May, 2010

In–theater Peritoneal Dialysis for Combat-related Renal Failure

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Note: The opinions expressed here are those of the authors and do not necessarily reflect those of the Canadian Forces Medical Service or the US Department of Defense

Citation: Pina JS, Moghadam S, Cushner HM, Beilman GJ, McAlister VC. In-theater peritoneal dialysis for combat-related renal failure. *J Trauma* 2010 May;68(5):1253-6. PMID: 20453775

Abstract

Background: Complications of renal failure may prevent timely evacuation of injured soldiers. Conventional renal replacement therapy is not available in forward surgical units. **Method:** Records of in-theater improvised peritoneal dialysis (IPD) in level 3 hospitals or forward surgical units in Iraq or Afghanistan were reviewed to determine the following: cause of renal failure and associated injuries; type of dialysate, peritoneal access and exchange technique; patient outcome. These data were used to propose method for IPD using commonly available materials. **Results:** Improvised peritoneal dialysis (IPD) is described in four patients. Abdominal or chest drains were used with either improvised dextrose – electrolyte solution or commercial dialysate. Exchanges which were successful, despite fresh surgical wounds including full laparotomy, removed excess fluid and restored acid and electrolyte balance, but did not correct azotemia. Open abdominal packing prevented continuation of IPD after 48 hours. Two patients fully recovered, one died and one patient with a poor prognosis was lost to follow-up. **Conclusion:** IPD can be delivered effectively using readily available materials in forward surgical units and Level 3 combat support hospitals.

Introduction

There is an episode in the television serial M*A*S*H set in 1951 where Forward Surgical Team (FST) members initially try to treat injured soldiers in renal failure by improvising a system of peritoneal dialysis (PD) before attempting hemodialysis (HD) .[1] Historically, the United States Army fielded its first dialysis unit during the Korean War.[2] Since there was no commercial dialysis equipment available at that time, military clinicians used improvised equipment to perform HD. During the Vietnam War, the United States military provided dialysis support to wounded soldiers on a hospital ship and in a field dialysis unit .[3] Treatment of renal failure that occurred during Operation Iraqi Freedom usually consisted of HD or continuous renal replacement therapy (CRRT) and was supplied either on the USNS Comfort or in Landstuhl Regional Medical Center in Germany.[4] Despite the paucity of literature on the use of PD in a combat hospital, PD can be provided easily in a deployed setting since the supplies required to perform this procedure are readily available at combat support hospitals and probably available at FST facilities. Other types of renal replacement therapy, such as CRRT and HD require dialysis filters and blood pumps which are not part of the field hospital inventory and are difficult to supply in a combat zone. Although treatment of renal failure has progressed considerably in the last 50 years, the problem of dealing with acute renal failure (ARF) in a forward surgical setting has not yet been solved. In this article, we report independent attempts to sustain patients with ARF in the Afghanistan and Iraq theaters of Operations Enduring Freedom, Iraqi Freedom and the International Security Assistant Force (ISAF).

Levels of care in the combat theater (also known as echelons of care) are generally aligned with the combat unit the healthcare element is intended to support, i.e. battalions and brigades, divisions, corps and echelons above corps (EAC). There are five distinct levels: each successive one augments the previous level's treatment capacity while possessing the same treatment capabilities. The evacuation route typically flows through each echelon. The primary health support elements at Level 1, focused on life-saving, resuscitative actions, are self-aid/buddy aid, the combat lifesaver and the battalion aid station. Level 2 care is commonly provided by the area support company and the FST, where further resuscitation and damage control surgery primarily occur. Level 3, featured by the combat support hospital, is where further resuscitation, damage control and early repair work occur. This level has a host of subspecialty support, but the focus is trauma surgery, intensive care, and air evacuation out of theater or return to duty. Level 4, the general hospital or medical center, is the first level where definitive surgical repair and medical treatment occur. Level 5 centers provide highly subspecialized care and rehabilitative services and are typically located within the United States. Dialysis is routinely available only at Levels 4 and 5.[5].

The first report of the use of peritoneal lavage to remove solute in patients with ARF was published in 1938 by Jonathan Rhoads.[6] He reported on two patients with renal insufficiency treated by peritoneal lavage. He was able to demonstrate the removal of urea nitrogen in the effluent but the patients' blood urea nitrogen remained unchanged. Rhoads treated several more patients but did not persist because of an inability to distinguish acute from chronic renal failure.[7] Rhoads's report influenced Wilhelm Kolff who more than anyone else introduced the modern era of renal replacement therapy.[7] There are only a few modern reports of IPD usually involving adaptation of supplies in developing countries.[8] Currently in Afghanistan and Iraq, injured coalition soldiers with renal failure have to be evacuated to Landstuhl Regional Medical Center, a level 4 hospital in Germany, for hemodialysis.[4] A mobile level 4 hospital with HD is also available on USNS Comfort.[4] The patients described in the current report were either too unstable or otherwise ineligible for transfer to these units.

Method

The hospital records of patients who underwent in-theater improvised peritoneal dialysis in level 3 hospitals or forward surgical units in Iraq or Afghanistan were reviewed. The following data were recorded: patient details, cause of renal failure and associated injuries, type of dialysate or method for making dialysate, technique of improvising peritoneal dialysis (peritoneal access and exchange) and patient outcome. These data were used to determine if IPD should be attempted in situations where conventional renal replacement therapies are not possible and to propose a method for IPD using commonly available materials.

Results

The injuries and clinical status of patients requiring IPD are summarized in Table 1. The methods used to institute IPD and their impact on patient care and outcomes are summarized in Table 2. We are not aware of other attempts at IPD but we were unable to do a comprehensive search.

Patient #1 was a nine year-old boy (28 Kg) who was shot through the right side of the pelvis by a negligent discharge of an AK47. His initial care was provided by a local hospital where a laparotomy was performed and the right femoral artery was ligated through a groin incision to control hemorrhage. Three days later he appeared to be dying. His family brought him a hundred miles to our forward surgical unit at a level 3 hospital. The level of gangrene extended above the inguinal ligament anteriorly. It was necessary to disarticulate the hip to debride all the necrotic tissue. The patient had been anuric since admission with a massive positive fluid balance, Creatinine of 7.1 mg/dL, pH of 7.05 and serum potassium of 6.9 mEq/L. One day after amputation, the laparotomy incision was opened and two Jackson-Pratt abdominal drains were inserted into two areas of the abdomen and pelvis. Stoma appliances were applied to the skin around the drain sites. The drains were brought through the front of the bag which was placed to catch fluid leakage. These tube drains were used to deliver and removed dialysate which had been prepared according to a recipe summarized in Table 3. Exchanges were tested with 100 ml volumes several hours after surgery and increased to 200 to 500ml with dwell times of one to four hours. The patient's creatinine level remained at approximately 7 mg/dl but fluid balance, pH (7.05 – 7.45) and serum potassium (6.9 – 5.0 mEq/L) normalized over the first week. PD was continued for 10 days with a total of 27exchanges. Urine output returned after 8 days. The patient was weaned from the ventilator 4 days after admission. The patient was mobile with crutches and his creatinine had dropped to 1.28 at the time of discharge.

Patient #2 was a 23 year-old male (65 Kg) who received multiple gunshot injuries to the right side. He was treated in a local hospital before transfer to the level 3 forward surgical hospital. One bullet had caused extensive neurovascular and soft tissue injury in the axilla as the bullet tracked through the scapula and shoulder. Another had fractured the right pubic ramus and there was evidence of bilateral renal contusion. A third bullet had fractured the right tibia and fibula. Despite resuscitation, including fluid, blood products, and mechanical ventilation, the patient remained in acute renal failure. Surgery included a right arm amputation, laparotomy, and external fixation of the right leg. The patient remained hemodynamically stable but anuric. Five days after admission, one week after the injury, management became difficult because of fluid overload. Serum creatinine was 8.65 mg/dL, pH 7.28 and potassium 2.9 mEq/L. An abdominal drain (Jackson-Pratt catheter) was placed via the lower part of the laparotomy incision into the pelvis. Exchanges were started immediately and were initially performed with commercial 4.25% dextrose (Dianeal, Baxter) and then with 1.5% dextrose (Dianeal, Baxter). A total of 19 liters were exchanged to remove an additional 3 liters. Despite an ongoing increase in serum creatinine, the patient stabilized. The patient was transferred to a local hospital for ongoing care. Long-term outcome is not known.

Patient #3 was a 32 year-old Ugandan male with pneumonia, transaminitis, anemia, thrombocytopenia, normal renal function with normal urinalysis, and a normal total white blood cell count with lymphopenia on admission. Malaria studies, Q fever titers, stool culture and microscopic exam, and blood cultures were all negative. Despite broad-spectrum antibiotics, the patient required mechanical ventilation. Bronchoscopy failed to reveal an etiology. There was no evidence of pulmonary hemorrhage. On hospital day 8, the patient went into cardiopulmonary arrest due to an obstructed endotracheal tube. After 8 minutes of cardiopulmonary recuscitation with reintubation, reoxygenation and Advanced Cardiac Life Support protocol, he regained a pulse and blood pressure. Since the arrest, the patient's neurologic examination was consistent with anoxic brain injury. Sedation and control of agitation was accomplished with midazolam and fentanyl. The patient developed classic acute tubular necrosis (ATN) with typical dark brown muddy casts in the urine sediment. Five days after the cardiac arrest, the serum BUN and Cr rose to 132 mg/dL and 5.9 mg/dL respectively, and he maintained a non-gap metabolic acidosis, yet he was not oliguric or hyperkalemic. Uremic mental status changes could not be adequately assessed while he was on intravenous sedatives. Since HD or CRRT filters were not available at this level 3 hospital, the critical care team started PD. A pediatric chest tube was used as the infusion/effluent catheter since the facility does not stock conventional PD catheters. The team started 1-liter exchanges of a 2.5% dextrose-based solution (with added sodium lactate) with 1.5-hour dwell times, which were tolerated well. Initially when 2-liter exchanges were attempted, the patient became hypoxemic, possibly due to compromised venous return and mechanical effects on the thorax. The patient received a total of 42 exchanges over 7 days. Eventually, 2-liter, 1.5%-2.5% dextrose solutionbased exchanges with 2-hour dwell times were the average treatment. We observed downtrending of the serum creatinine from a high of 7.7 mg/dL to 6.4 mg/dL, while the BUN continued to peak at a very high level of 199 mg/dL. The patient never developed hyperkalemia, oliguria or fluid overload and the metabolic acidosis improved. When the patient's sedation was lightened, the patient began to respond to voice and commands, despite his extreme uremic state. The patient stabilized from a pulmonary and renal point of view such that he could be air evacuated to Johannesburg, South Africa, for follow-on care. He completely recovered his neurologic, pulmonary and renal function and is home with his family in Uganda today.

Patient #4, a 19 year-old male (68 Kg), was brought to the level 3 forward surgical unit in shock, having been thrown out of a moving truck. He suffered multiple fractures of vertebrae and ribs. There was massive soft tissue injury on his back and buttocks from shear stress. He required an urgent laparotomy and splenectomy to control hemorrhage from a fractured liver and spleen. He was anuric and he developed abdominal compartment syndrome. A second laparotomy was performed and the abdomen left open with a gauze and opsite dressing. An abdominal drain (Jackson-Pratt catheter) was placed in the gauze to drain effluent. A second drain had been placed in the pelvis. PD was instituted by instilling commercial 4.25% dextrose solution (Dianeal, Baxter) into the pelvis. Volumes of 0.5 – 1 L dwelled for 2 - 4 hours for the first two days. After this, fluid leaked via the abdominal packing soon after instillation. Continuous exchange was attempted for another 48 hours with less effect. Eleven exchanges were performed using a total volume of approximately 20 liters of dialysate, removing about 3 liters of additional fluid. However the patient deteriorated after exchanges became less effective. As the serum creatinine rose to 14.4 mEq/dL, the patient developed acidosis and hyperkalemia before he suffered cardiac arrest and death, 8 days after admission.

Discussion

Military clinicians often face ARF in the severely injured patient. Modern developments such as damage control resuscitation and rapid evacuation reduce the requirement for in-theater renal replacement therapy. For this reason dedicated expert teams capable of supporting patients with renal failure have not been deployed in Afghanistan or Iraq.[3] However, evacuation to level 4 hospitals is not available to patients who are too unstable for air transport or to local victims of conflict. All of the patients in this series were local nationals or citizens of a third-party country. When considering dialysis for local patients, providers should expect rapid recovery of native renal function, since chronic dialysis cannot be supported by level 3 hospitals and it may not be available in the host country. In the case of foreign nationals, dialysis can be performed until the patient is stable enough for transport to a higher level of care. The depletion of resources by a single patient with chronic renal failure is the same dilemma that Rhoads faced in 1938.[6,7]

In some situations US Military and Coalition Forces members with ARF may be too unstable for transfer. Survival of these wounded soldiers may require the initiation of renal replacement therapy to stabilize them for evacuation to a level 4 healthcare facility. While this group is more likely to require renal replacement therapy, air evacuation of injured coalition soldiers may not be possible because of the complications of ARF such as fluid overload, acidosis and hyperkalemia. Experience with acute renal replacement used in the care of carefully selected local patients may be extremely beneficial if the procedure is applied in preparing soldiers for evacuation.

None of our patients had any evidence of pre-morbid renal insufficiency. Patients #1 and #3 clearly fall into the group where short term renal replacement therapy permits recovery from otherwise fatal injuries because definitive surgical or medical treatment can be completed quickly whereas patients #2 and #4 have less certain outcomes because multiple complex surgeries are required to achieve stability. The dilemma facing health care providers in the forward surgical setting is not so much distinguishing patients with ARF from those with chronic renal failure but predicting how long a patient may require IPD.

The recipe given in Table 3 for improvised dialysate uses materials commonly available in critical care. The method of adding the correct amount of each ingredient in order to approximate conventional dialysate has been simplified to avoid hazardous calculations during a period of stress. The availability of an onsite pharmacist or of commercial dialysate would make this process easier. However the measuring techniques and solutions used are familiar to critical care staff, who should be capable of making improvised dialysate at the point of care so long as the formula is available to them.

In all of the patients in this series, PD had to be instituted prior to healing of the abdominal incision, and the size of the laparotomy incision limited the efficiency of IPD. This was particularly so in Case #4 who required open abdominal packing for abdominal compartment syndrome. Patients #1 and #3 are examples of how one can fully improvise peritoneal dialysis by creating a dialysate from scratch and using a thoracostomy tube or an abdominal surgical drain in lieu of a commercial PD catheter. Although azotemia and uremia were not reversed by IPD, it is believed that fluid overload, hyperkalemia and acidosis were prevented in order to allow for recovery or safe transfer to a higher level of care that could provide hemodialysis

In the episode of M*A*S*H, BJ and Hawkeye were unsuccessful with PD and so resorted to improvised HD with materials ordered from the Sears catalogue and sausage casing from Packo's Café in Toledo.[1] In developed countries, trauma-related acute renal failure is usually treated with conventional HD or by CRRT. PD is usually reserved for stable patients with chronic renal failure and then instituted only after the mini-laparotomy incision has healed. Trauma patients often have larger abdominal incisions and cannot wait for healing before the exchanges are to begin. Leakage of fluid interferes with but does not prevent adequate dialysis. The problem of leakage is considerably worse if the abdomen has to be packed open. The efficacy of exchanges may deteriorate after a few days because the direct flow or communication between infusion and effluent tubes limits dialysate exposure time to an adequate amount of peritoneal surface area.

The fictionalized care given in the drama M*A*S*H is remarkably accurate because of advice given to the writers by physician veterans of the Korean War. Both the physicians and the writers believed improvised HD would be feasible in a forward surgical hospital. This has proved not to be the case. A low technology renal replacement therapy such as IPD is possible and could be a valuable adjunct to soldier care.

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Table 1. Injuries and clinical status of patients requiring improvised peritoneal dialysis

Patient	Injury	Surgery	Cause of renal failure	Indication for dialysis
#1: male, age 9 years, local civilian	Gunshot wound right iliac fossa and thigh, gangrene right leg	Laparotomy, hip disarticulation – amputation	Septic shock	Acidosis, hyperkalemia, fluid overload
#2: male, age 23 years, local security force	Gunshot wound right arm and leg , fractured pelvis, bilateral renal contusion	Arm amputation, fasciotomy and external fixation leg	Renal contusion, Hypovolemic shock	Acidosis, hyperkalemia, fluid overload
#3: male, age 32 years, contract worker from 3rd party country	Cardiopulmonary arrest secondary to pneumonia	None	Anoxic injury	Acidosis, fluid overload, possible uremic coma
#4: male, age 19 years, local security force	Massive soft tissue injury, fractured liver, spleen, abdominal compartment syndrome	Laparotomy, splenectomy, liver repair, debridement	Hypovolemic shock	Fluid overload

Table 2. In-theater improvised peritoneal dialysis						
Patient	**Catheter / abdominal surgery**	**Dialysate**	**Volume / dwell time**	**Duration of dialysis and total number of exchanges**	**Effect of dialysis**	**Outcome**
#1	Two abdominal drains, midline laparotomy with closure	Improvised 4.5% dextrose solution	500 ml / 2–4 hours	10 days / 27 exchanges	Fluid, acid and electrolyte balance normalized	Full recovery, discharged home
#2	Abdominal drain placed into pelvis	1.5% Dianeal (Baxter)	2 L / 4 hours	3 days / 6 exchanges	Fluid removed, worsening azotemia	Transferred to local hospital for ongoing care
#3	Pediatric chest drain placed into pelvis	Improvised 1.5% and 2.5 % dextrose solutions	1.5-2 hours	7 days / 42 exchanges	Improvement of mental status and fluid-electrolyte-acid imbalance avoided despite persistent anuria and azotemia	Transferred to home hospital on ventilator; full recovery after prolonged ICU stay and hemodialysis
#4	Two abdominal drains, midline laparotomy with abdominal packing	4.25% Dianeal (Baxter)	Initial: 500 ml Later: continuous	4 days / 11 exchanges	Fluid removed, azotemia, acidosis unaltered	Death with multiple organ failure

Table 3: Recipe to make 500ml of improvised peritoneal dialysate			
	1.25% dextrose	2.5% dextrose	4.5% dextrose
5% dextrose water	125 ml	250 ml	449.75 ml
10% $CaCl_2$	0.25 ml	0.25 ml	0.25 ml
5% $NaHCO_3$	50 ml	50 ml	50 ml
0.9% saline	324.75ml	199.75 ml	0
Instructions	Remove appropriate volume from a 500 ml bag of 5% dextrose, add the other ingredients and fill back to a total volume of 500 ml with 0.9% saline.		