Chapter 14
Hemodialysis Prescription

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Case Presentations

Case 1: Routine Hemodialysis Prescription

A 10-year-old boy (130 cm, 25 kg) is transferred to the pediatric dialysis unit for hemodialysis treatment. The primary renal disease is antenatally diagnosed posterior urethral valves with chronic obstructive nephropathy resulting in end-stage kidney failure. Renal replacement therapy by hemodialysis has been started acutely 2 years ago following deterioration of renal function because of a severe urinary tract infection. Dialysis was initiated with a central venous catheter followed by creation of an AV fistula that is successfully used for dialysis treatment since 12 months. Since 6 months the boy is anuric.

Hemodialysis was performed with a *GAMBRO AK 200 Ultra S* dialysis machine with pediatric blood lines with a priming volume of 85 mL. Treatment was delivered with the local standard prescription of three times weekly for 4 h with blood flow of 150 ml per minute using a high-flux dialyzer with 1.0 m^2 surface area. Dialysate flow was set at 500 mL/min with a temperature of 37 °C. The dialysate solution composition was as follows: potassium 3 mmol/L, Ca 1.25 mmol/L, sodium 140 mmol/L, and bicarbonate 34 mmol/L.

Anticoagulation was performed by low-molecular-weight heparin 20 mg i.v. By this prescription, dialysis dose was achieved with an average Kt/V of 1.3 and pre-dialysis blood values of 55 mmol/l BUN and inorganic phosphorus between 1.8 and 2.2 mmol/l. Growth did not improve under this dialysis prescription. About every other week, extra dialysis sessions were indicated due to volume overload and hypertension.

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Three months ago, he was switched to hemodiafiltration. For enhanced dialysis efficacy, 2,200 mL/h substitution fluid was delivered in the predilution mode. Blood flow rate was increased to 190 ml/min, and intensive nutritional training was instituted. Volume status and blood pressure are now better controlled; repeated echocardiography has shown improvement of left ventricular hypertrophy since start of hemodiafiltration. Due to improvement of nutritional status and weight gain, dry weight is currently being reset. Quality of life is judged as acceptable by family and caretakers. The boy visits school in the morning and starts dialysis treatment in early afternoon.

Clinical Questions

1. What is the standard HD prescription for this boy?
2. What is the standard anticoagulation for this boy?
3. How can the dose of dialysis be tailored to the patient's current needs?
4. How can volume control be tailored to the patient's current needs?

Diagnostic Discussion

1. The choice of dialysis machine and the initial standard prescription of frequency and duration of dialysis sessions vary between centers and rather depend on local policies than on individual patient characteristics. The choice of the dialyzer depends on patient size and needs [1–3]. According to the patient's body surface area of 0.96 m^2, a dialyzer with a comparable effective surface area (1 m^2) was chosen. The setting of blood flow rate depends on dialyzer characteristics and target clearance. The dialyzer chosen for the boy has a recommended flow rate of 100–300 mL/min, with a urea clearance of 180 mL/min at 200 mL/min blood flow and 500 mL/min dialysate flow. In our patient with a body weight of 25 kg, a urea clearance of 5 mL/min/kg was considered appropriate; thus, 125 mL/min should be achieved. This target urea clearance should be clearly met with a blood flow of 150 mL/min (as prescribed). In order to keep the extracorporeal blood volume (max. 8 mL/kg body weight) as low as possible, pediatric blood lines were chosen. Together with the dialyzer, the calculated extracorporeal blood volume was 138 mL, i.e., approximately 5.5 mL/kg body weight in our patient. For enhanced dialysis efficacy, hemodiafiltration was used with 2,200 mL/h substitution fluid delivered in a predilutional fashion.
2. Most standard anticoagulation regimes during hemodialysis are heparin based. Unfractionated heparin or low-molecular-weight heparin is used [4]. Dosage guidelines exist for heparin with an initial bolus dose between 10–65 IU/kg body weight and 300–1,000 IU/m^2 body surface area and a maintenance dose between 10–30 IU/kg/h. The smaller the child or infant, the lower the heparin dose can be when normalized to body size. To optimize the dosage, the activated clotting time (ACT) should be measured and kept around 50% over the baseline ACT

prior to anticoagulation, but should not exceed 200 s. Low-molecular-weight heparin, as used in this patient, is usually given at the beginning of the dialysis session with a dosage of about 1 mg/kg body weight. Anticoagulation dosage can be checked by measuring factor Xa activity, which should be around 0.5–0.8 U/ml 30 min after application.

Contraindications for heparin-based anticoagulation are bleeding risks, i.e., due to surgery or heparin-induced thrombocytopenia. In perioperative dialysis sessions, regional citrate anticoagulation is an alternative option [5]. Contraindications for citrate anticoagulation are insufficiency of liver function, acidosis or alkalosis, and hypernatremia. In rare cases, such as in heparin-induced thrombocytopenia, alternative medications have been used, such as glycosaminoglycan (danaparoid) and direct thrombin inhibitors like lepirudin and argatroban.

3. Hemodialysis dosing is affected by treatment time, dialyzer size, blood and dialysate flow rates, and the type of access [1, 3]. The definition of the target dialysis dose follows recommendations derived from adult guidelines. Those adult guidelines are mainly based on observed correlations of urea kinetics with patient mortality [2, 6]. The most widely used urea kinetic modeling uses the clearance of urea (K), the duration of the dialysis session (t), and the volume of urea distribution (V): Kt/V (formula by Daugirdas: $Kt/V = -\ln(Ct/Co\text{-}0{,}008 \cdot t) + (4\text{–}3{,}5 \cdot CtCo) \cdot UF/W$ where Co urea pre-dialysis, Ct urea post-dialysis, t treatment hours, UF liters of ultrafiltration, w dry weight). A minimum Kt/V level of 1.2–1.4 thrice weekly is thought to be acceptable. However, many children do not show improvement of appetite, weight gain, and statural growth despite reaching these target doses, reflecting clinical signs of underdialysis. Increasing blood flow up to 200 ml/min/m^2, using online hemodiafiltration with a high flux dialyzer, will improve not only small solute clearance but also the (not measurable) clearance of other uremic toxins. Moreover, in chronic dialysis, increasing total dialysis time via increasing the number of dialysis sessions per week should be taken into consideration (see Chap. 15 on intensified regimens).
4. Volume overload leads to hypertension and left ventricular hypertrophy, resulting in increased morbidity and mortality in pediatric and adult hemodialysis patients [7]. Volume control can be achieved by the mainstays of adequate ultrafiltration and fluid restriction. Current recommendations allow an amount of fluid removal of 1.5–2% per hour of estimated dry weight. The prescription of ultrafiltration during each hemodialysis session should have two main goals: achieving the estimated dry weight (see Chap. 26) and avoiding adverse effects of fluid removal. Aggressive fluid removal can lead to intradialytic hypotension with painful symptoms like headache, muscle cramps, abdominal pain, and vomiting. Moreover, associations between intradialytic hypotension, cardiac stunning, and poor survival have been observed, even among patients with normal coronary arteries, which is the case in most children [8]. Therefore, volume control should preferably be achieved via controlled fluid intake rather than by aggressive removal. Fluid restriction must be accompanied by a restriction of dietary salt: to maintain osmotic balance, every 8 g of salt intake prompts the intake of 1 L of free water.

Case 2: Hemodialysis Prescription in an Uncooperative Patient

A 16-year-old girl (143 cm, 40 kg) is transferred to the pediatric dialysis unit for hemodialysis treatment because of chronic transplant failure. A short trial with peritoneal dialysis had to be terminated because of relapsing peritonitis. The primary renal disease is congenital nephrotic syndrome with bilateral nephrectomy. Relevant comorbidities are inner ear deafness and severe mental retardation. Deceased donor transplantation was performed at the age of 18 months, with subsequent loss of the allograft to rejection.

Hemodialysis was started with a central venous catheter due to expected lack of cooperation and restlessness during dialysis sessions. As the catheter was repeatedly torn out by the patient, an arteriovenous fistula was created on the left upper arm and punctured with flexible cath needles. Hemodialysis sessions were performed with permanent presence of a family member. Frequently, additional sedation with diazepam was needed to allow performance of hemodialysis.

Hemodiafiltration was performed with the local standard prescription of three times weekly for 4 h with a blood flow of 250 ml/min using a high flux dialyzer with a 1.4 m^2 surface area. However, frequently interrupted sessions and flow problems led to inadequately low dialysis dose with an average weekly Kt/V of 3.6 and corresponding pre-dialysis blood values of 30 mmol/l BUN and 2.8 mmol/l phosphate. Even more importantly, excessive fluid intake at home resulted in overt chronic overhydration and high blood pressure. Repeated attempts to increase ultrafiltration or to extend the duration of the dialysis sessions were not tolerated by the patient, and additional dialysis sessions were not accepted by the stressed family. Intense and repeated training of the family aimed for strictly reduced salt intake and finally led to a tolerable level of blood pressure, although estimated dry weight was never reached.

Clinical Questions

1. How to prescribe dialysis dose in a restricted dialysis setting?
2. How to manage volume control in a restricted dialysis setting?
3. How to prescribe anticoagulation in an uncooperative patient on hemodialysis?
4. How to deal with uncooperative patients who depend on hemodialysis?

Diagnostic Discussion

1. In case of a restricted dialysis situation as exemplified by this case of a severely mentally impaired adolescent, the delivery of an optimal or even adequate dialysis dose can be challenging. In this setting with lacking cooperation and agitation during dialysis sessions, the choice of access is not necessarily guided by the optimal medical standards but needs to consider in the first place what creates the least discomfort and self-endangerment for the patient. A central venous catheter eliminates the need for repetitive puncture of an arteriovenous fistula and the risk

of needle dislocation during dialysis but subjects the patient to the risk of accidental or deliberate catheter removal. In the described patient, the sum of these factors led to a dialysis dose that remained constantly below currently suggested minimal levels.

While "conventional" dialysis aims to achieve optimal dialysis quality and is regarded as a rehabilitative treatment, in a restricted situation, it might be necessary to accept certain trade-offs. In such a situation, the approach can be to prioritize comfort and alignment with patient preferences to improve quality of life and reduce the burden of dialysis. While rigorous dialysis quality standards should be applied whenever possible, these guidelines may have less relevance for a certain subgroup of patients [9, 10]. Palliative care in ESRD has become an important issue in the "geriatric renal community," but integrating medical, social, and ethical considerations from that paradigm may be helpful to provide better individualized care for a pediatric patient with comparable needs. Such liberalizations in protocols may be regarded as medically suboptimal, yet they can make a huge difference for patients and families.

2. It was obvious that adequate fluid removal could not be performed in our patient despite increasing the prescription to the maximal tolerated ultrafiltration rate of 2% per hour of estimated dry weight.

   As neither longer hemodialysis sessions nor intensified dialysis with 5–6 sessions per week were tolerated by the girl and her family, we had to focus on interdialytic fluid management. Isolated fluid restriction is often not practicable as permanent thirst will result in psychological distress to the whole family and an inacceptable reduction of quality of life. Thirst on the other hand is in most cases the result of high salt intake that subsequently has to be satisfied by water ingestion. In such patients, control of fluid status and blood pressure can only be accomplished by a substantial and sustained reduction of dietary salt intake. This approach became successful in our case when the change in dietary habits was extended to the whole family [11].

3. Anticoagulation in the extracorporeal circuit is needed to prevent clotting in the dialysis filter or tubes and inherently increases the risk of bleeding events. In patients with mental retardation, a central venous catheter includes a higher risk of bleeding if the incompliant patient pulls out the catheter. With an arteriovenous fistula, the patient may pull out the needle during dialysis, and the compliance for adequate compression after dialysis sessions may be absent.

   Some patients with mental retardation have a high risk of thrombosis, i.e., if they are immobilized due to their neurological disease and therefore dependent on chronic systemic anticoagulation. These patients may benefit from heparin-based or oral anticoagulation without the need for extra medication during dialysis.

   Most standard hemodialysis anticoagulation protocols are heparin based. However, if the patient is prone to auto-aggressive self-injuries or at risk of accidents due to hyperactivity, bleeding risk should be minimized with an altered anticoagulation management. In such patients, regional citrate anticoagulation may be an option [5]. For citrate dialysis, stable blood flow rates are needed, but these may be difficult to achieve in the uncooperative patient because of uncontrollable movements and arm and body position. In individual cases, even a regime without anticoagulation may be possible, with short dialysis sessions, high blood flow rates, and intermittent saline flushes.

Taken together, patients with mental retardation on hemodialysis present additional special needs and risks for bleeding or thrombotic complication that have to be taken into account when individualizing anticoagulation management. In any case, particularly close monitoring of anticoagulation to avoid over-treatment is recommended in these patients, such as frequent ACT measurements in heparinization.

4. The need to hemodialyze pediatric patients with mental retardation is increasing and presents major challenges [12]. Similar to young infants, mentally impaired patients cannot understand why they are receiving dialysis and are unable to fully cooperate with the associated procedures, in particular if these are painful or restrictive. These patients may profoundly refuse dialysis and may try to pull out dialysis needles and catheters and thereby endanger themselves, dialysis staff, and other patients. In contrast to young children, however, older children with cognitive or behavioral impairment frequently are of considerable physical strength and are able to create a hostile environment by verbal and physical acts and threats of violence.

   Routine medical sedation before dialysis is risky in the chronic setting; physical restraints cause additional emotional stress and – besides violation of ethical and dignity aspects – are ineffective and will likely even exacerbate an already challenging situation. Probably the best care in patients with cognitive impairment is the introduction of strictly fixed routine protocols that allow patients to accommodate to the repeated dialysis-associated procedures, together with support of a trusted (ideally loved) contact person acting as a "sitter." This "sitter" can create an atmosphere of trust and care, while the dialysis center personnel perform their tasks, help the patients to tolerate necessary painful procedures, and distract and pacify them to remain calm during the dialysis session. In patients who are living with their families, the "sitter" is usually a family member. This represents a major advantage with regard to trust but poses additional stress on the family member who is also not used to the dialysis procedure and will need significant training and counseling to be able to see stressful conditions from the staff's point of view [13]. In contrast, nonfamily members sitting for the patient will more readily identify with the dialysis staff position but may face a greater challenge being accepted by the patient and creating a calm and trusting environment.

   In any case, hemodialysis in uncooperative pediatric and adolescent patients with mental impairment causes major challenges to the patients, their families and the caregivers but are mostly feasible to handle by experienced hemodialysis staff with the support of a trusted "sitter" team. Currently, there is increasing awareness of the need for guidelines supporting the dialysis staff in these situations in adult patients due to the increasing prevalence of patients with dementia, likely resulting in valuable information for the pediatric community [14].

Clinical Pearls

1. Choice of dialysis machine, frequency, and duration of dialysis sessions depends on center policy. Choice of dialyzer, flow rates, and extracorporeal blood volume depends on patient size and treatment targets.
2. Hemodialysis dosing is determined by treatment time, dialyzer size, blood and dialysate flow rates. The definition of targets is derived from adult guidelines; therefore, individual clinical assessment of appetite, weight gain, and growth remains essential to detect underdialysis.
3. Standard anticoagulation regimes are based on unfractionated or low-molecular-weight heparin; alternate options are indicated in special situations, such as regional citrate anticoagulation in patients with increased bleeding risks or heparin-induced side effects.
4. Volume control is essential to prevent cardiovascular morbidity and mortality and should preferably be achieved via controlled fluid intake rather than by aggressive removal.
5. In restricted dialysis situations, it might be necessary to prioritize comfort and alignment with patient and family preferences to improve quality of life and reduce the burden of dialysis.

References

1. Warady BA, et al. Pediatric dialysis. New York: Springer; 2012.
2. Daugirdas JT, Blake PG, Ing TS. Handbook of dialysis. 5th ed. Philadelphia: Wolters Kluwer Health; 2014.
3. Fischbach M, et al.; The European Pediatric Dialysis Working Group. Hemodialysis in children: general practical guidelines. Pediatr Nephrol 2005;20(8):1054–66.
4. Kessler M, et al. Anticoagulation in chronic hemodialysis: progress toward an optimal approach. Semin Dial. 2015;28(5):474–89.
5. Fajardo C, et al. Inpatient citrate-based hemodialysis in pediatric patients. Pediatr Nephrol. 2016;31(10):1667–72.
6. Gotch FA, et al. A mechanistic analysis of the national cooperative dialysis study (NCDS). Kidney Int. 1985;28:526–34.
7. Paglialonga F, Consolo S, Galli MA, Testa S, Edefonti A. Interdialytic weight gain in oligoanuric children and adolescents on chronic hemodialysis. Pediatr Nephrol. 2015;30(6):999–1005.
8. Hothi DK, Rees L, McIntyre CW, Marek J. Hemodialysis-induced acute myocardial dyssynchronous impairment in children. Nephron Clin Pract. 2013;123(1–2):83–92.
9. Grubbs V, et al. A palliative approach to dialysis care: a patient-centered transition to the end of life. Clin J Am Soc Nephrol. 2014;9:2203–9.
10. Vandecasteele SJ, et al. A patient-centered vision of care for ESRD: dialysis as a bridging treatment or as a final destination? J Am Soc Nephrol. 2014;25:1647–51.
11. Lindley EJ. Reducing sodium intake in hemodialysis patients. Semin Dial. 2009;22(3):260–3.
12. Watson AR, et al. Factors influencing choice of renal replacement therapy in European paediatric nephrology units. Pediatr Nephrol. 2013;28(12):2361–8.
13. Mieto FS, et al. The mothers' experiences in the pediatrics hemodialysis unit. J Bras Nefrol. 2014;36(4):460–8.
14. Allon M, et al. The demented patient who declines to be dialyzed and the unhappy armed police officer son: what should be done? Clin J Am Soc Nephrol. 2014;9(4):804–8.