialysis population. Reducing the morbidity and mortality associated with hypertension is of paramount importance, and understanding its etiology in chronic dialysis patients is critical in order to optimize treatment [5]. A range of strategies may be used and should be understood to improve control of blood pressure. To reduce the disease burden in patients with ESRD, vigorous control of hypertension is recommended [11]. In this article, we review different aspects of hypertension, focusing mainly on the hemodialysis population.

CASE STUDY

**Initial Presentation**

A 51-year-old African American female presents to the local emergency department with shortness of breath and chest pain.

**History**

The patient has a history of diabetes mellitus, uncontrolled hypertension, and ESRD secondary to hypertension on hemodialysis for 1 year. Chest x-ray shows cardiomegaly and pulmonary edema. Electrocardiogram is consistent with left ventricular hypertrophy, and echocardiogram confirms the same with an ejection fraction of 45%, notable for diastolic dysfunction. She is initiated on a beta blocker and nitroglycerine drip and transferred to a facility for further management. She states that her blood pressure has been difficult to control for the past 20 years and is noted to be high even after hemodialysis. She denies use of tobacco, alcohol, or drugs and is compliant with her medications. She does not exercise but strictly adheres to a low-sodium diet.

**Physical Examination**

The patient is 67 inches tall and weighs 161 lb. She appears healthy but in slight respiratory distress. Blood pressure is 246/131 mm Hg, heart rate is 94 bpm, and body mass index is 31 kg/m².

From the Division of Nephrology and Hypertension, Emory University School of Medicine, Atlanta, GA.
Hypertension is appreciated in both lower extremities. Organomegaly or renal bruit. Pitting edema (2+) up to mid-lung fields. Abdominal examination does not reveal organomegaly or renal bruit. Fitting edema (2+) up to mid-shin is appreciated in both lower extremities.

- What mechanisms are responsible for development of hypertension in ESRD?

The pathophysiology is complex, and multiple mechanisms are likely involved in blood pressure dysregulation in patients on hemodialysis [11]. Initial studies aimed at elucidating the pathophysiology of hypertension in this category of patients concluded that 90% of cases resulted from sodium and volume overload (volume-dependent), while the majority of the remaining had elevated renin activity (renin-independent), resulting in a rise in renin and blood pressure during hemodialysis as fluid is removed [12].

There are a multitude of additional factors that distinctly affect hypertension. Erythropoietin acts via various mechanisms, including increased blood viscosity, vascular endothelial dysfunction, and direct vasoconstrictor effects [5]. Other factors such as increased sympathetic outflow, as measured by excessive catecholamine release [13] and vasoactive substances (e.g., endothelin, sodium pump inhibitors, and nitric oxide synthetase inhibitors) contribute to the mechanisms of hypertension. Of these, nitric oxide was the first to be identified [14], which may cause vasodilatation and inhibition of vascular smooth muscle cell proliferation [15]. It is inhibited by asymmetric dimethylarginine (ADMA), which accumulates in hemodialysis patients [16]; their levels are 6- to 10-fold higher as compared with healthy subjects. ADMA may inhibit nitric oxide synthases, and hemodialysis can reduce plasma concentration by 65% [17].

Other possible mechanisms include calcium-related metabolic alterations that occur in ESRD. Patients with ESRD develop secondary hyperparathyroidism, which in turn causes entry of calcium into smooth muscles of blood vessels leading to vasoconstriction and hypertension [18]. In a study by Fliser et al [19], infusion of physiologic doses of parathyroid hormone increases blood pressure and intracellular calcium in healthy subjects. However, treatment with alfalcaldiol, an active vitamin D analogue, significantly decreased parathyroid hormone, platelet intracellular calcium, and mean blood pressure [20]. See Table 1 for mechanisms of hypertension in ESRD.

In brief, the mechanisms of hypertension are difficult to unravel in patients on hemodialysis given their intricacy. The heterogeneity of the dialysis population results in probable significant overlap of the above-mentioned causes. However, a majority consensus agrees that the most predominant factor is related to expanded extracellular volume.

- What is the optimal blood pressure goal in patients on dialysis?

Hemodialysis patients in general have an elevated systolic blood pressure, but the diastolic blood pressure seems to decrease, and the resultant effect is a high pulse pressure, resulting in catastrophic effects on the cardiovascular system [21]. No randomized prospective trials have evaluated target blood pressure in dialysis patients. According to the National Kidney Foundation K/DOQI guidelines, predialysis and postdialysis blood pressures should be less than 140/90 and less than 130/80 mm Hg, respectively [22]. However, these guidelines are unfortunately not applicable to the hemodialysis population. Ideal blood pressure in a hemodialysis patient should be associated with hemodynamic stability during dialysis, orthostatic tolerance after dialysis, the best cardiovascular survival, and optimal health-related quality of life [23]. There is confounding data regarding goals.

According to an observational study by Port et al [24] on approximately 4500 individuals on hemodialysis, a significantly increased adjusted mortality risk was noticed among patients with a low predialysis systolic pressure (< 110 mm Hg) but no association with an elevated mortality risk could be observed for predialysis systolic hypertension except for an elevated risk of cerebrovascular death risk. Postdialysis systolic pressures (> 180 mm Hg) and diastolic pressures (> 110 mm Hg) were associated with an elevated mortality risk as well. Also, in a retrospective analysis of 13,792 incident hemodialysis patients by Tentori et al [25], patients were evaluated for correlation between survival and achieving K/DOQI clinical practice guidelines for multiple parameters. Achieving the goal predialysis blood pressure of less than 140/90 mm Hg was associated with an increased mortality.

Opinion-based recommendations are offered, but goals
should be individualized based on a complete assessment of prevailing comorbidities and should target normalization of the pulse pressure [26]. In general, an ideal goal for postdialysis systolic blood pressure seems to be a value higher than 110 mm Hg and lower than 150 mm Hg. However, hemodialysis patients are generally older and often have cardiac complications, so a reasonable predialysis target systolic blood pressure could be 150 mm Hg [21]. A randomized controlled trial is needed to identify the optimal blood pressure for hemodialysis patients.

- Which measurement of blood pressure is better: predialysis, postdialysis, or home?

There are several issues relating to blood pressure measurement that may be unique to hemodialysis patients. For example, the presence of a functioning dialysis access in one extremity may limit the measurement of blood pressure to the other arm. The standard recommendation that blood pressure be measured in both arms and the higher value used as the representative one cannot be applied in this population [27]. In addition, there is loss of the normal nocturnal decline in blood pressure [28], which is associated with adverse cardiovascular outcomes.

There are conflicting data as to whether blood pressure measurements before or after dialysis sessions are reliable predictors of interdialytic blood pressure. According to Mendes et al [29], postdialysis values are minimally better predictors than predialysis blood pressures, and the average of pre- and posthemodialysis values is marginally better than both. Similarly in a study by Mitra et al [30], the best representation of interdialytic blood pressure was the 20-minute postdialysis reading. His study also concluded that walk-in predialysis pressures overestimate mean interdialytic pressures due to a high incidence of white-coat effect. In contrast to this, Zoccali’s [31] concept is that predialysis blood pressure was a better predictor of left ventricular mass index than postdialysis blood pressure.

Predialysis systolic blood pressure may overestimate the mean interdialytic systolic blood pressure by 10 mm Hg, while the postdialysis systolic blood pressure may underestimate the mean systolic blood pressure by 7 mm Hg [32]. Some studies, however, have suggested that the postdialysis blood pressure may be more reflective of interdialytic blood pressure [32,33]. Ambulatory blood pressure monitoring (ABPM) is another modality of assessing intradialytic blood pressure assessment and is the gold standard for the diagnosis of white-coat hypertension [28]. It has been in use for more than 4 decades. According to Peixoto [34], ABPM has generally been considered the most accurate method for studying blood pressure in hemodialysis patients over time. ABPM involves wearing a small device usually hooked to the belt that is connected via a hose to a blood pressure cuff around the arm. While the patient goes about his usual activity, the device automatically inflates at 20- to 30-minute intervals and records the blood pressure and heart rate. In a study by Amar et al [35] involving 57 hypertensive hemodialysis patients, it was noted that measuring 24-hour pulse pressure via ABPM was an independent predictor of cardiovascular mortality. Although ABPM provides useful data, it is difficult to use this technology for the routine management of hypertension in hemodialysis patients. In summary, interdialytic ABPM closely correlates with left ventricular hypertrophy [36] and all-cause mortality [37] compared with blood pressure recordings in the dialysis units and, in contrast with home blood pressure recordings, offers greater insight into circadian rhythms [28].

In a recent review by Agarwal [37], it was noted that home blood pressure readings are also superior to diagnose hypertension. Agarwal et al [38] noted that a home systolic blood pressure of ≥ 150 mm Hg averaged over 1 week had the best combination of sensitivity (80%) and specificity (84.1%) in diagnosing systolic hypertension. Monitoring of blood pressure at home is a cost-effective means that could help diagnose occult hypertension in chronic hemodialysis patients [39]. A composite of blood pressure measurements over a period of 1 to 2 weeks rather than isolated readings should be used for guidance [40].

- What complications related to hypertension are seen in ESRD?

In this case, the patient developed hypertensive emergency resulting in congestive heart failure (CHF) despite being on dialysis and multiple medications, indicative of inadequate fluid removal. Hypertensive emergencies are defined as acute, life-threatening, and usually extreme increases in blood pressure and are associated with acute end-organ damage [41]. CHF is highly prevalent and is a leading cause of death in such patients. Patients on hemodialysis are also at particular risk of hemorrhagic strokes because of chronic exposure to heparin, as well as to acute coronary events. Left ventricular hypertrophy (LVH) is common in hypertensive patients and is endemic in the ESRD population [42]. Hypertension may contribute to the development of atherosclerotic coronary artery disease, particularly in the presence of the many lipid abnormalities observed in ESRD [43]. Hypertension, anemia, and comorbid conditions such
as coronary artery disease are particularly important risk factors for CHF in ESRD [44].

• How is hypertension managed in patients who have ESRD?

Management of patients on hemodialysis is challenging [45]. It may be dichotomized into 2 broad categories: nonpharmacologic and pharmacologic.

Nonpharmacologic Management

Reduction of salt intake is the first keystone of therapy to achieve adequate blood pressure control. According to Mailloux [46], salt restriction is often overlooked as a means of controlling hypertension in this population of patients. Historically, in 1944 Kempner [47] published the first reported benefit of a reduced dietary salt intake in controlling hypertension in patients with chronic renal failure. The first mention of the ability to control hypertension in hemodialysis patients without the use of medications was in 1961 [48]. The first 4 patients treated by long-term dialysis in Seattle were hypertensive, and their hypertension was well controlled by a low-sodium diet and ultrafiltration alone. Drug therapy had been stopped in 3 patients as it was producing too many side effects and was relatively ineffective [48].

It has been anticipated that salt restriction to 1000 mg/day or less helps decrease thirst and control interdialytic fluid gain [49], although a 2-g sodium restriction is usually prescribed for most hemodialysis patients. A 2-g sodium restriction equates to an interdialytic weight gain of 1.25 kg over 2 days; however, this is rarely achieved. Sodium balance may also be addressed by reducing dialysate sodium concentration. In a study by Flanigan et al [50], there was a reduction in both the number of antihypertensive medications prescribed and blood pressure by gradually lowering the sodium concentration in the last 30 minutes of hemodialysis.

Improvement of blood pressure control is necessary in the hemodialysis population, first by slow and smooth removal of extracellular volume (dry weight) and thereafter by the use of appropriate antihypertensive medication [21]. The term “dry weight” was first coined by Thomson in the 1970s [51] and has been defined as not merely the absence of edema but the minimal body sodium content and volume of body water that can be tolerated without inducing hypotension [52]. It is assessed by history, pre- and posthemodialysis blood pressures (including orthostatics), examination of neck veins, and presence of edema [53]. Gradual fluid removal with longer dialysis permits a greater degree of total fluid loss and attaining the dry weight. According to a recent randomized controlled trial conducted by Agarwal [54], it was found that reduction of dry weight is a simple, efficacious, and well-tolerated maneuver to help improve hypertension in hemodialysis patients. However, achieving a lower dry weight and decreasing blood pressure by such an approach is not immediate, and it could take weeks or months before a stable reduction in blood pressure is noticed; Charra et al [55] has labeled this “the lag phenomenon.” This was shown in a group of 61 patients, wherein 6 months were necessary for predialysis mean blood pressure to reach a plateau of normal values after the dry weight method and tapering of antihypertensive drugs were applied [56]. Dry weight is a very subjective measure determined by the nephrologist after observing several dialysis sessions for the absence of edema, low blood pressure, and/or the occurrence of cramps. Dry weight also has to be continually monitored, as the patients’ flesh weight may change according to dietary intake, and thus the dry weight or fluid weight (ie, the amount of fluid gained in between hemodialysis treatments) will also need to be changed, or patients can become either volume overloaded or too dry, resulting in severe hypotension, syncope, and cardiovascular events.

Supporting the concept that achievement of true dry weight improves blood pressure control is the fact that patients who perform daily dialysis, whether it is peritoneal dialysis or daily hemodialysis, have much better blood pressure control and require less antihypertensive medication [57]. Furthermore, a randomized controlled trial by Culleton et al [58] revealed that compared with conventional hemodialysis (3 times weekly), frequent nocturnal hemodialysis improved left ventricular mass, reduced the need for blood pressure medications, improved some measures of mineral metabolism, and improved selected measures of quality of life. In a study done by Pierratos et al [59], nocturnal hemodialysis proved to be the most efficient form of dialysis at a low cost with improved blood pressure control.

Other nonpharmacologic strategies, including exercise, weight loss in obese individuals, discontinuing tobacco, and limiting alcohol intake, may also contribute to achieve hypertension management goals, as they are effective in the general population [60]. Aerobic exercise has been suggested in many patient populations, including those with chronic renal failure, as a measure to control blood pressure. According to a study by Miller et al [61] conducted on 107 patients, it was observed that the average relative benefit of exercise was a 36% reduction in antihypertensive medications ($P = 0.018$) with an average annual cost savings of $885 per patient-year ($P = 0.005$) in the exercise group.

Pharmacologic Management

According to Agarwal and Sinha [62], randomized trials suggest benefits of antihypertensive therapy among hemodi-
alyis patients. Of note, randomized trials on angiotension-converting enzyme (ACE) inhibitors, beta blockers, calcium channel blockers (CCBs), and angiotensin-receptor blockers (ARBs) within the past few years have shown attenuation of cardiovascular disease. Essentially all classes of antihypertensive medications are useful in anuric hemodialysis patients with the exception of diuretics [63]. Dosing, frequency, and type of medication is influenced by their pharmacokinetic profiles [63]. Antihypertensive agents need to be tailored in accordance with underlying disease profile in hemodialysis patients, and no specific class of antihypertensive drug has proven to be more beneficial than others [9]. Randomized controlled clinical trials are needed to determine the most advantageous antihypertensive agent(s) to use in ESRD patients on chronic hemodialysis. Among all classes, CCBs are the most commonly prescribed antihypertensive agents [6] and offer the advantage of not being cleared during hemodialysis [64] (Table 2).

The role of diuretics in the management of hemodialysis patients has not been clearly defined. An observational study by Bragg-Gresham et al [65] suggested there may be a survival advantage to diuretic use in hemodialysis patients with little to no residual renal function. Patients on continuous ambulatory peritoneal dialysis (CAPD) are dependent on residual renal function for solute and water clearances, and this declines with time on dialysis. In a prospective, randomized, open-label study, Medcalf et al [66] showed that furosemide given at 250 mg per day produced a clinically significant preservation in urine volume over 1 year of CAPD. This was associated with a possible improvement in fluid balance and no increase in side effects but did not have effect on preserving residual renal function.

However, because the renin-angiotensin system is active in many ESRD patients and because of the high cardiovascular disease burden, ACE inhibitors and ARBs are an attractive class of medications for the ESRD population. According to Takahashi et al [67], the ARB candesartan significantly reduced cardiovascular events and mortality in patients on chronic maintenance hemodialysis and therefore improved the prognosis of such patients. Similarly, a study by Suzuki et al [68] concluded that ARBs may be effective in reducing nonfatal CVD events in patients undergoing long-term hemodialysis. In an observational study Efrati et al [69] showed that ACE inhibitors, independently of their antihypertensive effect, may dramatically reduce mortality among chronic hemodialysis patients 65 years or younger. Of particular interest, a randomized controlled study by Li et al [70] showed that the ACE inhibitor ramipril may slow the rate of decline in residual renal function by 0.93 mL/min per 1.73 m² per year in CAPD patients and reduce the progression to anuria [70].

ACE inhibitors notoriously cause hyperkalemia, but interestingly in ESRD patients they may cause development of erythropoietin resistance [71]. N-acetyl-seryl-aspartyl-lysyl-proline (AcSDKP) is a physiological inhibitor of hematopoiesis [72] and is degraded by ACE. AcSDKP accumulates in patients with ESRD and may explain erythropoietin hyporesponsiveness, particularly in patients treated with ACE inhibitors [23]. In addition, a high incidence of anaphylactoid reaction with the AN69 dialyzer has been reported in ESRD patients on ACE inhibitors.

Another option available is the weekly application of a transdermal clonidine patch [73]. Minoxidil, a potent vaso-

### Table 2. Antihypertensive Medications

<table>
<thead>
<tr>
<th>Class</th>
<th>Approximate Half-Life, hr</th>
<th>Cleared by Hemodialysis?</th>
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<tr>
<td>Adrenergic receptor blockers</td>
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<td>α-Antagonist</td>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
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ACE = angiotensin-converting enzyme; LA = long-acting.
dilator, may also be used, but caution should be observed as they are normally excreted through the kidneys [74] and it should be used with a beta blocker to maintain efficacy. Its main side effects include hirsutism, pericardial effusion, and edema, which can be problematic in dialysis patients. Most ACE inhibitors as well as beta blockers are removed with dialysis, while CCBs and ARBs are not and are of particular significance especially for patients exhibiting a renin-dependent form of hypertension, ie, blood pressure rises throughout the hemodialysis procedure with higher posthemodialysis renin levels than prehemodialysis (Table 2).

- What is the impact of residual renal function in dialysis patients?

Residual renal function is an important factor influencing mortality in dialysis patients [75] and has achieved immense recognition in the past 2 decades. It is generally present in patients being initiated on hemodialysis or peritoneal dialysis but tends to decrease over time. It is of essential importance to dialysis adequacy, morbidity, and mortality, particularly in long-term CAPD patients [76]. Residual renal function contributes significantly to the overall health and well-being of dialysis patients. It provides small solute clearance, plays an important role in maintaining fluid balance, phosphorus control, removal of middle molecular uremic toxins, and shows strong inverse relationships with valvular calcification and cardiac hypertrophy in dialysis patients. Balancing sodium intake and removal is easier with residual renal function since sodium removal can be increased by diuretics. Furthermore, patients with residual renal function have fewer problems with potassium.

However, the decline of residual renal function contributes significantly to anemia, inflammation, and malnutrition. More importantly, its loss is a powerful predictor of mortality, especially in patients on peritoneal dialysis [77]. Whereas the role of residual renal function for survival is well recognized in the peritoneal dialysis population, it has not received much attention in the hemodialysis population. In a recent study by Vilar et al [78], there were strong data showing that residual renal function contributes significantly to improved outcomes in hemodialysis patients and that efforts to preserve it are warranted. However, comparative outcome studies should be controlled for the presence of residual renal function.

**Patient Follow-up**

The patient’s dry weight at the outpatient hemodialysis center was 77 kg. Review of her outpatient hemodialysis flow sheets revealed that her predialysis blood pressure was ranging from 160 to 170/80 to 85 mm Hg and postdialysis blood pressure from 150 to 160/75 to 85 mm Hg. During the hospitalization, her dry weight was lowered to 73 kg and dosages of her blood pressure medications adjusted. An ARB was added as part of her regimen to provide cardiac protection, LVH regression, and better control of hypertension even during the hemodialysis session. She then achieved prehemodialysis blood pressures of 145 to 150/70 to 75 mm Hg and posthemodialysis blood pressures of 120 to 131/62 to 71 mm Hg. Interdialytic blood pressures were ranging between 125 to 141/63 to 68 mm Hg. As an outpatient she was instructed not to take any of her blood pressure medications the morning of her scheduled dialysis, a common practice to avoid intradialytic hypotension; consequently, her prehemodialysis systolic blood pressures were elevated and averaging greater than 160 mm Hg. While in the hospital, she was allowed to take one of her blood pressure medications, an ARB, before hemodialysis for better control of her blood pressure throughout the dialytic process.

**Summary**

Blood pressure control is not adequate in a vast majority of hemodialysis patients, which in turn translates into an elevated rate of CVD. Compared with the general population, the incidence of CVD is approximately 10- to 20-fold in ESRD patients and it is a major cause of death [79]. Blood pressure measurements should be performed customarily in patients with ESRD. Although ABPM provides a superior assessment of blood pressure monitoring, its low practicality limits its utilization. Home blood pressure measurements are a reliable and inexpensive method of tracking blood pressure recordings and provide a tool for the diagnosis of obscured hypertension. Of note, it best correlates with ABPM and LVH. Aiming for a blood pressure of less than 140/90 mm Hg or the lowest possible value as tolerated by the patient should be the target. Achievement of dry weight is a key factor in obtaining optimal blood pressure control. Salt restriction to less than 2 g per day should be reinforced repeatedly to ESRD patients. Adequate blood pressure control usually will require pharmacologic therapy as well and should be tailored according to the physiology of the patient, ie, renin-dependent, as well as to the presence of other end-organ damage and disease comorbidities. There are no studies specifically addressing which class of antihypertensive drugs provide better organ protection in dialysis patients; however, ACE inhibitors and ARBs are recommended as the principal choices given their protective effects in patients with or at risk for cardiovascular disease [80].

Other practical issues for treating hypertension in hemodialysis patients include generally holding blood pressure medications the morning of the hemodialysis session to avoid intradialytic hypotension to allow achievement of true
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