Supplemental Appendix

Air Embolism Case study

A 45 year-old man had been undergoing an uneventful hemodialysis session, when his blood clotted in the tubing. The dialysis technician, in violation of unit protocol, utilized a hand crank to return the blood manually to the patient. The patient became acutely combative, and developed weakness, numbness and tingling in his left upper and lower extremities, as well as a left facial droop. He was immediately transferred to a emergency room. A thorough evaluation for an ischemic stroke or an arrhythmia was unrevealing. His neurologic symptoms resolved within few hours, and he had no recurrence during subsequent dialysis sessions. Examination of the sequestered dialysis tubing revealed a large amount of blood clots and air. No mechanical or computer problems were identified in the dialysis machine. In summary, this patient developed a transient ischemic attack as a consequence of an acute air embolism during a dialysis session resulting from human error.

Hemolysis Case study

A 52 year-old woman with end-stage renal disease developed back pain, chest tightness and shortness of breath one hour after starting a hemodialysis session. The dialysis nurse noted a pink dialysate effluent. The dialysis session was stopped without returning the extracorporeal blood to the patient. Further evaluation revealed kinking of the arterial bloodline. The patient was sent to the emergency room, where she was noted to have pink serum, schistocytes on a peripheral smear, and hyperkalemia (serum potassium 6.7 mmol/L) with peaked T-waves on the electrocardiogram. She was dialyzed in the hospital with resolution of her hyperkalemia and symptoms.

Venous Needle Dislodgement Case study

A 74 year-old woman with dementia and intermittent confusion initiated a routine dialysis session with a blood pressure of 160/80. Two hours later, she suddenly became unresponsive, and her repeat systolic blood pressure was 70 mm Hg. The pressure alarms were not triggered. The dialysis nurse lifted the patient's blanket and noted dislodgement of the venous needle from the thigh graft, with a large pool of blood between the patient's legs and on the floor. The patient was placed in the Trendelenburg position, the blood pump turned off, and direct pressure applied to the venous needle site. Three liters of normal saline were infused rapidly. The patient subsequently became responsive and her repeat blood pressure was 120/70. This case illustrates several important principles regarding VND: (1) Patients with dementia are at increased risk of VND due to their propensity to inadvertently pull the needles from their access; (2) There was a delay in discovering the complication because the access area was covered by a blanket during the dialysis session; (3) The lack of a pressure alarm being triggered gave the nurse a false sense of security; and (4) prompt, appropriate emergent management once the complication was recognized prevented a catastrophic outcome.

Allergic reaction Case study

A 25 year-old man had an uneventful first dialysis session and was discharged home to continue outpatient dialysis. Within five minutes of starting his second dialysis session, he developed chest pain, dyspnea, wheezing, and hypotension. He rapidly proceeded to have a full cardiac arrest and could not be resuscitated. His autopsy revealed no evidence of a myocardial infarction, clean coronary arteries, no pulmonary embolism, and no evidence of hemorrhage. The post-mortem

serum IgE levels were 100-fold higher than normal values, indicating an anaphylactic reaction. Review of his medical records revealed that his first dialysis session (in the hospital) used a steam-sterilized dialyzer, whereas his second session (at the outpatient dialysis unit) used a different dialyzer sterilized with ethylene oxide. In summary, this patient experienced a fatal (Type A) anaphylactic shock due to hypersensitivity to ethylene oxide.

Other errors during dialysis

There are multiple arenas in the dialysis environment wherein human error may potentially cause a dialysis emergency. The most common errors include failure to follow the dialysis prescription, errors in the dialysate composition, contamination of the water system, administration of the wrong medication or dose, and cross-contamination [1, 2]. To minimize human error, all dialysis units follow a culture of safety with appropriate training, continuing education, treatment protocols, verifying medications, uniformity in dialyzer use, and root cause analysis. Deviation from these protocols may lead to catastrophic consequences. For example, death during dialysis has occurred rarely as a consequence of addition of bleach to water supply or an error in the composition of the dialysate[3]. The case study below illustrates a dialysis emergency arising from an error in preparing the dialysate.

Hypocalcemia Case study

A 37 year-old man with end-stage renal disease developed facial numbness and tingling in his extremities one hour after starting dialysis, and was sent to the emergency room. He had severe hypocalcemia (serum calcium 5.8 mg/dl) with a positive Chvostek sign and a prolonged QT interval on his electrocardiogram. A continuous intravenous calcium infusion normalized his

serum calcium and resolved his symptoms. His pre-dialysis serum calcium had been 9.5 mg/dl four days earlier on routine monthly laboratory evaluation.

The standard dialysate calcium concentration at this patient's dialysis unit was 2.5 mEq/L (5 mg/dl). Several weeks earlier, he had been switched to a 2.0 mEq/L dialysate calcium concentration due to persistent hypercalcemia. This required the nurse to use a "0 calcium" jug, and manually add 2.0 mEq/L calcium. On that particular day, the nurse had labeled the jug as having a 2.0 mEq/L calcium concentration, but forgot to add calcium. As a consequence of this human error, the patient had inadvertently been dialyzed against a calcium-free dialysate, thereby precipitating severe hypocalcemia.

A comprehensive review of all dialysis prescriptions at this 60-patient unit revealed that 31 patients were prescribed an unconventional dialysate potassium or calcium. Clearly, the large number of unconventional dialysis prescriptions increased the risk of human error that could potentially lead to future dialysis emergencies. Consequently, 29 patients were resumed on a standard dialysate, and only two patients were continued on a high (3.5 mEq/L) dialysate to treat hypocalcemia subsequent to a recent parathyroidectomy.

Emergencies during home hemodialysis (HHD)

With the recent growth of home hemodialysis, adverse events may be seen more often with this modality. A retrospective study of 29 patients who had dialyzed at an in-center initially for 6 months, followed by HHD for 6 months was evaluated. The number of adverse events reported was 5.84/100 treatments for in-center as compared to 3.34 /100 treatments for home-HD with no deaths[4]. A prospective crossover study of in-center HD (ICHD) followed by HHD showed an adverse event rate of 5.3/100 treatments for ICHD as compared to 2.1 for HHD[5]. Although, there

could be bias in regards to occurrence and reporting of increase adverse events during in-center HD (ICHD was the initial phase), it is probable that the adverse events during HHD were not significantly higher than ICHD[5]. Subsequent studies on HHD have shown a rate of 0.038/1000 dialysis treatment for severe adverse events requiring intervention; 0.06/1000 dialysis treatments for life-threatening events[6, 7]. These adverse events have been mostly related to blood loss or suspected air embolism. Other adverse events including fatal hemorrhage from venous needle dislodgement, vascular access rupture and exsanguination into saline bag due to faulty wash-back procedure have been reported[8-10].The reader is encouraged to read recent excellent articles on home hemodialysis and its safety[6, 10, 11].

References

1. Kliger, AS: Maintaining safety in the dialysis facility. *Clin J Am Soc Nephrol,* 10**:** 688-695, 2015.
2. Holley, JL: A descriptive report of errors and adverse events in chronic hemodialysis units. *Nephrol News Issues,* 20**:** 57-58, 60-51, 63 passim, 2006.
3. Dialysis error demands full investigation. http://www.edmontonjournal.com/simons+dialysis+error+demands+full+investigation/11106626/story.html.Accessed May 2nd, 2016.
4. Sands, JJ, Lacson, E, Jr., Ofsthun, NJ, Kay, JC, Diaz-Buxo, JA: Home hemodialysis: a comparison of in-center and home hemodialysis therapy in a cohort of successful home hemodialysis patients. *ASAIO J,* 55**:** 361-368, 2009.
5. Kraus, M, Burkart, J, Hegeman, R, Solomon, R, Coplon, N, Moran, J: A comparison of center-based vs. home-based daily hemodialysis for patients with end-stage renal disease. *Hemodial Int,* 11**:** 468-477, 2007.
6. Wong, B, Zimmerman, D, Reintjes, F, Courtney, M, Klarenbach, S, Dowling, G, Pauly, RP: Procedure-related serious adverse events among home hemodialysis patients: a quality assurance perspective. *Am J Kidney Dis,* 63**:** 251-258, 2014.
7. Tennankore, KK, d'Gama, C, Faratro, R, Fung, S, Wong, E, Chan, CT: Adverse technical events in home hemodialysis. *Am J Kidney Dis,* 65**:** 116-121, 2015.
8. Allcock, K, Jagannathan, B, Hood, CJ, Marshall, MR: Exsanguination of a home hemodialysis patient as a result of misconnected blood-lines during the wash back procedure: a case report. *BMC Nephrol,* 13**:** 28, 2012.
9. Gill, JR, Storck, K, Kelly, S: Fatal exsanguination from hemodialysis vascular access sites. *Forensic Sci Med Pathol,* 8**:** 259-262, 2012.
10. Hawley, CM, Jeffries, J, Nearhos, J, Van Eps, C: Complications of home hemodialysis. *Hemodial Int,* 12 Suppl 1**:** S21-25, 2008.
11. Pauly, RP, Eastwood, DO, Marshall, MR: Patient safety in home hemodialysis: quality assurance and serious adverse events in the home setting. *Hemodial Int,* 19 Suppl 1**:** S59-70, 2015.