The Acute Dialysis Orders Objective Structured Clinical Examination (OSCE)

Fellow Performance on a Formative Assessment of Acute Kidney Replacement Therapy Competence

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Abstract

Background and objectives Acute kidney replacement therapy (KRT) prescription is a critical nephrology skill. We administered a formative objective structured clinical examination (OSCE) to nephrology fellows to assess acute KRT medical knowledge, patient care, and systems-based practice competencies.

Design, setting, participants, & measurements Prospective cohort study of an educational test using the unified model of construct validity. We tested 117 fellows: 25 (four programs) in 2016 and 92 (15 programs) in 2017; 51 first-year and 66 second-year fellows. Using institutional protocols and order sets, fellows wrote orders and answered open-ended questions on a three-scenario OSCE, previously validated by board-certified, practicing clinical nephrologists. Outcomes were overall and scenario pass percentage and score; percent correctly answering predetermined, evidence-based questions; second-year score correlation with in-training examination score; and satisfaction survey.

Results A total of 76% passed scenario 1 (acute continuous RRT): 92% prescribed a ≥20 ml/kg per hour effluent dose; 63% estimated clearance as effluent volume. Forty-two percent passed scenario 2 (maintenance dialysis initiation); 75% correctly prescribed 3–4 mEq/L K+ dialysate and 12% identified the two absolute, urgent indications for maintenance dialysis initiation (uremic encephalopathy and pericarditis). Six percent passed scenario 3 (acute life-threatening hyperkalemia); 20% checked for rebound hyperkalemia with two separate blood draws. Eighty-three percent correctly withheld intravenous sodium bicarbonate for acute hyperkalemia in a nonacidotic, volume-overloaded patient on maintenance dialysis, and 32% passed overall. Second-year versus first-year fellow overall score was 44.4±4 versus 42.7±5 (one-tailed P=0.02), with 39% versus 24% passing (P=0.08). Second-year in-training examination and OSCE scores were not significantly correlated (r=0.15; P=0.26). Seventy-seven percent of fellows agreed the OSCE was useful in assessing "proficiency in ordering" acute KRT. Limitations include lack of a validated criterion test, and unfamiliarity with open-ended question format.

Conclusions The OSCE can provide quantitative data for formative Accreditation Council for Graduate Medical Education competency assessments and identify opportunities for dialysis curriculum development.

CJASN 14: 1346–1354, 2019. doi: https://doi.org/10.2215/CJN.02900319

Introduction

We previously developed an acute dialysis objective structured clinical examination (OSCE) to formatively assess fellow competence in managing three commonly encountered situations requiring acute kidney replacement therapy (KRT): (*1*) acute continuous RRT (CRRT), (*2*) maintenance hemodialysis (HD) initiation in moderate uremia, and (*3*) acute HD for life-threatening hyperkalemia and volume overload in ESKD (1). Examinees use institutional procedures and order sets to write scenario-specific dialysis orders, and then answer related, open-ended questions. Two questions per scenario address evidence-based concepts. The OSCE does not require sophisticated simulation techniques, takes <2 hours, is easy to administer, and is freely available.

Acute HD and CRRT are critical nephrology skills that are difficult to quantitatively and longitudinally assess in high-stakes summative examinations using multiple choice questions, the format of the nephrology certifying and in-training examinations. The 2018 American Board of Internal Medicine nephrology certification examination blueprint indicates that 11.5% of questions pertain to ESKD (HD, peritoneal dialysis and their complications; home HD; ESKD complications; and dialysis medical director topics), and 4% to acute KRT (2). Thus, few questions on the certifying or in-training examination (which parallels the certifying

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examination) directly assess acute KRT prescribing ability (3). The Accreditation Council for Graduate Medical Education (ACGME) milestones framework requires program directors ensure fellows demonstrate skill in performing acute and maintenance dialysis, a Patient Care sub-competency (4).

We prospectively administered the OSCE to fellows at 15 training programs in 2016 and 2017, determining performance overall, on each scenario, and on clinically relevant, evidence-based questions. We compared first- and second-year fellow scores and evidence-based question performance. We also assessed fellow and program director satisfaction with the OSCE as a formative assessment.

Materials and Methods

Test Development and Initial Validation

As previously described, the test assesses medical knowledge, patient care, and systems-based practice competencies in three common, critically necessary, acute KRT skills (1). They are as follows: scenario 1, acute CRRT in a septic, hypotensive oncology patient; scenario 2, maintenance HD initiation in a moderately uremic patient with CKD, with congestive heart failure and volume overload; and scenario 3, acute HD in a patient on maintenance dialysis with severe, life-threatening hyperkalemia and volume overload. The blueprint, questions, and rubric (Supplemental Material, Appendices 1,2, and 3) were developed by the principal investigators (L.K.P. and C.M.Y.) and refined by a nine-member test committee of board-certified, practicing clinical nephrologists. Examinees write dialysis orders for each scenario (history, physical examination, radiology and laboratory data), and answer open-ended clinical questions. Institutional order sets/protocols are used at the program director's discretion.

Passing score was determined by the test committee (1,5,6), and validated by ten board-certified, practicing volunteers (median 3.5 years from graduation), none of whom were on the test committee. There were 49 test items (58 points). As previously described (Table 1), pass threshold was 46 out of 58 points (15 out of 20 for scenario 1; 17 out of 21 for scenario 2, and 14 out of 17 for scenario 3) (1). No item had a median relevance less than "important," and 95% of positive point items were rated easy to medium difficulty. Content validity index (a measure of how well test items represent essential dialysis skills) was 0.91 (95% confidence interval [95% CI], 0.85 to 0.95) (1,7,8). There were two evidence-based questions per scenario (9–14). Validator tests were graded using the rubric (L.K.P. and C.M.Y., blinded to the other's scoring). Inter-rater reliability was good (κ=0.68; 95% CI, 0.59 to 0.77). Median test time was 75 minutes. Mean validator score was 49±3 (95% CI, 46 to 51). Cronbach α (a measure of test item internal consistency) was 0.84 for validators and 0.76 for fellows (1,15,16).

Fellow Testing

The testing protocol was approved by the Walter Reed National Military Medical Center (WRNMMC) Department of Research Programs as exempt from institutional review board review per 32CFR219.101(b) (1,2).

Four ACGME-accredited programs (including WRNMMC) administered the OSCE in May–July 2016. One did not test first-year fellows. Results are reported in the initial validation study (1). Fifteen ACGME-accredited programs

Table 1. Acute dialysis orders objective structured clinical examination description

Question Scenario and Topic (1)	Total Points	Passing Score (%)	Evidence-Based/Standard-of-Care Questions
1. Order acute CRRT in a septic, acidemic, hypoxic, coagulopathic, hypotensive, oncology patient.	20	15 (75)	A. Correct for hypalbuminemia when calculating anion gap. B. Obtain at least 20 ml/kg per hour effluent. C. (2017 administration only) Estimate clearance using effluent rate.
2. Order maintenance HD initiation for a uremic patient with volume overload and an AV fistula[a]	21	17 (81)	A. Avoid low K dialysate (<3 meq/L) in those with normal serum K, unless only a low K dialysate is available. B. Identify uremic encephalopathy (mild to severe) and serositis (pleural, pericardial) as urgent/absolute indications for dialysis.
3. Manage acute, life-threatening hyperkalemia and volume overload in anuric patient with ESKD on maintenance HD[b]	17	14 (82)	A. Bicarbonate therapy not indicated in acute hyperkalemia in volume-overloaded patient with ESKD without acidosis. Negligible effect. B. Repeat serum K at 2–4 h and at 6 h after dialysis, due to rebound.
Overall	58	46 (79)	NA

CRRT, continuous RRT; HD, hemodialysis; AV, arteriovenous; K, potassium; NA, not applicable.
[a]One item could yield one bonus point (use of smaller gauge dialysis needles in a new AV fistula in scenario 2).
[b]Points could be lost on this question if intravenous sodium bicarbonate was administered (−1 point), if epinephrine was administered (−1 point), or if intravenous Lasix was administered in this anuric patient with ESKD (−1 point).

(including those from 2016) tested fellows in May–August 2017.

Each program received a randomly generated numeric identifier series equal to the number of fellows scheduled. Fellows were assigned an identifier by the program, with fellow-identifier association known only to the program. Fellows from the four programs that tested both years were assigned new identifiers in the second year, not linked to those used previously. Examinees were told beforehand when the OSCE would be given, knew the general topic, but were not encouraged to study for it. They had 2 hours to complete the test, and indicated on the answer sheet their training year (second-year fellows testing in July and August were scored as first-year fellows), time to take the test, and in 2017, whether they had taken the test before. After testing, they received a link for an optional, online, anonymous satisfaction survey. Program directors also received a link for their own anonymous survey (Supplemental Material, Appendices 4 and 5).

Program directors graded the test and shared results with fellows. Using the identifier, they submitted the total score, each scenario score, and in-training examination score for the same training year. Graded tests (anonymous identifier only) were returned to WRNMMC for rescoring (L.K.P. or C.M.Y.) and evidence-based question scoring.

Evidence-based questions 2B (uremic encephalopathy and serositis/pericarditis as urgent/absolute indications for initiation of maintenance dialysis) (12) and 3B (repeat serum potassium (K) at 2–4 and 6 hours after dialysis for acute hyperkalemia to check for rebound) (14) were answered incorrectly by >50% of fellows during initial validation (1). In 2017, we expanded analysis of these questions. We also recorded whether fellows correctly estimated CRRT clearance as effluent volume (scenario 1) (17) Objectives were as follows:

(1) to determine median time to take the OSCE;
(2) to determine interrater scoring agreement between programs and WRNMMC investigators;
(3) to determine overall and scenario pass percentages and mean scores, hypothesizing that second-year fellows (third-years analyzed as second-years) would perform better than first-year fellows, and fellows in programs testing in 2016 would improve in 2017, and perform better than those at programs administering the test for the first time;
(4) to identify evidence-based questions incorrectly answered by >50% of second-year fellows;
(5) to determine fellow satisfaction with the OSCE as a formative evaluation tool;
(6) to determine whether OSCE score correlated with in-training examination score for second-year fellows (3,18).

Statistical Analyses

Percentages, medians (ranges), means (SD and 95% CI), and counts reported as appropriate. *t* Test, Fisher exact test, κ statistic, and Pearson *r* statistic were used as appropriate. Significance thresholds were $P<0.05$. One-tailed *P* values used for comparisons between second- and first-year fellows, using the hypothesis that second-year fellows would perform significantly better than first-year fellows. All other comparisons were two-tailed.

Results

Fifteen programs participated in 2017. Four were repeat programs (2016 and 2017). Figure 1 shows the testing flow diagram. A total of 117 fellows took the test (51 first- and 66 second-year fellows, including three third-years), and 114 tests were rescored by WRNMMC. Of these, 105 were program-scored. Repeat programs tested 25 fellows in 2016 (seven first- and 18 second-year) and 22 fellows in 2017 (11 first- and 11 second-year). Eight fellows (all second-year) self-identified as having tested in 2016 and 2017.

In total, 105 out of 117 tests were graded by the program and at WRNMMC. Inter-rater agreement for passing overall between programs and WRNMMC was moderate (κ=0.56; 95% CI, 0.40 to 0.72). Programs passed 44 out of 105 (42%) overall, whereas WRNMMC scorers passed 36 out of 105 (34%) (P=0.32).

Median testing time reported by first-time takers (n=86) was 65 minutes (range 35–120 minutes). Correlation between testing time and overall score was weak (Pearson r =0.22; P=0.05).

Overall and scenario scores are shown in Table 2. Fellows performed best on scenario 1 (acute CRRT), with 76% passing, and intermediately on scenario 2 (urgent initiation of maintenance HD), with 43% passing. They performed least well on scenario 3 (management of severe hyperkalemia in ESKD), with 6% passing. Second-years were no more likely to pass overall or for a given scenario than first-years, although their mean scores were higher for the overall test and for scenario 2.

Figure 2 shows performance on evidence-based questions. Overall, second-years performed no better than first-years (56% versus 58% correct; P=0.36). Ninety-two percent correctly prescribed ≥20 ml/kg per hour effluent volume CRRT dose in scenario 1 (Q1B). Sixty-three percent calculated CRRT clearance as effluent volume (Q1C), a question considered "hard" by the test committee. Seventy-five percent correctly prescribed a 3–4 mEq/L K dialysate for maintenance HD initiation of a patient with a normal serum K (Q2A), and 83% recognized that intravenous bicarbonate was not indicated in a volume-overloaded, hyperkalemic patient on maintenance HD without acidosis (Q3A).

Two evidence-based questions were answered correctly by <50% of fellows. Only 12% correctly identified the two urgent/absolute indications for maintenance dialysis initiation—uremic encephalopathy and serositis/pericarditis (Q2B). We investigated this further in 2017, and 61% identified pericarditis and 39% identified encephalopathy as urgent/absolute indications for maintenance dialysis initiation. Eighty-nine percent indicated "uremia" (without qualifiers) as an indication. Only 3% made no mention of any uremic symptom or sign as an urgent indication. The other question (Q3B) required that K levels be checked for rebound at 2–4 and 6 hours after HD for acute hyperkalemia. Only 20% answered correctly, but 93% (82 out of 88) did check K at least once between 2 and 6 hours after dialysis.

Fellows at the four repeating programs did not have higher pass percentages or scores in 2017 versus 2016. In 2016, 36% (nine out of 25) passed versus 45% (ten out of 22) in 2017 (P=0.56, Fisher exact test, two-tailed). Overall scores were not significantly different: 44.1±3.3 (2016) versus 44.9±5.9 (2017) (P=0.56; *t* test, two-tailed). In 2017, fellows

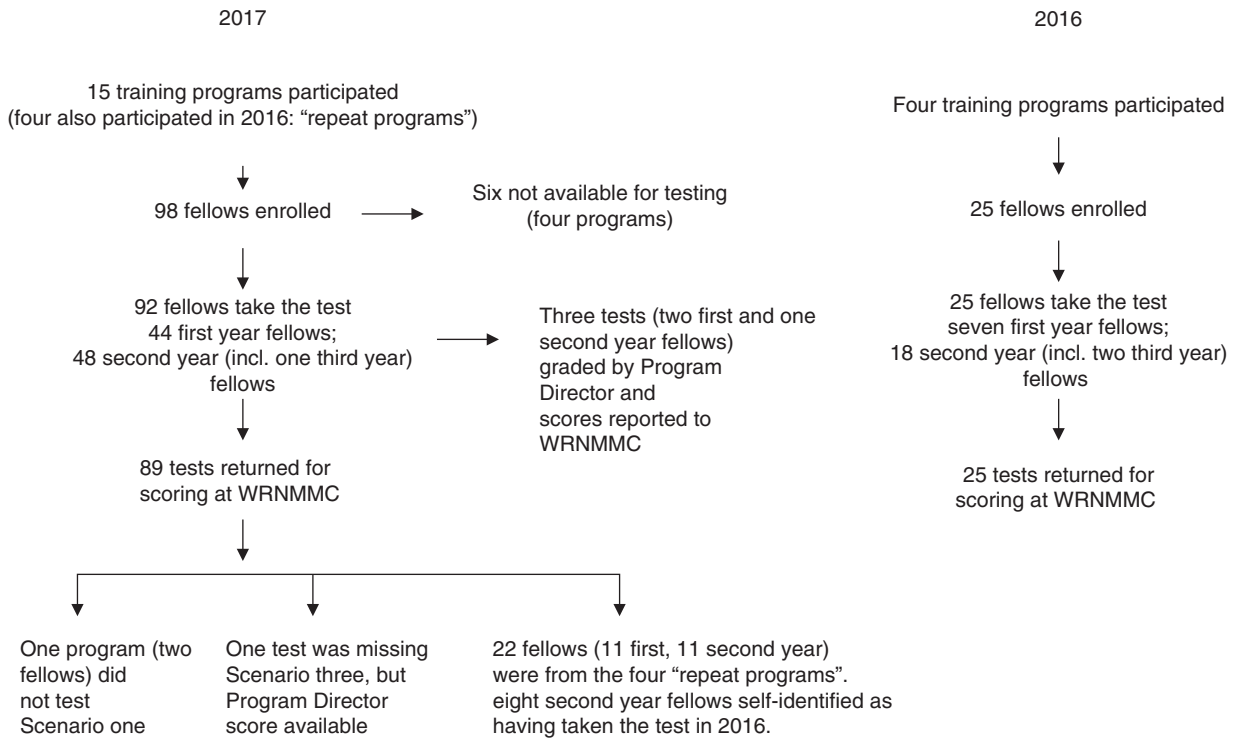

Figure 1. | Flow diagram of fellow testing in 2016 and 2017.

from the four repeating programs (n=22) did not have significantly higher pass percentages than those from the 11 first-time programs (n=64): 45% (ten out of 22) versus 25% (16 out of 64) (P=0.11, Fisher exact test, two-tailed). However, in 2017, 64% of second-year fellows from repeating programs (n=11) passed overall (Figure 3), significantly greater than the overall pass percentage for first-year fellows at programs initially giving the OSCE in 2016 and 2017 (n=38, 24%; P=0.03, Fisher exact test, two-tailed), but not significantly greater versus first-years (n=11) at the four repeating programs, or second-years in 2016 and 2017 at programs initially giving the test (n=51).

There was no significant correlation between in-training examination scores and overall OSCE score for second-year fellows (n=57; Pearson r=0.15; P=0.26).

The fellow satisfaction survey (2016 and 2017) had a 56% response (65 out of 117; first-years 51%, second-years 58%). Over 80% strongly agreed/agreed that each scenario "permitted me to assess my proficiency" in ordering KRT (Figure 4). Seventy-seven percent strongly agreed/agreed the OSCE overall was "useful to me in assessing my proficiency in ordering" acute KRT.

In 2017, the program director satisfaction survey response was 80% (12 out of 15). Seventy-five percent strongly agreed/agreed that overall the OSCE was "useful to fellows in assessing their proficiency in ordering" acute KRT. Program director feedback indicated that many institutions' CRRT orders (especially hemodynamic monitoring and citrate anticoagulation) are protocolized templates, and fellows may not be able to reproduce orders without referring to them. Another criticism was that some questions confused fellows, who were unsure of the detail needed or the type of answer being sought.

Discussion

The acute dialysis orders OSCE is a formative assessment (1,19,20), testing commonly used, critically important KRT skills. Locally graded, it permits timely, personalized feedback. Program directors may identify specific fellow or curriculum deficiencies, and adjust accordingly. Fellows have the opportunity for self-assessment in a low-stakes setting.

The OSCE evaluates the ACGME Patient Care and Systems-Based Practice competencies, asking fellows to translate medical knowledge into clinical practice (4). The simulation is simple, inexpensive, and freely available. Standardized patients and sophisticated equipment are not required. Scenarios may be given individually, if desired.

We addressed OSCE construct validity as a unified model, assessing content, response process, internal structure, relation to other variables, and consequences (21). We previously focused on content and internal structure (1). The OSCE was developed and initially validated by clinically active, board-certified nephrologists, who knew the "performance domain" of acute dialysis (7). The content validity index indicated test items were highly representative of the construct, with relevance "essential" or "important" for all test items. Test items appear to have internal consistency (*i.e.*, item performance correlates with the overall test outcome), assessed by Cronbach α (15,16). Inter-rater reliability was good for investigator graders (1), and moderate for programs versus investigators (programs tended to

Table 2. Results of fellow testing

Test Overall[a]	All Fellows	First Year	Second Year	*P* Value (First versus Second Year)[b]
No. of fellows	111	49	62	NA
Overall score, mean±SD (95% CI)	43.6±4.6 (42.7 to 44.5)	42.7±5.0 (41.3 to 44.1)	44.4±4.0 (43.4 to 45.4)	*P*=0.02
Proportion reaching pass threshold (46/58 points)	32% (36/111)	24% (12/49)	39% (24/62)	*P*=0.08
Scenario 1				
No. of fellows	112	49	63	NA
Overall score, mean±SD (95% CI)	16.1±2.0 (15.7 to 16.5)	16.0±1.9 (15.5 to 16.5)	16.3±2.1 (15.8 to 16.8)	*P*=0.2
Proportion reaching pass threshold (15/20 points)	76% (85/112)	69% (34/49)	81% (51/63)	*P*=0.1
Scenario 2				
No. of fellows	114	49	65	NA
Overall score, mean±SD (95% CI)	16.5±2.3 (16.1 to 16.9)	16.0±2.5 (15.3 to 16.7)	16.8±2.1 (16.3 to 17.3)	*P*=0.03
Proportion reaching pass threshold (17/21 points; 1 bonus point possible)	43% (49/114)	35% (17/49)	49% (32/65)	*P*=0.09
Scenario 3				
No. of fellows	113	49	64	NA
Overall score, mean±SD (95% CI)	11.0±1.8 (10.7 to 11.3)	10.7±2.0 (10.1 to 11.3)	11.2±1.7 (10.8 to 11.6)	*P*=0.08
Proportion reaching pass threshold (14/17 points)	6% (7/113)	6% (3/49)	6% (4/64)	*P*=0.65

NA, not applicable; 95% CI, 95% confidence interval.
[a]Scored by Walter Reed National Military Medical Center investigators (L.K.P., C.M.Y.).
[b]On the basis of the hypothesis that second-year fellow performance would be better than that of first-year fellows, *P* values are for one-tailed tests. Fisher exact test used for pass threshold comparisons. Unpaired *t* test used for score comparisons.

upgrade), suggesting the rubric is sufficiently clear and detailed. The final rubric (https://nerdc.org) was modified for greater clarity on the basis of program director surveys. All reflect structural validity (21). Seventy-seven percent of fellows responding to the post-test survey agreed the OSCE was "useful in assessing proficiency in ordering" acute KRT, suggesting examinees understood the test construct in the same way as the test committee (a response process validity measure).

Because there is no validated criterion test of KRT competency, we addressed the relationship of OSCE performance to other variables by prospectively evaluating performance of validators versus fellows, first-versus second-year fellows, and repeating versus first-time programs. Validators had significantly higher pass percentages, scores, and evidence-based question performance, as predicted (1). Although overall scores were greater for second-versus first-years, this did not result in higher overall/individual scenario pass percentages, or evidence-based question performance. This suggests that fellows learn most KRT skills in the first year. Second-years at repeating programs had a significantly higher pass percentage (64%) than did first-years at first-time programs, suggesting curriculum changes and/or individual formative-feedback led to improvement as a consequence of testing. Although second-year fellow in-training examination scores did not correlate with overall score, the in-training examination addresses the whole spectrum of nephrology medical knowledge. Acute and maintenance dialysis comprise only a small part.

Fellow performance differed substantially between scenarios. They performed well on scenario 1 (acute CRRT), with almost all correctly prescribing a ≥20 ml/kg per hour effluent rate (Q1B) (10). However, many programs had order sets that prevented effluent prescriptions <20–25 ml/kg per hour using constrained pick lists. Over 60% estimated urea clearance using effluent rate (Q1C), suggesting fairly sophisticated knowledge of CRRT clearance (17). The majority of first-year rotations are inpatient, often intensive care unit–based, and fellows appear well prepared to manage CRRT (22). At many programs, cardiovascular monitoring and responses to decompensation during CRRT are not routinely managed by nephrologists, but by intensivists. Monitoring was not included in some standard order sets, and fellows often did not address these issues in the orders, although specifically asked to do so. Constrained picklists and standard order sets (often within the electronic medical record) may have biased fellow performance, an example of an unintended educational consequence of electronic order entry (23,24).

Fellows performed less well on scenario 2 (initiation of maintenance dialysis). As in scenario 1, some lost points because of failure to order monitoring. Over 70% ordered an appropriate K dialysate for a patient with a normal

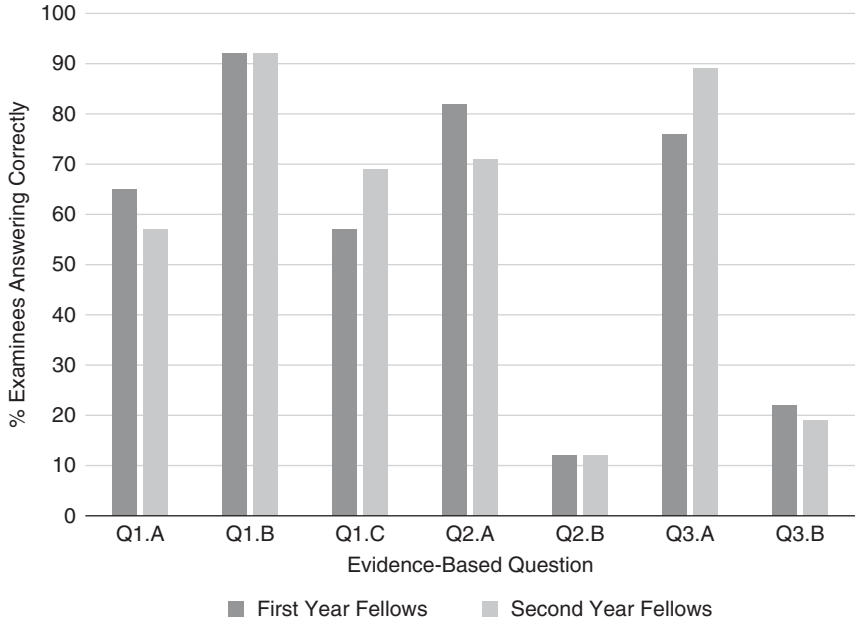

Figure 2. | **Fellow performance on evidence-based questions.** Scenario 1: Order acute CRRT in septic, hypotensive patient. Q1A: Correct for hypalbuminemia when calculating anion gap (9). Q1B: Obtain at least 20 ml/kg per hour effluent (10). Q1C: (2017 administration only) Estimate clearance using effluent rate (17). Scenario 2: Order maintenance HD initiation for moderately-uremic, volume-overloaded patient. Q2A: Avoid low K dialysate (<3 meq/L) in those with normal serum K (11). Q2B: Identify uremic encephalopathy and serositis (pleural, pericardial) as urgent/absolute indications for dialysis (12). Scenario 3: Manage acute hyperkalemia and volume overload in an anuric patient with ESKD. Q3A: Bicarbonate therapy not indicated in volume-overloaded ESKD patient without acidosis (13). Q3B: Repeat serum K at 2–4 hours and at 6 hours after dialysis, due to rebound (14).

serum K and congestive heart failure (11). Only 12% answered that the two absolute/urgent indications for maintenance dialysis initiation were uremic serositis/pericarditis and encephalopathy (12,25). Some were unsure whether the question referred to the patient in the scenario, although the text indicated that the two were "not necessarily (present) in this patient." The patient was described as having "mild asterixis," but only 39% answered "uremic encephalopathy," including in the follow-up question asking for four other indications for maintenance dialysis initiation. 89% did answer that "uremia" was an indication. Only 3% made no mention of uremic signs or symptoms at all. Initiation thresholds for maintenance dialysis are subjective (26). Patients are initiated earlier than formerly. Fellows may be less aware of uremic encephalopathy and serositis as absolute indications for initiating maintenance dialysis, as they are now rarely seen (25).

Fellows performed least well on scenario 3 (acute hyperkalemia in ESKD). The first question asked examinees to provide "orders, monitoring, treatments, and dispositions" to an ER intern with an anuric patient with ESKD with a K of 7.9 meq/L, weakness, dyspnea, and marked volume overload after obvious dietary indiscretion. Many lost points because of insufficient detail, especially for dosing, sequence, and frequency of intravenous calcium, insulin, and glucose. However, 75% recognized that intravenous sodium bicarbonate was not indicated for hyperkalemia in a nonacidotic patient with ESKD, in acute congestive heart failure (13). Although over 90% checked for rebound hyperkalemia after dialysis, only 20% checked twice (14), and many did not check at the conclusion of dialysis, trusting that hyperkalemia had resolved.

Acute hyperkalemia treatment is controversial, and medical and dialytic standard of care may differ between institutions. Several program directors commented that examinees were unsure how much detail to include, and lost points, although further questioning revealed they knew the material. The final test version (https://nerdc.org) was modified to encourage examinees to include detailed answers in the first part of scenario 3. This is one of the benefits of a formative OSCE: fellows can practice skills in a low-risk environment and program directors can interact with fellows to determine if knowledge deficits do indeed exist, and adjust scores accordingly. It is also important that fellows not approach the treatment and monitoring of acute, symptomatic hyperkalemia casually.

The differences in scenario performance is an outcome (consequence) of testing that can be addressed at a curriculum level. At our own program, we intensified the dialysis didactic curriculum, introduced material earlier in the training year, and focused more on hyperkalemia management. Another participating program also reported making curriculum changes. An advantage of the formative OSCE is that grading is at program level. Allowances can be made for local protocols/procedures, while ensuring fellows know the data underlying constrained pick lists and protocols. Fellows might have been more comfortable with multiple choice testing, where at least one answer is correct and need only be recognized (24). Because fellows receive specific, detailed feedback, and can refer directly to the

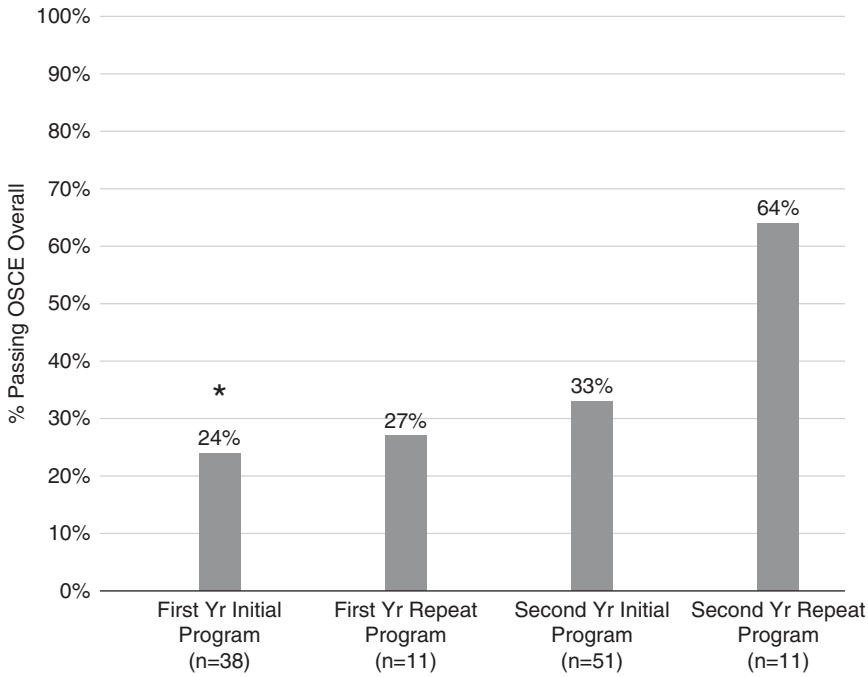

Figure 3. | **Pass performance of first- and second-year fellows from initial testing programs (2016 and 2017, *n*=15) and repeat testing programs (2017, *n*=4).** **P*=0.03, Fisher exact test, two-tailed versus second-year fellows at four programs that repeated administration of the test in 2017.

rubric, they may develop a more nuanced self-directed study plan than with a centralized, infrequent, general test of clinical nephrology knowledge, such as the in-training examination. Individual scenarios, which only take about 30 minutes, could be administered frequently at relevant time points (*e.g.*, after specific rotations, at the end of the first year) or diagnostically for a struggling fellow.

Programs can use the OSCE for ongoing assessment of six of the 24 ACGME nephrology subcompetencies (patient care 1–3, medical knowledge 1–2, and systems based practice 1) (4). It provides quantitative, practical, granular data on fellow prescription of dialysis therapy, and might reveal overdependence on computerized provider order entry, particularly in the era of electronic medical record click-box dialysis orders (23,24).

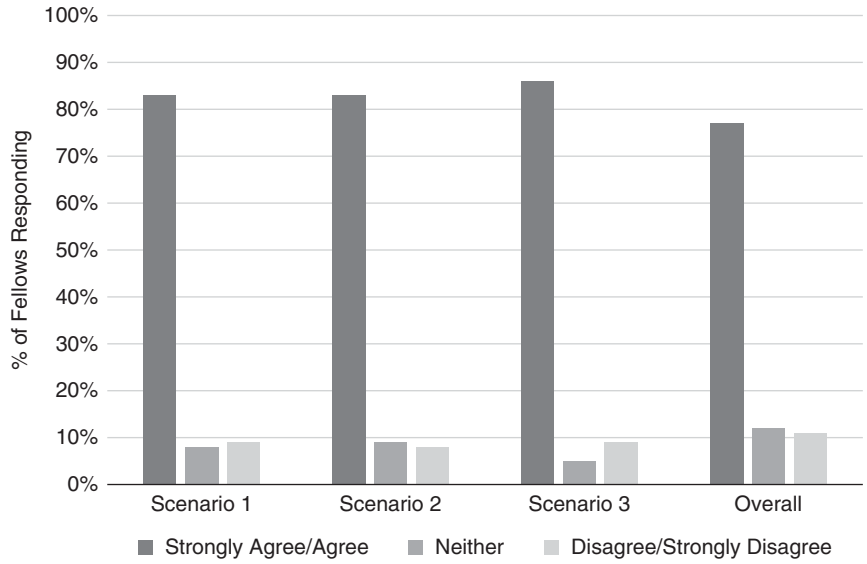

Figure 4. | **Fellow satisfaction survey results after testing.** Scenario 1: "Question 1 permitted me to assess my proficiency in ordering acute CRRT in a critically ill patient with AKI." Scenario 2: "Question 2 permitted me to assess my proficiency in ordering HD initiation in a moderately uremic patient at ESKD." Scenario 3: "Question three permitted me to assess my proficiency in managing acute hyperkalemia and volume overload in an ESKD patient on chronic HD." Overall: "Overall, the acute dialysis OSCE was useful to me in assessing my proficiency in ordering acute RRT."

Our future goal is to expand the menu of available questions in the KRT performance domain, collaborating with program directors and clinical nephrologists throughout the United States. We are validating a peritoneal dialysis scenario, and previously published an OSCE simulating rare HD-specific emergencies (27). Suggested topics include vascular access assessment, home HD, water purification/monitoring, and management of dialysis-associated cardiovascular complications. Expert technical understanding and provision of KRT is a critical skill for all nephrologists, and the acute dialysis orders OSCE should prove valuable in quantitively assessing individual KRT competence and program curriculum efficacy.

Acknowledgments

We would like to thank the nephrology fellows who participated in the objective structured clinical examination. We would also like to thank Robert M. Perkins and Matthew A. Sparks for their critical review of the manuscript.

The views expressed in this article are those of the authors and do not reflect the official policy of the Department of Army/Navy/Air Force, Department of Defense, or the US Government.

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Disclosures

Dr. Prince, Dr. Nee, and Dr. Yuan have nothing to disclose.

Funding

There was no grant funding or support for this work.

Supplemental Material

This article contains the following supplemental material online at http://cjasn.asnjournals.org/lookup/suppl/doi:10.2215/CJN.02900319/-/DCSupplemental.

Supplemental Appendix 1. NERDC dialysis orders OSCE blueprint.

Supplemental Appendix 2. NERDC dialysis orders OSCE test (final).

Supplemental Appendix 3. NERDC dialysis orders OSCE rubric (final).

Supplemental Appendix 4. NERDC dialysis orders OSCE fellow survey 2017.

Supplemental Appendix 5. NERDC dialysis orders OSCE program director survey 2017.

References

1. Prince LK, Campbell RC, Gao SW, Kendrick J, Lebrun CJ, Little DJ, Mahoney DL, Maursetter LA, Nee R, Saddler M, Watson MA, Yuan CM; Nephrology Education Research & Development Consortium: The dialysis orders objective structured clinical examination (OSCE): A formative assessment for nephrology fellows. *Clin Kidney J* 11: 149–155, 2018
2. American Board of Internal Medicine: Nephrology Certification Examination Blueprint, 2018. Available at: https://www.abim.org/~/media/ABIM%20Public/Files/pdf/exam-blueprints/certification/nephrology.pdf. Accessed July 14, 2018
3. Rosner MH, Berns JS, Parker M, Tolwani A, Bailey J, DiGiovanni S, Lederer E, Norby S, Plumb TJ, Qian Q, Yeun J, Hawley JL, Owens S; ASN In-Training Examination Committee: Development, implementation, and results of the ASN in-training examination for fellows. *Clin J Am Soc Nephrol* 5: 328–334, 2010
4. Accreditation Council for Graduate Medical Education; American Board of Internal Medicine: The Internal Medicine Subspecialty Milestones Project, 2015. Available at: http://www.acgme.org/Portals/0/PDFs/Milestones/InternalMedicineSubspecialtyMilestones.pdf. Accessed November 21, 2016
5. Ebel RL: *Essentials of Educational Measurement*, Englewood Cliffs, NJ, Prentice-Hall, 1972, pp 492–494
6. Livingston SA, Zieky MJ: *Passing Scores: A Manual for Setting Standards of Performance on Educational and Occupational Tests*, Princeton, NJ, Educational Testing Service, 1982, pp 26–29
7. Lawshe CH: A quantitative approach to content validity. *Person Psychol* 28: 563–575, 1975
8. Wilson FR, Pan W, Schumsky DA: Recalculation of the critical values of Lawshe's content validity ratio. *Meas Eval Couns Dev* 45: 197–210, 2012
9. Vichot AA, Rastegar A: Use of anion gap in the evaluation of a patient with metabolic acidosis. *Am J Kidney Dis* 64: 653–657, 2014
10. Palevsky PM, Zhang JH, O'Connor TZ, Chertow GM, Crowley ST, Choudhury D, Finkel K, Kellum JA, Paganini E, Schein RM, Smith MW, Swanson KM, Thompson BT, Vijayan A, Watnick S, Star RA, Peduzzi P; VA/NIH Acute Renal Failure Trial Network: Intensity of renal support in critically ill patients with acute kidney injury. *N Engl J Med* 359: 7–20, 2008
11. Jadoul M, Thumma J, Fuller DS, Tentori F, Li Y, Morgenstern H, Mendelssohn D, Tomo T, Ethier J, Port F, Robinson BM. Modifiable practices associated with sudden death among hemodialysis patients in the dialysis outcomes and practice patterns study. *Clin J Am Soc Nephrol* 7: 765–774, 2012
12. Singh A, Kari J: Management of CKD Stages 4 and 5. In: *Handbook of Dialysis, 5th Edition*, Chapter 2, edited by Daugirdas JT, Blake PG, Ing TS, Philadelphia, PA, Wolters Kluwer Health, 2015.
13. Allon M, Shanklin N: Effect of bicarbonate administration on plasma potassium in dialysis patients: Interactions with insulin and albuterol. *Am J Kidney Dis* 28: 508–514, 1996
14. Blumberg A, Roser HW, Zehnder C, Müller-Brand J: Plasma potassium in patients with terminal renal failure during and after haemodialysis; relationship with dialytic potassium removal and total body potassium. *Nephrol Dial Transplant* 12: 1629–1634, 1997

15. Bland JM, Altman DG: Cronbach's alpha. *BMJ* 314: 572, 1997
16. Tavakol M, Dennick R: Making sense of Cronbach's alpha. *Int J Med Educ* 2: 53–55, 2011
17. Claure-Del Granado R, Macedo E, Chertow GM, Soroko S, Himmelfarb J, Ikizler TA, Paganini EP, Mehta RL: Effluent volume in continuous renal replacement therapy overestimates the delivered dose of dialysis. *Clin J Am Soc Nephrol* 6: 467–475, 2011
18. Jurich D, Duhigg LM, Plumb TJ, Haist SA, Hawley JL, Lipner RS, Smith L, Norby SM: Performance on the nephrology in-training examination and ABIM nephrology certification examination outcomes. *Clin J Am Soc Nephrol* 13: 710–717, 2018
19. Bloom BS: Learning for mastery. *Evaluation Comment.* 1: 1–12, 1968
20. Boston C: *The Concept of Formative Assessment, ERIC Digest,* ERIC Clearinghouse on Assessment and Evaluation, College Park, MD
21. Cook DA, Beckman TJ: Current concepts in validity and reliability for psychometric instruments: Theory and application. *Am J Med* 119: 166.e7–166.e16, 2006
22. Liebman SE, Moore CA, Monk RD, Rizvi MS: What are we doing? A survey of United States nephrology fellowship program directors. *Clin J Am Soc Nephrol* 12: 518–523, 2017
23. Campbell EM, Sittig DF, Ash JS, Guappone KP, Dykstra RH: Types of unintended consequences related to computerized provider order entry. *J Am Med Inform Assoc* 13: 547–556, 2006
24. Tierney MJ, Pageler NM, Kahana M, Pantaleoni JL, Longhurst CA: Medical education in the electronic medical record (EMR) era: Benefits, challenges, and future directions. *Acad Med* 88: 748–752, 2013
25. Bleyer A: Indications for Initiation of Dialysis in Chronic Kidney Disease, 2018. Available at: https://www.uptodate.com/contents/indications-for-initiation-of-dialysis-in-chronic-kidney-disease?search=uremia%20symptoms&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1#H1147970492. Accessed September 22, 2018
26. Rivara MB, Chen CH, Nair A, Cobb D, Himmelfarb J, Mehrotra R: Indication for dialysis Initiation and mortality in patients with chronic kidney failure: A retrospective cohort study. *Am J Kidney Dis* 69: 41–50, 2017
27. Prince LK, Abbott KC, Green F, Little D, Nee R, Oliver JD 3rd, Bohen EM, Yuan CM: Expanding the role of objectively structured clinical examinations in nephrology training. *Am J Kidney Dis* 63: 906–912, 2014

Received: March 9, 2019 **Accepted:** May 29, 2019

Published online ahead of print. Publication date available at www.cjasn.org.

Supplements: Table of Contents

Prince LK, et al. The Acute Dialysis Orders Objective Structured Clinical Examination (OSCE): Fellow Performance on a Formative Assessment of Acute Renal Replacement Therapy Competence (Nephrology Education Research and Development Consortium—NERDC)

*The OSCE test and rubric may be accessed at https://nerdc.org

Supplement 1.
NERDC Dialysis Orders OSCE
Examination Blueprint
Overall Objective: To assess proficiency in ordering acute RRT

1. Case 1.
    1. Objective: Demonstrate ability to order CRRT in a septic, hypotensive, acidotic, hypoxic, coagulopathuc oncology patient with AKI in the ICU.
        a. Question 1. Assess acid-base status
            i. 1.a. Detect an anion gap metabolic acidosis, taking into account hypoalbuminemia
            ii. 1.b. Use the Winter's formula to assess compensatory respiratory alkalosis
        b. Question 2. Using facility-associated standard order sets, write CRRT orders tailored to the specific clinical situation.
            i. 2.a. Indicate CRRT machine to be used and filter set.
            ii. 2.b. Indicate dialysis access type.
            iii. 2.c. Indicate modality (e.g.: CVVH, CVVHD, CVVHDF)
            iv. 2.d. Address coagulopathy with either a heparin-free method, or regional citrate. (Include details of intervention, including pre-filter replacement, and details of regional citrate administration, including calcium monitoring.)
            v. 2.e. Address volume removal in hypotensive patient, who is near euvolemic at onset of therapy.
            vi. 2.f. Address lactic acidosis with bicarbonate-containing replacement fluid and/or dialysate.
            vii. 2.g. Address clinical monitoring of patient, including pressor titration parameters, during the procedure.
            viii. 2.h. Indicate that Qb should be maintained on the lower side (50-200 ml/min) due to hypotension.
            ix. 2.i. If using replacement fluid, indicate rate, electrolyte components, and pre-or post-filter infusion. If dialysate not used, must use physiologic replacement fluid.
            x. 2.j. If using dialysate, indicate rate and electrolyte components (Must be calcium free if citrate is used.).
            xi. 2.k. Must obtain at least 20 ml/kg/hr effluent (UF + dialysate) rate for any CRRT modality.
        c. Question 3. Explain choice of bicarbonate concentration in dialysate and/or replacement fluid, taking into account potential for alkalosis if using citrate anticoagulation or high effluent rates.
        d. Question 4. Demonstrate recognition that volume removal rate may increase as BP stabilizes and input volumes increase in oligoanuric patient.
        e. Question 5. Understand principals of clearance in CRRT and impact on drug dosing.
            i. 5.a. Calculate urea clearance, using effluent volume.
            ii. 5.b. Recognize that drug dosing during CRRT must be based on attained clearance and known sieving coefficients.

2. Case 2
    2. Objective: Demonstrate ability to order initiation of hemodialysis in a moderately uremic patient at ESRD, with CHF and a mature AV fistula.
        a. Question 1. Assess acid-base status.
            i. 1.a. Detect anion gap metabolic acidosis.
            ii. 1.b. Use delta-delta calculation to recognize underlying metabolic alkalosis.
        b. Question 2. Using facility-associated standard order sets, write hemodialysis initiation orders tailored to the specific clinical situation, including recognition of potential risk of dialysis disequilibrium syndrome.
            i. 2.a. Order a baseline EKG, address cardiac and O2 saturation monitoring, and consider nasal cannula O2 (per facility SOP) in this patient with partially compensated congestive heart failure and volume overload.
            ii. 2.b. Recognize risk of dialysis dialysis disequilibrium syndrome, and limit Qb and Qd to reduce clearance.
            iii. 2.c. Limit clearance by using smallest surface area dialyzer available in facility.
            iv. 2.d. Prescribe dialysate based on clinical situation and electrolytes, including recognition of normal serum potassium and underlying metabolic alkalosis with mild hypocalcemia (after correction for hypoalbuminemia).
            v. 2.e. Concurrent flow may be used to limit clearance, but is optional.
            vi. 2.f. Limit clearance by limiting treatment time.
            vii. 2.g. To avoid hypotension, limit volume removal during first treatment.
            viii. 2.h. Mannitol is no longer recommended, but if used, must be used correctly.
            ix. 2.i. Adjust anticoagulation based on low risk of hemorrhagic pericarditis.
            x. 2.j. Indicate dialysis access and consider specifying protocol for first use of fistula.
        c. Question 3. Indicate the two absolute indications for urgent initiation of chronic dialysis in ESRD.
        d. Question 4. Indicate four other indications for initiation of chronic dialysis in ESRD.
        e. Question 5. Know the pathophysiology, symptoms and signs of dialysis disequilibrium syndrome.

Supplement 2. NERDC Dialysis Orders OSCE Test

DO NOT ENTER YOUR NAME ON THIS TEST OR THE NAME OF YOUR PROGRAM.
PROGRAM DIRECTOR:
Did your program administer the OSCE in 2016 (last year)? _____Yes _____No
Nephrology Education Research and Development Consortium (NERDC)
Version: Final
Total Points: 58
January 30, 2016 (Amendment: 7 March 2017)

Anonymous ID Number:

Dialysis Orders OSCE: 3 scenarios
Time: Up to 120 minutes

Time it took you to complete test: _____
Are you a first or second year fellow? _____
If you are a second year fellow, did you take this test as a first year fellow? ____ Yes ____No

This is a formative test. Please read the following cases carefully, write a set of dialysis orders (you should use the standard order sets available at your institution, if permitted by your Program Director), and answer content questions for each patient below. Normal laboratory values are given within each case.

Case 1. Acute CRRT for AKI (Total points: 20)

55-year-old anuric female in the ICU with septic shock. Pt has a past medical history significant for acute myelogenous leukemia, and prior to transfer was on the oncology ward. She is neutropenic, with an absolute neutrophil count of 200, and completed her initial induction cycle of cytarabine and daunarubicin 10 days ago. She complained of feeling feverish with body aches about midnight, but had no other specific complaints and general review of systems was negative. No other past medical history, no surgeries, medications as listed below, no known allergies, and no other pertinent history at this time. The ICU calls you for acute dialysis due to worsening acidemia, and have already placed a hemodialysis catheter.

Physical Examination: Wgt 80kg; O_2 saturation 92% on 70% FIO2; RR 16-25

VS trend	6:00 am	7:00 am	8:00 am	9:00 am	10:00 am
HR (bpm)	145	140	120	125	120
BP (mmHg)	75/32	80/40	80/40	90/50	92/45
Temperature ^{o}F	103.5	103.5	102.7	102	102

Intubated, sedated female with no acute findings on exam except coarse breath sounds throughout and bilateral lower extremity petechia. No edema.

Tubes/Lines/Drains: Endotracheal tube, oral-gastric tube, Foley catheter, right IJ port, left IJ central line, 2-18 gauge IVs, and a **left femoral hemodialysis catheter.**

Vent setting: Intubated at 530 am. Assist Control; Tidal Volume 400ml; PEEP 8; FiO2 70%

Ins/Outs	6:00 am	7:00 am	8:00 am	9:00 am	10:00 am
Normal Saline	2000ml	0ml	1000ml	1000ml	250ml
Albumin 5%	0ml	250ml	0ml	0ml	250ml
Norepinephrine	Turned on	Titrated up	Titrated up	Stable high dose	Stable high dose
Vasopressin		Added	Stable dose	Stable dose	Stable dose
Blood products	1U PRBC	2U platelets			
Antibiotics/IV Medications	250 ml	50 ml	0 ml	100 ml	0 ml
Urine Output	15 ml	5 ml	0 ml	0 ml	5 ml

Labs

CBC	6:00 am	10:00 am
WBC (3.6-10.6K)	0.6	0.55
Hgb g/dL (12.8-17.7)	6	7.2
HCT (%) (37.5-50.9)	18	21.7
PLT (162-427K)	<10K	25K

Basic Metabolic Panel	6:00	8:00	10:00
Na (136-145 meq/L)	140	144	145
K+ (3.5-5.1 meq/L)	3.4	4.9	5.0
Cl- (98-107 meq/L)	103	110	112
HCO3- (22-26 meq/L)	20	15	6
BUN (5-20 mg/dL)	9	8	15
Cr (0.7-1.2 mg/dL)	0.8	1.1	1.1
GLucose (74-104 mg/dl)	99	97	105
Lactate (< 2 mmol/L)	6	13	22
Serum Albumin (3.5-5.2 g/dL)	2.5	2.3	2.3
Serum Calcium (8.6-10.2 mg/dL)	8.0	8.1	8.0
Serum Phosphorus (2.5-4.5 md/dL)	4.5		
iCa (1.1-1.35 mmol/L)	1.0		

ABG:	6:00	8:00	9:00	10:00
pH (7.35-7.45)	7.35	7.32	7.22	7.12
pCO2 (35-45 mHg)	36	30	25	19
PaO2 (75-100 mmHg	125	90	62	65
HCO3 (22-26 meq/L)	19	15	10	6

INR: (0.8-1.2 in patient not on warfarin)	1.9		2.0	

Radiology: CXR, portable film: diffuse interstitial infiltrates consistent with pulmonary edema

Medications: Pipercillin/Tazobactam 2.25gms IV every 6 hrs; Fluconazole 400 mg PO daily; Esomeprazole 40mg po daily, vasopression under titration IV; norepinephrine under titration IV; propofol IV and fentanyl IV titration for sedation

Answer the following questions:

1. Completely describe the acid-base abnormality in this patient, including compensatory responses at 10 am. (You may assume a normal anion gap of 12 meq/L.)
2. **(15 points)** You and your attending decide to perform CRRT. With the above information, please write an initial set of CRRT orders for this patient using the standard CRRT machine and filter set at your institution (e.g. NxStage, Prisma/Prismaflex, Fresenius in CRRT mode). **Do not use SLED or SHIFT. Include patient and therapy monitoring as part of your orders, as well as nursing interventions in response to monitoring thresholds.**
3. Please explain your choice of bicarbonate concentration in your dialysate and/or replacement fluid.
4. Your patient is stable after 6 hour of CRRT. The pressor requirement has decreased significantly, and the current average hourly volume input is 250 ml/hour. Urine output remains < 10 ml/hour. What modifications might you make to your prescription?
5. a. Estimate the patient's urea clearance in ml/min. (Show your work.)
   b. In general, discuss how will you adjust drug dosing while the patient is on CRRT. (You need not make calculations for specific drugs.)

Answers:

1.

2. Please attach your orders. Put your anonymous ID number on them.

3.

4.

5.

Case 2. Dialysis Initiation in ESRD (Total points: 21)

75-year-old female with CKD stage 5, presumed secondary to hypertensive nephrosclerosis, with eGFR of 10 ml/min/1.73m^2 at last visit, has been lost to follow-up due to many hospital admissions for exacerbations of congestive heart failure over the past 3 months. She has worsening metabolic acidosis and increasingly difficult-to-control volume status. Her diuretics have been titrated upwards, which improved her dyspnea on exertion and lower extremity edema, but have resulted in an increasing BUN/Cr, with increasing "soft" uremic signs and symptoms such as poor appetite, and increasing fatigue. She has a left upper extremity arteriovenous fistula with a good thrill and bruit that has been evaluated by the dialysis nurses and vascular surgeons and deemed ready to use. Today, she is complaining of decreased appetite with nausea and vomiting, a "funny taste in her mouth," inability to sleep after 2 or 3 am, and significant fatigue.

Past Medical History: HTN since age 35, noted after developing pre-eclampsia with first pregnancy; Hyperlipidemia; CKD stage 5 as above with worsening metabolic acidosis; congestive heart failure with ejection fraction of 35-40% on last Echocardiogram one month ago, and history of diastolic dysfunction; secondary hyperparathyroidism; anemia of chronic kidney disease

Past Surgical History: Placement of left upper extremity arteriovenous fistula 9 months ago. No other.

Allergies: none known
Family History: non-contributory.
Social History: lives with husband in single family home and works part-time in a nail salon. No history of tobacco or alcohol use.

Medications: amlodipine 10mg daily, carvedilol IR 12.5mg twice daily, telmisartan 40mg daily, lasix 80mg twice daily, atorvastatin 40mg daily, aspirin 325mg daily, calcium carbonate 650mg, 2 tabs twice daily with meals, calcitriol 0.25mcg three times a week, sodium bicarbonate 650mg two tabs twice daily, darbapoietin 25mcg subcutaneously once a month, ferrous sulfate 325mg two times daily

Physical Examination: HR 84 (regular rate and rhythm) ; BP 158/98; Ht: 5'0"; Wt: 135 lbs (126 lbs 3 months ago). RR 16. O2 saturation on room air: 94%
Significant findings include soft bibasilar crackles, + S4, no pericardial rub, and 2+ BLE pitting edema to knees. She has mild asterixis. Left upper arm fistula, well developed, with good thrill and bruit. Patient alert and oriented to person, place, time and situation.

Labs:
Na 144 meq/L (136-145); Cl 95 meq/L (98-107); K 4.5 meq/L (3.5-5.1); HCO3 25 meq/L (22-26); BUN 95 mg/dL (5-20); Cr 6.13 mg/dL (0.7-1.2); Glucose 84 mg/dL (74-104); Calcium 7.4 mg/dL (8.6-10.2); Phosphorus 7.4 mg/dL (2.5-4.5). Albumin 3.2 g/dL (3.5-5.2).

eGFR 5 ml/min/1.73m2.
WBC 8.5K (3.6-10.6); Hgb 8.0 g/dL (12.8-17.7); Hct 25% (37.5-50.9), Platelets 241K (162-427)

Answer the following questions:

1) Recognizing that there is no pH and pCO2, describe as completely as possible the acid-base abnormality(s). (Assume a normal anion gap of 12 meq/L.)
2) **(11 points)** Please write a complete set of dialysis orders for this patient's first day of dialysis, and delineate your plan for hemodynamic and respiratory monitoring, nursing interventions based on monitoring thresholds, choice of kidney, Qb/Qd, duration of first treatment, anticoagulation, and choice of dialysate composition.
3) In general (not necessarily in this patient), name the two absolute indications for urgent chronic dialysis initiation in ESRD.
4) Name 4 other compelling indications for chronic dialysis initiation in ESRD.
5) a) What neurologic condition could this patient be at risk for during and post-dialysis initiation?
   b) What is the pathophysiology?
   c) What are the symptoms and signs (list mild and severe)?

Answers:

1.

2. Please attach your orders. Put the anonymous ID number on them.
3. a.
   b.

4. a.
   b.
   c.
   d.

5. a.
   b.

c. Mild:

   Severe:

Case 3. Acute Inpatient Dialysis in an ESRD patient (Total points: 17)

55 year old, anuric man with ESRD secondary to obstructive nephrolithiasis presents at midnight on a Sunday to the emergency room with weakness, increasing shortness of breath, and dyspnea on exertion over the last 8 hours. He is on a Monday, Wednesday, Friday hemodialysis schedule and his last dialysis was Friday, for 4 hours 15 minutes. He left at his dry weight of 102kg. Upon questioning, he reports going to a family reunion on Sunday at noon and enjoying a lunch of crabs, shrimp, carrot raisin salad and French fries with sweet tea.

Past Medical History: ESRD due to obstructive nephrolithiasis s/p cadaveric renal transplant in 1995 and returned to ESRD due to chronic rejection. Gout, HTN, hyperlipidemia, paroxysmal atrial fibrillation, renal osteodystrophy

Past Surgical History: Cadaveric renal transplant in 1995, peritoneal dialysis catheter placement in 2004 and removal in 2006. Left upper arm AV fistula placed in 2006—which is functioning well with venous pressures <80 mmHg at 200 ml/min blood flow rate.

Allergies: None known.
No contributory family history
Social History: lives with wife in a single family home and is retired

Medications: warfarin 5mg daily, Lopressor 100mg twice daily, telmisartan 80mg daily, nephrocap 1 daily, colchicine 0.6mg per day prn acute gout flare, allopurinol 100mg daily, calcium carbonate 500mg three tabs with each meal, sevelamer carbonate 800mg three tabs with each meal and 1 tab with snacks, erythropoietin 4500 units subcutaneously three times weekly, ergocalciferol 50,000IU weekly, calcitriol 1 mcg three times weekly, lovaza 2 grams twice daily

Chronic Dialysis Prescription: L upper arm AVF; Optiflux 200; Qb 400 ml/min; Qd 600 ml/min; Dialysate: 140 mEq/L Na, 2 mEq/L K; 30 mEq/L HCO3; 2.5 mEq/L Ca. Heparin (usually receives no more than 1000 units at beginning of therapy, due to warfarin use). 4 hours 15 minutes, three times weekly. Dry Weight 102 kg.

Physical Examination: VS: HR: 94--irregular; BP 196/106; afebrile; 86% 02 saturation on room air→ increases to 92% on 6L 02 by nasal cannula; Wt: 109kg
Significant findings include crackles ½ up bilateral lung fields with decreased breath sounds at the bases, 1+ BLE edema. His left upper arm AV fistula is well developed, and has a good thrill and bruit.

Labs:
Renal function panel: Na 138 meq/L (136-145), K 7.9 meq/L (3.5-5.1), Cl 100 meq/L (98-107), HC03 24 meq/L (22-26), BUN 31 mg/dL (5-20), Cr 8.53 mg/dL (0.7-1.2), Ca 8.9 mg/dL (8.6-10.2), P 5.5 mg/dL (2.5-4.5)
INR: 3 (2-3 for patient on warfarin)

Chest X-ray: diffuse interstitial infiltrates, small bilateral pleural effusions

You are called at 1:00 am from the Emergency Room with the above information. The intern states that they have not initiated therapy for hyperkalemia because they think it is just a lab error because the patient received his full hemodialysis treatment last Friday, and will be receiving dialysis tomorrow routinely in the morning. They are awaiting a repeat potassium level.

Please answer the following questions:
1) **(6 points)** What orders, monitoring, treatments, and/or dispositions do you ask the intern to do at this point over the next 60-90 minutes, if any?
2) Is acute dialysis indicated? Why or why not?
3) Estimate the time it will take in this situation to begin dialysis.
4) **(4 points)** Please write a complete set of dialysis orders for this patient, including your patient and therapy monitoring plan during the treatment.
5) What are your criteria for stopping dialysis, and how long, at minimum, do you estimate that you will need to continue dialysis?
6) What is your monitoring plan (including follow-up labs) once the patient has completed your prescribed dialysis session?
7) Repeat potassium sent before the intern called you returned at 8.1 meq/L. In addition to dietary indiscretion, indicate at least 2 other potential contributors to his hyperkalemia.

Answers:
1.

2.

3.

4. Please attach your orders. Put the anonymous ID number on them.

5.

6.

7. a.
   b.

Thank you for completing the test. Please complete the post-test survey at the link given to you by the program director. The survey is anonymous, and the ip address will not be available to your program director, or to NERDC. Your program director will grade your test, and give you the results. He/she will also send a copy of the graded test, the score, and this year's ITE score (if you have taken it) to NERDC, but your name will not be given to NERDC and you will remain anonymous.

Supplement 3. NERDC Dialysis Orders OSCE Rubric
Objective: To assess proficiency in ordering acute RRT
Total Points: 58
Rubric: To guide scoring of questions and order sets
Evidence-based/Standard of care items are **bolded**. There are 2 per question scenario.
(Case 1) Objective: Order CRRT in a septic, hypotensive, acidotic, hypoxic, coagulopathic oncology patient with AKI in the ICU. (Total points: 20)

1. a. Anion gap metabolic acidosis (0.5 point) with
   b. Appropriate compensatory respiratory alkalosis. (0.5 point)
   In part a, examinee must recognize that correction for hypoalbuminemia must be made when calculating the anion gap (2.5 meq/L increase in anion gap for each 1 g/dL decline in albumin below the baseline of 4 g/dL). **(Vichot AA, Rastegar A. Use of the anion gap in the evaluation of a patient with metabolic acidosis. Am J Kidney Dis. 2014 Oct;(64(4): 653-7.)** The Winter's formula must be correctly used in part b, to assess respiratory compensation.
2. Initial CRRT orders (Use of standard order sets or forms is encouraged.) Examinee must recognize that this patient is severely hypotensive, acidemic (with a primary metabolic (lactic) acidosis), coagulopathic, and hypoxic with probable pulmonary edema due to capillary leak/sepsis, but not markedly total body volume overloaded—although ongoing inputs must be handled in the setting of anuria. Must meet minimum of 20 ml/kg/hr effluent rate, and use bicarbonate dialysate/replacement fluid. Heparin anticoagulation is contraindicated. Orders as follows:
   a. Indicate machine (NxStage, Prismaflex, Fresenius in CRRT mode; etc) and filter set. Options set by the individual training program or hospital. (1 Point)
   b. Indicate access type (double-lumen femoral temporary dialysis catheter). (1 Point)
   c. Indicate modality (i.e., convection only, convection + diffusion, diffusion only) (1 Point)
   d. Must address coagulopathy with heparin free saline boluses/flushes, continuous saline infusions, pre-filter replacement fluid, or use regional citrate. **Heparin is contra-indicated**. (2 points: 1 for correct intervention, 1 for details of intervention; -1 point if Heparin is used)
      i. If regional citrate is chosen, pre-filter infusion of sodium citrate (concentration and rate) must be specified, monitoring of ionized calcium post-filter and systemically, provision for calcium replacement peripherally, and specification of dialysate (if used) that does not contain calcium, and has appropriate Na (lower) concentration based on sodium concentration of citrate anticoagulant.
      ii. If regional citrate used with NxStage, RFP453 dialysate (130 meq/L Na, 25 meq/L HCO3, 0 meq/L Calcium) is required.
   e. Must address volume removal. Patient should be started isovolemic, or at low net volume removal (100-250ml/hr as tolerated), with advancement as tolerated. (1 Point)
   f. Must address acidemia secondary to lactic acidosis, and use bicarbonate containing dialysate/replacement fluid, if available. (1 Point)
   g. Must address vital signs, pressor titration parameters, and mean arterial pressure (MAP) threshold <55-60mmHg or state MAP goals. (1 Point—all must be present)

   h. Must adjust Qb between 50-200ml/min (probably on the lower side due to hypotension). (1 Point)
   i. For replacement fluid, indicate rate (1 pt), electrolyte components (1 pt), and pre- or post-filter infusion (1 pt). (Total: 3 Points) If dialysate not used, must use physiologic replacement fluid (i.e. NOT normal saline.) If not using replacement fluid (ie, CVVHD alone), give 3 points for free.
   j. For dialysate, indicate rate (1 pt), electrolyte components (1 pt) (Must be calcium free if citrate is used). (Total: 2 Points) If not using dialysate (ie, CVVH alone), give 2 points for free.
   k. **Must obtain at least 20 ml/kg/hr effluent (UF + dialysate) rate for any CRRT modality (Intensity of Renal Support in Critically Ill Patients with Acute Kidney Injury. NEJM 2008, 359:7-20.)** (1 Point)
3. Examinee must recognize that bicarbonate concentration should be physiologic range (25-35 mEq/L). If using citrate, bicarbonate should be on the lower side to avoid alkalosis, as citrate is an additional base source. If using high effluent rate, recognize that one should consider lower bicarbonate concentration to avoid alkalosis. (1 Point)
4. Examinee must consider increase in volume removal rate, at least to keep even with input. (1 Point)
5. Understanding of clearance calculation in the setting of CRRT and implications for drug dosing.
   a. Examinee must calculate clearance based on volume of effluent per hour. The calculation would be [(volume effluent (ml)/hour)/60 minutes/hour]. (1 point)
   b. Must recognized that drug doses should be based on clearance and known sieving coefficients, and not necessarily dosed for CrCl<10 ml/min. (1 points)

(Case 2) Objective: Order initiation of hemodialysis in a moderately uremic patient with an AV fistula. (Total points: 21)

1. Anion gap metabolic acidosis (0.5 point) with underlying metabolic alkalosis (0.5 point).

2. Orders for patient's first day of hemodialysis. The examinee must acknowledge the risk (albeit low) of dialysis disequilibrium syndrome, and decrement dialysis efficiency accordingly. Also must recognize the risk of cardiovascular events/symptoms appearing during first dialysis (esp. in this patient with cardiomyopathy), and consider dialysate K concentration of 3 mEq/L or greater and 2.5 mEq/L Calcium. Recognize that AV fistula is being used for the first time. Recognize patient has an anion gap acidosis, but an underlying metabolic alkalosis, and is at risk for tetany--use a 25 mEq/L HCO3 dialysate (or lowest available at facility). Patient is volume overloaded, but volume removal should be extremely gentle on the first day (if at all), and isolated UF (which does not involve clearance of urea) may be considered.

a. EKG before initiation, nasal cannula O2, and cardiovascular monitoring plan during treatment. (1 point)
b. Low blood flow and dialysate rates (Not more that 200-250 ml/min Qb; Qd no more than 2X Qb). (1 point).
c. Smaller surface area (lower clearance) kidney: (Lowest available or not more than 1.2 m^2). (1 point)
d. Dialysate: 140 mEq/L Na (or standard Na bath) (1 pt); 3-4 mEq/L K (1 pt); 25-32 mEq/L HCO3 (1 pt); 2.5 mEq/L calcium (1 pt) dialysate. (Total: 4 points. Note here that patient has underlying alkalosis and marginally low serum calcium (about 8.0 mg/dL corrected for albumin). Higher HCO3 dialysate should not be used, due to risk of tetany. The patient has a normal serum potassium, so low potassium dialysate should be avoided, unless there is only a standard dialysate available. Dialysate K < 3 meq/L has been associated with an increased risk of sudden cardiac death in retrospective cohort studies, although prospective data is lacking. **(Jadoul M, et al. Modifiable practices associated with sudden death among hemodialysis patients in the DOPPS. Clin J Am Soc Nephrol. 2012 May;7(5):765-74.)**
e. Concurrent flow (optional)
f. Short time (1-3 hours)—no more. (1 point)
g. Limited volume removal first treatment (No more than 10ml/kg/hr), or use isolated UF. (1 point)
h. Mannitol +/-, 0.5-1 gm/kg, but must be stopped 15-30 minutes before end of procedure. Another way is to give 5-10 gm mannitol bolus if symptoms occur—but it shouldn't be done as a prn order. (UpToDate is no longer recommending mannitol.) (Optional use with no points for use or no use, but minus 1 point if used incorrectly)
i. Tight Low dose heparin or heparin free—She is at (low) risk for hemorrhagic pericarditis. (1 point)
j. Indicate access (AV fistula) (1 point). Bonus point for using 17 g needles for first use of access and/or limiting number of attempted needle sticks before calling physician . (Bonus 1 point)

3. Must recognize that uremic encephalopathy (mild-severe) and serositis (pleural, pericardial) are urgent/absolute indications for initiation of chronic dialysis in ESRD. **(Daugirdas, Blake and Ing, Handbook of Dialysis (5th Ed); 2015, Wolters Kluwer Health, Philadelphia, PA. Singh A, Kari J. Chapter 2. Management of CKD Stages 4 and 5. Pp29-31, Table 2.3)** (2 points—1 point for each)

4. May chose from the following: Intractable and not responsive to conservative therapy: a) volume overload/CHF/HTN; b) hyperkalemia; c) acidosis; d) hyperphosphatemia; e) weight loss/malnutrition; f) gastrointestinal dysfunction/nausea/vomiting; g) decline in function and/or well-being; h) uremic platelet dysfunction. (4 points—1 point for each)

5. Must indicate that patient is at risk for dialysis disequilibrium syndrome. Early symptoms include nausea, vomiting, disorientation, restlessness, and headache. Seizures and coma can occur in severe cases. The physiology appears to be due to a rapid decrease in plasma solute concentration (osmolality) due to dialytic clearance, with water translating across the blood brain barrier to allow for osmotic equilibrium, with resultant cerebral cellular swelling and cerebral edema. Unclear as to the relative contribution of slower urea removal from brain relative to serum vs. existing idiogenic osmols vs. development of intracerebral acidosis. Dialysis should be stopped immediately if symptoms occur. (3 points: 1 for DDS, 1 for symptoms and signs (0.5 for mild; 0.5 for severe, which must include seizures), 1 for pathophysiology)

(Case 3) Objective: Manage acute and life-threatening hyperkalemia and volume overload in an ESRD patient on chronic dialysis (Total points: 17)

1. Examinee must recognize need to start acute medical therapy for hyperkalemia immediately.
    a. Patient should be placed on a monitor, EKG done (1 point).
    b. 1 gm of calcium (gluconate or chloride) should be administered over 2-3 minutes (1 point—0.5 point for Ca gluconate, 0.5 point for time (no greater than 5 minutes).
    c. Amp of 50% dextrose with 5-10 units regular insulin (with subsequent 10% dextrose infusion at 50 ml/hour optional). (1 point)
    d. Transfer to the ICU, or maintain in a monitored setting in the ER, if that is the standard procedure for the hospital. (1 point)
    e. Albuterol neb (10 mg in 4 ml saline over 10 minutes) may be used, but recognize the potential for tachycardia, and should not be used without prior insulin/dextrose. (1 point, 0 points if no insulin or dextrose.) (Epinephrine is NOT recommended: -1 point.)
    f. B**icarbonate therapy is not indicated—he is not acidotic, and has been shown to have negligible effect in patients with ESRD.** (-1 point) He is already volume overloaded. **(Allon M, Shanklin N. Effect of bicarbonate administration on plasma potassium in dialysis patients: Interactions with insulin and albuterol. AJKD. 1996. Oct;28(4): 508-14.)**
    g. Potassium must be repeated 30-60 minutes after therapy, and monitored thereafter. (1 point)
    h. (-1 point) for IV Lasix, as the patient is 20 years at ESRD, and is anuric, unless the examinee indicates that it could be used if the patient is not anuric, in which case, 0 points.
    i. No points for sodium polystyrene sulfonate (Kayexalate™). It will not have an effect for 4-6 hours.
2. Must recognize the need for acute dialysis→ You must be able to remove the potassium. Diuretics will not help—as the patient is anuric. Potassium binders will not begin their effect for at least 4-6 hours. He is significantly volume overloaded (7 kg over dry weight), hypoxic, and anuric. (2 points. 1 point for recognizing need for acute dialysis. 1 point for correct explanation, i.e. hyperkalemia (0.5 point) and significant volume overload (0.5 point). No points for other options which do not include dialysis)
3. At minimum 1-2 hours. (1 point) The nurses should come in immediately. Recognize that it will take at least 30-60 minutes minimum to turn on and rinse the machine and prepare it for dialysis. Then, it must be brought to the ICU (or ER), and the patient must be accessed.
4. Examinee must decide on appropriate K concentration in the dialysate, and monitor appropriately, as well as plan for volume removal.
    a. No 0 K bath. 1 or 2 mEq/L K dialysate are both fine. 30-60 minute iStat potassium after one at the beginning of therapy to guide therapy and adjust K+ in dialysis appropriately. Once K is in the 6-7 mEq/L range, switch to 2 mEq/L K dialysate, if on 1 mEq/L K bath. (2 points, 1 for dialysate selection, 1 for monitoring)
    b. Up to 1-1.5 liter per hour or 10 mg/kg/hour volume removal. (He is 7 kg above dry weight) (1 point)
    c. Continue dialysis and UF for at least 3-4 hours. (1 point)
    d. Otherwise, standard orders: LUA AVF access. Na constant or Na modeling; Qb and Qd per standard prescription. Dialyzer per standard prescription. HCO3 and Calcium per standard prescription. Heparin per standard prescription—1000 units at beginning of dialysis. (No points)

5. Examinee must recognized that potassium should be NORMAL (< 4-5 mEq/L) (1 point) and at least 3 hours must elapse (1 point) before discontinuation, as rebound is expected, especially as the medical therapy used will shift K into cells, thus preventing clearance. 3-4 hours of dialysis will allow removal of 3-4 liters of volume—leaving him still at 3-4 liters above dry weight.
6. After dialysis is completed, must recognize need to repeat K+ in 2-4 hours, once again at 6 hours, as rebound is likely to occur. May need to repeat dialysis daily (especially due to volume overload). (1 point: 0.5 point for 2-4 hours post, 0.5 point for 6 hours post) **(Blumberg A, Roser HW, Zehnder C, Muller-Brand J. Plasma potassium in patients with terminal renal failure during and after hemodialysis: Relationship with dialytic potassium removal and total body potassium. NDT. 1997: 12(8): 1629.)**
7. Other potential contributors (1 point):
    a. Medications: Telmisartan, Lopressor (0.5 point—must include telmisartan)
    b. Access Recirculation (unlikely in view of history, but a possibility) (0.5 point)

No points for hemolysis, as there are two successive K values of approximately 8 meq/L.

Supplement 4. Post-Acute Dialysis OSCE Fellow Survey

1. I am a
    a. First Year Fellow
    b. Second Year Fellow
2. Question 1 permitted me to assess my proficiency in ordering acute CRRT in a critically ill patient with AKI.
    a. Strongly agree
    b. Agree
    c. Neither agree or disagree
    d. Disagree
    e. Strongly disagree
3. If you have any comments or criticisms about Question 1, please enter them here.

4. Question 2 permitted me to assess my proficiency in ordering hemodialysis initiation in a moderately uremic patient at ESRD.
    a. Strongly agree
    b. Agree
    c. Neither agree or disagree
    d. Disagree
    e. Strongly disagree
5. If you have any comments or criticisms about Question 2, please enter them here.

6. Question 3 permitted me to assess my proficiency in managing acute hyperkalemia and volume overload in an ESRD patient on chronic hemodialysis.
    a. Strongly agree
    b. Agree
    c. Neither agree or disagree
    d. Disagree
    e. Strongly disagree
7. If you have any comments or criticisms about Question 3, please enter them here.

8. Overall, the Acute Dialysis OSCE was useful to me in assessing my proficiency in ordering acute renal replacement therapy.
    a. Strongly agree
    b. Agree
    c. Neither agree or disagree
    d. Disagree
    e. Strongly disagree
9. If you have any comments or criticisms about the OSCE overall, please enter them here.

Supplement 5. Post-Acute Dialysis OSCE Program Director Survey 2017

1. Have you administered the OSCE previously (in 2016)?
    a. Yes
    b. No
2. If you answered "Yes" to #1, did you make any curriculum changes because of your previous experience with the OSCE?
    a. Yes
    b. No
3. If you answered "Yes" to #2, please describe any curriculum changes you made.

4. Question 1 permitted fellows to assess their proficiency in ordering acute CRRT in a critically ill patient with AKI.
    a. Strongly agree
    b. Agree
    c. Neither agree or disagree
    d. Disagree
    e. Strongly disagree
5. If you have any comments or criticisms about Question 1, please enter them here.

6. Question 2 permitted fellows to assess their proficiency in ordering hemodialysis initiation in a moderately uremic patient at ESRD.
    a. Strongly agree
    b. Agree
    c. Neither agree or disagree
    d. Disagree
    e. Strongly disagree
7. If you have any comments or criticisms about Question 2, please enter them here.

8. Question 3 permitted fellows to assess their proficiency in managing acute hyperkalemia and volume overload in an ESRD patient on chronic hemodialysis.
    a. Strongly agree
    b. Agree
    c. Neither agree or disagree
    d. Disagree
    e. Strongly disagree
9. If you have any comments or criticisms about Question 3, please enter them here.

10. Overall, the Acute Dialysis OSCE was useful to fellows in assessing their proficiency in ordering acute renal replacement therapy.
    a. Strongly agree
    b. Agree

c. Neither agree or disagree
d. Disagree
e. Strongly disagree

11. If you have any comments or criticisms about the OSCE overall, please enter them here.