Chapter 31

RENAL SUPPORT IN MILITARY OPERATIONS

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INTRODUCTION

Renal failure is a serious condition under any circumstances, linked significantly to increased mortality, although whether this relationship is causative or associative is unclear. Combat-related renal failure is uncommon, but potentially more serious than in the civilian context, due to the limitations of available treatment during deployment. This chapter covers renal support in military operations, including current options for support and future equipment development.

RENAL SUPPPORT IN THE DEPLOYED SETTING

History

Acute kidney injury (AKI), previously known as acute renal failure (ARF), following combat trauma was noted only infrequently until World War II, principally because most casualties succumbed to hypovolemic shock before they could develop AKI. During the war, civilian casualties with crush syndrome following bombing, and military casualties with AKI who had been successfully resuscitated, were increasingly described in the medical literature.[1] Following pioneering work during World War II by Willem Kolff, renal replacement therapy (RRT) developed significantly in the Korean War, principally through the work of Paul Teschan and colleagues.[2] Throughout the Vietnam War, a deployed renal team was based in Japan with forward projection to the Philippines and Saigon, equipped for both peritoneal dialysis (PD) and hemodialysis (HD). Many renal failure cases in Vietnam were due to "medical" causes (such as malaria), and the lower incidence of trauma-related AKI compared to previous conflicts was ascribed to improved initial resuscitation. In this conflict, "medical" AKI was predominantly treated with PD, while traumatic/surgical AKI was treated with HD.[3]

Incidence and Etiology

Although common in previous conflicts (up to 20% of severely wounded soldiers), the incidence of AKI in modern combat injuries is low (0.5% of all postoperative casualties in Korea surviving at least 48 h, 0.17% in Vietnam, and even lower in subsequent conflicts).[4,5] This decrease is likely to be multifactorial. Improved body armor reduces the number of severe torso injuries. Active field dressings, improved buddy-aid training, tourniquets, and intraosseous needle use allow for more rapid and effective control of hemorrhage. Additionally, improved initial resuscitation with helicopter-based evacuation to high quality deployed medical facilities allows for definitive surgery and restoration of circulating volume to help prevent AKI.

The most common pathology of renal failure related to combat trauma is acute tubular necrosis (ATN). ATN may be multifactorial in origin, but hypovolemia and hypotension are probably the two most common causative factors. ATN tends to develop over several days, in contrast to traumatic rhabdomyolysis, in which the development of renal failure and life-threatening metabolic complications can occur within hours of injury.

Prevention of Acute Kidney Injury and Renal Failure

With appropriate treatment, the natural history of AKI is recovery to dialysis-free function. Fewer than 10% of patients require long-term renal support following an acute episode of AKI. Ensuring adequate circulating volume replacement and renal perfusion are mainstays in prevention of AKI. Historical reports of maintaining patients for up to 2 weeks with oligoanuria and recovery of renal function demonstrate that meticulous attention to fluid balance, low protein intake, and general care (Borst or Bull regimes[6,7]) can be beneficial even in the absence of sophisticated supportive measures.

Indications for Renal Support

Until relatively recently, multiple definitions for ARF existed. The RIFLE (risk, injury, failure, loss, and end-stage disease) criteria[8] (Table 31-1) are increasingly used to standardize definitions and compare both treatments and thresholds for treatment with RRT. The term "acute kidney injury" is preferable to "acute renal failure."

Traditional indications for acute RRT are fluid overload, acidosis, or hyperkalemia. Additional indications are other severe electrolyte disturbances, and some cases of drug overdose or poisoning. Increased urea and creatinine levels are less acutely a reason to provide RRT. The rate of rise of potassium in an anephric patient depends on body size/muscle mass, metabolic/catabolic rate, tissue injury, and effects of medical therapies administered, but it is typically 0.5 to 3 mmol per liter per day. Likewise, the rate of creatinine rise is variable, but an adult male rendered anephric may show rises of between 90 and 250 mmol per liter

TABLE 31-1

RISK, INJURY, FAILURE, LOSS, AND END-STAGE KIDNEY DISEASE (RIFLE) CLASSIFICATION

Class*	Glomerular Filtration Rate Criteria	Urine Output Criteria
Risk	Serum creatinine × 1.5	< 0.5 mL/kg/h × 6 h
Injury	Serum creatinine × 2	< 0.5 mL/kg/h × 12 h
Failure	Serum creatinine × 3, or serum creatinine ≥ 4 mg/dL with an acute rise > 0.5 mg/dL	< 0.3 mL/kg/h × 24 h, or anuria × 12 h
Loss	Persistent acute renal failure = complete loss of kidney function > 4 weeks	
End-stage kidney disease	End-stage kidney disease > 3 months	

*RIFLE class is determined based on the worst of either glomerular filtration criteria or urine output criteria. Glomerular filtration criteria are calculated as an increase of serum creatinine above the baseline serum creatinine level. Acute kidney injury should be both abrupt (within 1–7 days) and sustained (more than 24 hours). When the baseline serum creatinine is not known and patients are without a history of chronic kidney insufficiency, calculating a baseline serum creatinine using the Modification of Diet in Renal Disease equation for assessment of kidney function, assuming a glomerular filtration rate of 75 mL/min/1.73 m^2, is recommended.

per day (1–3 mg/dL/d).

Efforts to discover markers of renal dysfunction predictive of the requirement for RRT (eg, cystatin C, neutrophil gelatinase-associated lipocortin, kidney injury molecule-1) currently lack sufficient sensitivity and specificity. Historically these markers have not been easily available to the deployed clinician; however, bedside tests are now available and efforts are being made to assess such markers' suitability as a panel of tests.

Acute life threatening complications are most likely to arise as a result of hyperkalemia and acidosis. Medical therapy (Table 31-2) should be the mainstay of management unless timely evacuation to an adequately appointed facility is impractical. Once started, renal support may be required for days or weeks. This requirement must be considered in the decision to provide RRT, particularly in cases involving local nationals or others with limited eligibility according to treatment matrices. These decisions may be ethically difficult.

Management Options

Broadly speaking, renal support may consist of PD, HD, or hemofiltration. Perhaps more significant than any postulated clinical benefits are the requirements of each mode for logistic support, transport, and on-going maintenance, as well as requirements for trained staff (Table 31-3). PD is least efficient, and has traditionally been relatively contraindicated for patients following abdominal trauma and laparotomy. Nonetheless, a small number of cases have been reported in which field-rigged dialysis systems have been successfully employed to provide PD following combat injures when evacuation was impractical or delayed.[9,10] Table 31-4 lists one option for constructing such a system.

Continuous RRT (CRRT) is usually delivered using a veno-venous technique of hemofiltration (CVVH). CVVH requires large bore venous access using specialized catheters, along with filters, circuits, and specialized replacement fluids, in addition to skilled staff. These considerations, along with the frequent requirement for anticoagulation, make CRRT difficult to provide on a routine basis in the initial period following battle injury, especially if experienced staff are unavailable. Anticoagulation requires careful deliberation, balancing the risk of precipitating further bleeding against the risk of clotting in the filtration circuit. Heparin-free techniques using predilution at the filter and alternative agents such as prostacyclin are used in standard practice, but evidence in the setting of immediate postcombat trauma is lacking. CRRT is the most frequently employed mode of renal support used in civilian critical care, especially if patients remain hemodynamically unstable.

Traditionally, HD requires a pure water supply in large quantities (up to several thousand liters daily), along with skilled staff and equipment designed for single use. Recently, technical advances in home dialysis have produced equipment that requires small volumes of water (as low as 10 liters daily) and can be safely managed by relatively unskilled assistants. The equipment is portable and sufficiently compact and lightweight to be carried by helicopter and existing transport aircraft. However, this new equipment is not presently standard military stock.

Current US Army doctrine provides for a hospital augmentation dialysis team; however, these teams have not been deployed to Iraq or Afghanistan since 2001 (principally because the need for such augmentation has not been reached), and the doctrine is being revised.[11] United Kingdom forces doctrine has equipped the Royal Air Force (RAF) with deployable CVVH capability. Two modules are held at the Tactical Medical Wing at RAF Brize Norton to provide a global

TABLE 31-2

MEDICAL THERAPY FOR ACUTE KIDNEY INJURY AND HYPERKALEMIA*

Drug	Dose	Action
Calcium chloride 10%	10 mL every 20 minutes until electrocardiograph normal or 50 mL maximum	Increases threshold potentials, stabilizes cell membranes against depolarization
Calcium resonium	30 g enema and 15 g PO every 8 hours with lactulose 10–20 L every 6 hours	Binds potassium in the gut, preventing absorption
Salbutamol nebulizers	5 mg (2.5 mg in presence of heart disease)	Reduces extracellular potassium levels by increasing cell uptake of potassium
Dextrose insulin	25 mL 50% dextrose and 10 IU rapid acting insulin (such as actrapid or humulin) over 15 minutes Consider 20% dextrose 1,000 mL and 100 IU actrapid at 2 mL/kg/h	Insulin facilitates glucose entry to cells, with accompanying potassium shift from plasma
Sodium bicarbonate	50–100 mL 8.4% bicarbonate over 15 minutes via central venous catheter or 200–400 mL 1.2% peripherally	To correct acidosis (enhances effects of insulin and shift of potassium to intracellular space)

*Consider hemodialysis if : potassium > 7.0 mmol/L; pH < 7.1; uremia > 45 mmol/L or blood urea nitrogen =126 mg/dL; or pericarditis is present.
IU: international unit
PO: per os, by mouth
Data source: UK Ministry of Defence. *Clinical Guidelines for Operations*. Joint Doctrine Publication 4-03.1. London, England: MOD; June 2010.

CVVH capability. Currently the concept of use entails flying the module along with supporting staff to the patient, providing RRT on the ground, and then returning the patient to the United Kingdom when stable. RRT cannot be undertaken during flight in part due to equipment power requirements, but also because the gravimetric analysis of fluid balance is disturbed by vibration. Following the loss of the air-bridge in 2010 as a consequence of volcanic dust, a third RRT module was deployed into theater in case of delays in returning critically ill patients. This module is now a Permanent Joint Headquarters asset and has been used once successfully to stabilize a soldier prior to strategic air evacuation.[12]

TABLE 31-3

COMPARISON OF RENAL SUPPORT MODES

Characteristic or Requirement	Peritoneal Dialysis	Hemodialysis	Hemofiltration
Systemic anticoagulation required	No	Usually	Usually
Purified water supply required	No	Yes	No
Efficiency of solute clearance	Poor	High	Moderate
Specialized replacement fluid required	No	Yes	Yes
Can be field rigged	Yes	No	No
Logistic support requirements	Low	High	Intermediate

Outcomes

In World War II, mortality rates from renal failure exceeded 90%. After the initiation of HD in Korea, trauma-related renal failure mortality fell to 68%, and remained at this level during the Vietnam War. "Medical" renal failure carried a much lower (approximately 10%) mortality rate, even if treated with the less efficient PD. In modern conflicts, AKI is so uncommon that an accurate attributable mortality rate is difficult to measure, since most reports are of small case series only.

TABLE 31-4

CONSTRUCTING A FIELD-EXPEDIENT PERITONEAL DIALYSIS SYSTEM*

Equipment Required	Procedures
IV tubing with roller clamp Mask, gown, cap Disinfectant Diagnostic peritoneal lavage catheter (chest tube or any other tube device with distal portholes may also be used) Drainage bag (emptied IV fluid bag or blood collection bag) Fluid for dialysis: • Lactated Ringer or Hartman solution can be used as a simple field expedient dialysate (both closely mimic the electrolyte profile of stock dialysate). • Glucose can be added to the dialysate to create a 1.5%–4.5% glucose solution. • 50 mL of 50% dextrose solution added to each liter of lactated Ringer solution will produce an approximately 2.5% glucose solution.	Catheter insertion: • The PD catheter can be placed using techniques employed in paracentesis or diagnostic peritoneal lavage. • The method used will depend on the training of the physician, comfort with the different techniques, and available equipment. • Placing a larger catheter/drain such as a chest tube is best accomplished using an open technique with visualization of tissue planes to minimize risk of bowel perforation. Management of PD: • Once the infusion/drainage device is placed, the dialysate can be infused. • Once the lactated Ringer solution bag is spiked with infusion tubing, air should be bled from the line prior to connecting to PD catheter. Up to 3 L of dialysate can be infused. • Dwell time should be 1–4 hours. • After an adequate dwell time has elapsed, the catheter can be connected to the drain bag. The drain bag should be placed in a dependent position (on floor) and the dialysate collected in the drain bag. • Multiple exchanges may be necessary each day as needed to correct the renal failure and fluid overload.

*It is important to note that sterile technique is vital to prevent peritonitis. Field conditions make this challenging, but diligence in this matter can prevent morbidity and mortality for the patient. Electrolyte measurement should be repeated after PD to follow the electrolyte changes and renal function.
IV: intravenous
PD: peritoneal dialysis
Data source: Givens M. Tricks of the trade. *Ann Nav Emerg Med.* March/April 2010:21.

SUMMARY

Combat-related ARF is rare in modern conflict, especially as an isolated injury, but it is important to be aware that it is associated with high mortality rates. The incidence of AKI over succeeding days is not well recorded in terms of frequency, severity, or outcome. As with other forms of renal failure, avoidance is better than post-hoc treatment. Adequate, rapid resuscitation and replacement of circulating volume is a key component of management. In the majority of cases, medical therapy for acute life-threatening disorders in the deployed situation can stabilize a patient's clinical condition pending transfer for formal RRT. A high positive fluid balance, progressive acidaemia, or rapidly rising serum potassium levels would indicate red flags for upgrading the urgency of evacuation.

RRT is best provided in large, well-appointed facilities out of theater, which relies on rapid, reliable evacuation systems. Failing such evacuation capabilities (and contingent upon eligibility matrices), future operations, especially insertion and contingency operations, may involve a small number of patients requiring in-theater renal support. Options for such management may be field-rigged PD or CVVH, depending on exact circumstances. Portable HD machines may provide a practical option in the future, although no military-specific information about this equipment is available to date.

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