Continuous Arteriovenous Hemodialysis and Continuous Venovenous Hemofiltration in Burn Patients with Acute Renal Failure

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Acute renal failure (ARF) is a very common condition that may occur in patients with major burn injuries. The majority of burn patients with ARF have a high mortality rate, ranging from 73% to 100%. There are several ways to treat ARF in burn patients, including peritoneal dialysis (PD), intermittent hemodialysis, and continuous renal replacement therapy (CRRT). CRRT is generally used in patients in whom intermittent hemodialysis has failed to control hypovolemia, as well as in patients who cannot tolerate intermittent hemodialysis. Additionally, PD is not suitable for patients with burns within the abdominal area. For these reasons, most patients with unstable hemodynamic conditions receive CRRT. In this study (conducted in our burn unit between 1997 and 2004), six burn patients received CRRT: three received continuous arteriovenous hemodialysis (CAVHD) and the other three received continuous venovenous hemofiltration (CVVH). The patients were all males, with a mean age of 49.8 years (range, 27–80 years), and a mean burnt surface area of 65.1% (range, 30–95%). Four patients died due to multiple organ failure, and two patients recovered from severe ARF. CRRT has been proven safe and useful for burn patients with ARF. According to this study, we conclude that CVVH is an appropriate tool for treating ARF, with a lower incidence of vascular complications than CAVHD.

Key Words: acute renal failure, burns, continuous arteriovenous hemodialysis, continuous venovenous hemofiltration
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Acute renal failure (ARF) is a severe complication which occurs in severely burnt patients. It has an incidence of between 0.5% and 30% (depending on the severity of the burns) [1]. Despite the advances in modern technology and medicine, the mortality rate is still between 73% and 100% (Table 1) [1–5].

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Continuous renal replacement therapy (CRRT) was developed for the treatment of ARF, and it has successfully been put to use on burn patients with ARF [1]. There are many types of CRRT, including continuous arteriovenous hemofiltration (CAVH), continuous venovenous hemofiltration (CVVH), continuous arteriovenous hemodialysis (CAVHD), continuous venovenous hemodialysis (CVVHD), continuous arteriovenous hemodiafiltration (CAVHDF), and continuous venovenous hemodiafiltration (CVVHDF). Each type of CRRT has a specific, major function to replace the function of the kidneys. However, which type of CRRT is more suitable for burn patients with

Table 1. Mortality rate and patient number in burn patients with acute renal failure (ARF)

	Burn patients with ARF, *n*	Mortality, *n* (%)
Cason (1953–56)	49	49 (100)
Vertel et al (1960–65)	24	21 (87.5)
Guys (1953–67)	22	21 (95.4)
East Grinstead & Halton (1958–79)	24	20 (83.3)
Davies et al (1958–79)	28	24 (86)
Cameron et al (1967)	22	21 (96)
Mercé et al (1980–82)	11	8 (73)
Leblanc et al (1987–94)	16	13 (82)
Davies et al (1990–91)	15	12 (80)
Minas et al (1990–98)	76	67 (88.1)
Holm et al (1994–98)	48	41 (85)

ARF is still debated. We used CAVHD and CVVH to support our burn patients with ARF.

Patients and Methods

Data collection

Between January 1997 and October 2003, six burn patients with ARF were treated with CRRT at the burn unit of Kaohsiung Medical University Hospital.

Charts on these patients were reviewed retrospectively. All these patients were admitted with second and third degree burn surface areas greater than 30% of their total body surface area (TBSA). Factors relating to renal failure were divided as follows: nephrotoxic agents (aminoglycosides, vancomycin, amphotericin B), sepsis, and hypotension (mean arterial pressure <70 mmHg for 3 hours). Information about dialytic support was also collected.

Renal replacement therapy was initiated at a serum creatinine (Cr) level > 5.0 mg/dL or blood urea nitrogen (BUN) level > 70 mmol/L, or in a patient with anuria or oliguria (urine < 350 mL/24 hours), or with pulmonary edema not responding to diuretics.

At the beginning, all patients received fluid replacement according to the Parkland formula (4 mL/kg/%BSA/first 24 hours) with crystalloids for resuscitation. Colloids, such as albumin and fresh frozen plasma, were given in the second 24 hours post-burn period. An hourly urine output of 0.5–1 mL/kg/hour was maintained by adjusting the infusion rate of fluids.

Burn wounds were covered with silver sulfadiazine. Surgical intervention—escharotomy, debridement, or skin grafting—was performed as necessary. Bronchoscopic examination was performed routinely after admission to check the airway, in case inhalation injury was suspected. Pain control as well as mild sedation were used to make the patient comfortable. Antibiotic therapy was given and adjusted when necessary.

Technical aspects of CRRT

The former three cases received CAVHD because the rolling pump was not available at that time. CAVHD was performed using the FH 66D (Gambro®, Germany) filter. Vascular access was obtained via the femoral artery and vein. The latter three patients received CVVH treatment. The Hemofilter 6S (Gambro®, Germany) was used for CVVH. A dual-lumen venous catheter was inserted into the femoral vein for the vascular routes. The hemofilter was changed when a clotting episode occurred during CRRT. Besides this, the tubular set was changed whenever line kinking was noticed. Heparin was used to maintain partial thromboplastin time (PTT) within 1.5–2 times of control value.

Results

All these patients were admitted to our burn center with a burn surface area > 30% TBSA. The mean burn surface area was 65.1% TBSA (30–95%). Three patients had naked flame burns, two had sustained scald burns, and one had an electrical burn injury. All these patients were males with a mean age of 49.8 (range, 27–80 years). Four of the patients had inhalation injuries.

The renal function of these patients was normal at the time of admission except for two patients who had mild renal function impairment (BUN, 32–35 mmol/L; Cr, 2.0 mg/dL). The symptoms/signs of sepsis were noted in all six patients before progression to ARF. The mean systolic blood pressure of the CAVHD group (114.7 mmHg) was greater than that of the CVVH group (97 mmHg). The mean duration of CRRT was 8.2 days (4–12 days). The duration of hospitalization was 10–57 days with a mean duration of 28.3 days. Ventilator support was given to all six patients during the course of CRRT.

The total mortality rate was 83.3%: multiple organ failure (MOF) being the cause of death in four cases,

Table 2. Clinical data of the burn patients in this study

Index	Patient					
	1	2	3	4	5	6
Age (yr)	27	59	30	62	41	80
Sex	M	M	M	M	M	M
TBSA burned (%)	95	70	85	30	71	40
Type of burn	Scald	Flame	Flame	Electric	Flame	Scald
Inhalation injury	–	+	+	+	+	–
BUN (admission) (mmol/L)	15	32	20	24	16	35
Cr (admission) (mg/dL)	1.3	2.0	1.4	1.3	1.2	2.0
BUN (initiation of CRRT) (mmol/L)	147	116	87	104	122	113
Cr (initiation of CRRT) (mg/dL)	5.9	5.0	4.7	5.1	4.9	3.8
Sepsis	+	+	+	+	+	+
Hypotension	+	+	+	+	+	+
Ventilator support during CRRT	+	+	+	+	+	+
Duration of CRRT (d)	4	7	5	12	10	11
Type of CRRT	CAVHD	CAVHD	CAVHD	CVVH	CVVH	CVVH
Blood pressure (initiation of CRRT)	110/80	114/54	120/70	106/83	95/70	90/50
Duration of hospitalization (d)	14	11	10	57	28	50
Outcome	Dead	Dead	Dead	Alive	Dead	Dead*

*Successfully weaned from CRRT, but died from acute myocardial infarction. TBSA = total body surface area; BUN = blood urea nitrogen; Cr = creatinine; CRRT = continuous renal replacement therapy; CAVHD = continuous arteriovenous hemodialysis; CVVH = continuous venovenous hemofiltration.

and cardiovascular disease in one case. Out of these six patients, two recovered from ARF successfully. However, only one patient survived; the other patient expired owing to acute myocardial infarction after 2 weeks of recovery from the course of ARF (Table 2). There was a 33.3% recovery rate in this series.

Overview of the complications that arose in CRRT is as follows. (1) The CAVHD group: thrombosis in one patient; pseudoaneurysm (tube insertion site) in one patient; two patients expressed decreased platelet count; line disconnection in one patient; line kinking in one patient; bleeding from the catheter insertion wound in one patient; and hypokalemia in one patient. (2) The CVVH group: one patient had decreased platelet count; line kinking in one patient; filter clotting in two patients; bleeding from the catheter insertion wound in one patient; infection of the insertion wound in two patients; and hypernatremia in one patient (Table 3).

Table 3. Complications in our continuous renal replacement therapy (CRRT) patients

Complications	CAVHD	CVVH
Vascular		
Thrombosis	1	0
Pseudoaneurysm	1	0
Vessel rupture	0	0
Blood		
Platelet decrease	2	1
CRRT machine		
Line disconnect	1	0
Line kinking	1	1
Filter clot	0	2
Insertion wound		
Bleeding	2	1
Infection	0	2
Electrolyte imbalance	1 (hypokalemia)	1 (hypernatremia)
Fluid overload	1	0

CAVHD = continuous arteriovenous hemodialysis; CVVH = continuous venovenous hemofiltration.

Discussion

In contrast to other natural disasters, burns exert a catastrophic influence on people in terms of the continuation of normal life, suffering, disability, and the loss of finances. ARF is a major complication with a high mortality rate in burn patients (Table 1). ARF is defined as an abrupt decrease in the glomerular filtration rate caused by intrinsic parenchymal disease

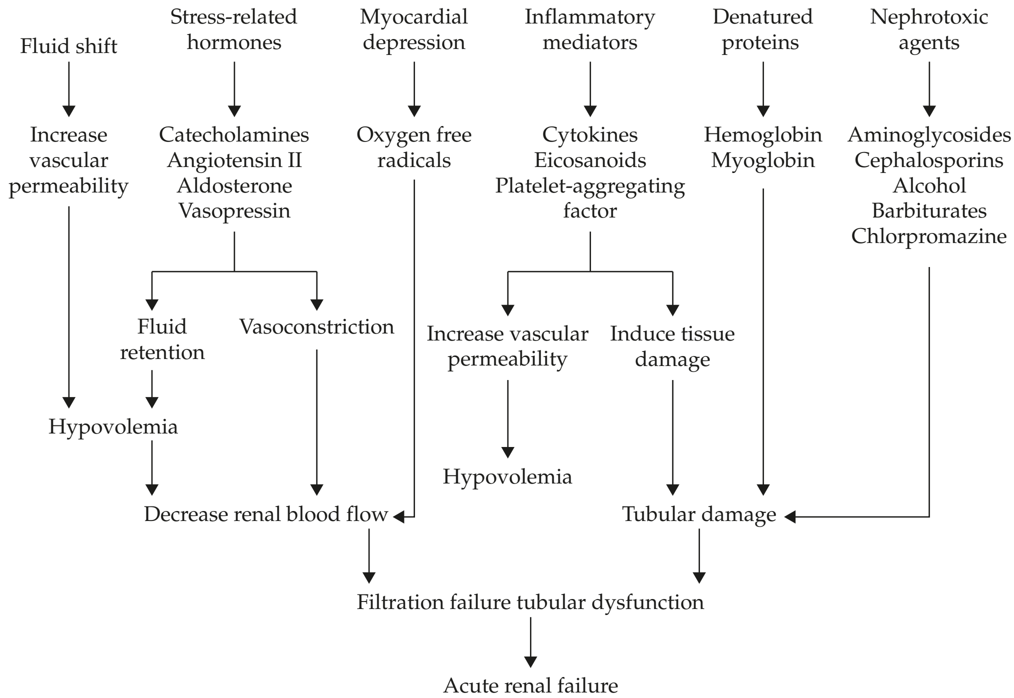

Figure. *Etiologic factors of renal failure in burn patients.*

or alternations in intrarenal hemodynamics, usually associated with azotemia and a decrease in urine output [2,6].

Two forms of ARF have been described in burn patients. The first form occurs in the first few days after injury and is related to hypovolemia with low cardiac output and systemic vasoconstriction during the resuscitation period. Hauben [7] reported that the volume of circulating plasma is reduced by 25% of the normal value where burn areas are more than 40% TBSA. However, this form of ARF has become less frequent due to the aggressive resuscitation policy at the acute stage of burn management. The other form develops during the second week and is related to sepsis and MOF. This form is now believed to be the most frequent cause of renal insufficiency in burn patients [1].

There are six etiologic factors related to the development of ARF in burn patients: fluid shift, stress-related hormones, myocardial depression, inflammatory mediators, denatured proteins, and nephrotoxic agents (Figure) [8–10].

Although the incidence of ARF requiring renal replacement therapy following burn injuries is nearly 1% in the most recent series [11], dialytic support has to be initiated early after ARF. Reported indications include fluid overload, hyperkalemia, pulmonary edema unresponsive to diuretics, acidosis, and uremic complications. Although peritoneal dialysis (PD) has been successful in the treatment of ARF, it has some complications such as low efficiency, low rate of ultrafiltration, the need for peritoneal access, respiratory problems, protein losses, increased intra-abdominal pressure, bacterial or fungal peritonitis, hernias, catheter malfunction, and fluid leakage [12,13]. In addition, it is contraindicated in abdominally injured patients, especially in burn patients. The conventional intermittent hemodialysis provides high and stable efficiency and a high rate of ultrafiltration. However, intermittent hemodialysis is associated with some complications such as post-dialytic rebound, difficulty in balancing of solutes, cardiac arrhythmias, and severe hypotension [13–16]. Additionally, it is contraindicated in hypotensives and critically ill patients who cannot leave the burn unit to go to the hemodialysis unit.

CRRT was first described by Scribner in 1960 and was first applied to patient care by Kramer in 1977 [13,17,18]. One of the advantages of CRRT is that hemodynamic stability is better tolerated by hypotensive patients [13]. With CRRT, volume control is continuous and immediately adaptable to the rapidly changing clinical circumstances common in the care of critically ill patients [18]. In addition, CRRT can correct fluid overload, improve urinary output, decrease neurohumoral activation, and prolong symptom-free and edema-free time [9,18,19]. Bellomo and Ronco [19] reported that patients treated with CRRT consistently maintain lower urea and Cr levels. Uremic control with CRRT is vastly superior to that achieved with standard intermittent hemodialysis. CAVH, CVVH, CAVHD, CVVHD, CAVHDF, and CVVHDF are all variations of CRRT.

In this present series, CAVHD and CVVH were used to treat the patients. CAVHD employs both diffusion dialysis and convectional filtration clearance on a continuous basis [15]. Arterial blood from an appropriately sized artery flows through a semipermeable filter; dialysate is delivered to an extracorporeal compartment in the filter case. Within this filter case, solutes such as urea, phosphate, and uremic toxins are driven by their electrochemical gradient to move across the membrane into the sterile dialysate, which is running countercurrent to blood on the other side of the membrane capillaries [18]. CAVHD has a great ability to remove significant quantities of circulating low molecules (BUN and Cr). Finally, clean blood flows back to the patient through the vein. Sufficient systolic blood pressure is needed to trigger the running of CAVHD. The systolic blood pressure of the patients we chose for CAVHD was > 90 mmHg.

In patients with burns exceeding 30% of TBSA, inflammatory mediators (tumor necrosis factor-α, interleukin-1 [IL-1], IL-6, IL-8) are released from macrophages and other inflammatory cells due to contact with microbial endotoxins or other microbial components, causing a systemic inflammatory response (Figure) [10]. Sepsis, the result of systemic inflammatory response syndrome, may occur if the patient has been infected [20,21]. Since CVVH has a great ability to remove significant quantities of circulating macromolecules (inflammatory mediators) [17,20,22], the effect of an efficient continuous therapy produces a lower degree of inflammation circumstance which blocks the progress of sepsis [6]. CVVH is an appropriate tool for removing a broad spectrum of inflammatory mediators [15,20]. Additionally, CVVH is triggered by a pump, so it can avoid interference caused by the fluctuation of cardiac function.

CRRT has been in use for burn patients with ARF. The results have improved since 1986 (Table 4) [1,4,11,23,24]. The successful weaning CRRT rate in this patient series was 33.3%. Because one patient suffered from acute myocardial infarction after successful weaning from CRRT, the overall mortality rate was 83.3%.

Despite its disadvantages and limitations, CRRT is of great help in the treatment of burn patients with ARF. Some of the disadvantages and limitations are as follows: filter blockages due to a blood clot because of hypoperfusion; bleeding at the cannulation site; immobilization in bed; slower solute and fluid removal; and the possibility of air embolism. Moreover, it is contraindicated in patients with the risk of increased intracranial pressure; there is prolonged exposure of blood to synthetic material; anticoagulation is often needed (that means it cannot be used in patients with coagulopathy, liver disease, or active bleeding); and there is the need for arterial access with CAVH, CAVHD, or CAVHDF [4,13,16,17].

Coagulative disorders, bleeding or hematoma, arteriovenous fistula, thrombosis, line disconnection or kinking, blockage of filter by clots, hypotension, cannulation site infection, hypothermia, errors in electrolyte

Table 4. Mortality rate after continuous renal replacement therapy (CRRT) in different studies

	ARF, *n*	Type of CRRT	Mortality, %
Hubsher et al	5	5-CAVH	80
Gueugniaud	44	12-CVVHDF, 6-CAVHDF	78
Leblanc et al	16	12-CAVHDF, 4-CAVH, 2-CVVHDF, 1-CVVH	81
Weksler et al	4	4-CVVH	23
Holm et al	48	48-CAVH	85
Tremblay et al	15	12-CVVHDF, 2-CVVH, 1-CVVHD	50
This series	6	3-CAVHD, 3-CVVH	83.3

ARF = acute renal failure; CAVH = continuous arteriovenous hemofiltration; CVVHDF = continuous venovenous hemodiafiltration; CAVHDF = continuous arteriovenous hemodiafiltration; CVVH = continuous venovenous hemofiltration; CVVHD = continuous venovenous hemodialysis; CAVHD = continuous arteriovenous hemodialysis.

and acid–base correction, fluid imbalance, and anaphylactic reaction are the major complications of CRRT [13]. In this series, the complications our patients experienced can be divided into four categories: (1) vascular (pseudoaneurysm of femoral artery), one in the CAVHD group; (2) manipulative error (line disconnection or kinking), two patients in the CAVHD and one in the CVVH group; (3) mechanism of CRRT (platelet decrease, filter clot, and thrombosis), three in the CAVHD and three in the CVVH group; and (4) problems with care (electrolyte imbalance, fluid overload, and wound infection), two in the CAVHD and three in the CVVH group. After an overview of these complications, we conclude that CVVH has a lower incidence of vascular complications than CAVHD. This result is comparable with that of Leblanc et al [4].

CRRT has been proven a safe and useful method in burn patients with ARF. It is most important to initiate CRRT as soon as possible once ARF has been diagnosed. In addition, choosing the appropriate CRRT is another key point for successful therapy. Arteriovenous CRRT's reputation for bringing undesirable vascular complications leaves venovenous CRRT as the preferred form of treatment for ARF. It is best to use continuous hemofiltration to treat ARF if the renal function of the patient is normal before injury. If the renal function before injury is not normal or there is a need to extract a large volume of fluid, continuous hemodialysis is an appropriate consideration. Dosages of anticoagulant must be adjusted carefully to prevent any bleeding tendency or filter clotting formation (check PTT and keep the patient's normal ratio within 1.5–2; keep activated clotting time from the venous limb within 160–200 seconds). Finally, cautious (and constant) monitoring of the running of CRRT is the most important factor that can prevent an unexpected error.

According to our preliminary experience, improvement in treatment results depends on the following suggestions. First, fluid and electrolytes should be calculated carefully to prevent fluid overload or hypotensive status. Second, anticoagulants should be prescribed and adjusted cautiously to preclude any bleeding tendency or filter clotting formation. Third, the temperature of the patient should be monitored carefully to prevent hypothermia. Fourth, any sign of infection should be watched for and antibiotic treatment should be adjusted accordingly or if necessary. Finally, the running of the machine should be constantly monitored to avoid interrupting the CRRT.

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使用連續性動靜脈透析與連續性靜脈透析於燒傷病患合併急性腎衰竭病人的比較

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燒傷病人合併急性腎衰竭的死亡率高達 73% 至 100%。目前有相當多針對腎衰竭的治療方式包含腹部透析、間歇性血液透析及連續性血液透析。一般而言，連續性血液透析通常使用於血壓不穩定或無法接受間歇性血液透析治療的病患。此外，腹部有燒燙傷口的病人也不適宜使用腹部透析治療。所以，大多數燒傷合併急性腎衰竭且心肺功能不穩定的病人多使用連續性血液透析。本研究中，自 1997 至 2004 年共有六位燒傷合併急性腎衰竭的病人接受續性血液透析 (三位使用連續性動靜脈透析、另三位使用連續性靜脈透析)。平均年齡是 49.8 歲 (27至80歲)、平均燒傷面積是 60.4% (11.5 至 95%)。四位病患死於多重器官衰竭、兩位患者成功順利脫離急性腎衰竭。本文討論連續性動靜脈透析與連續性靜脈透析的優缺點。結論為連續性靜脈透析在治療燒燙傷合併急性腎衰竭上優於連續性動靜脈透析。原因為連續性靜脈透析較能移除發炎因子並有較少的後遺症。

關鍵詞： 急性腎衰竭，燒傷，連續性動靜脈透析，連續性靜脈透析

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