Combination hemodialysis and centrifugal therapeutic plasma exchange: 18 years of Canadian experience

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Abstract
Hemodialysis (HD) and therapeutic plasma exchange (TPE) are extracorporeal treatments that may both be required in the same patient. When provided separately, 7–8 hours of therapy time is required. Simultaneous administration of both therapies can reduce time and personnel requirements. We report our 18-year institutional experience with combination HD and centrifugal TPE therapy. During combination therapy, the TPE circuit is attached to the HD circuit through an extension blood line connected to the HD venous return line, allowing simultaneous operation of both circuits. The HD circuit is anticoagulated with heparin and the TPE circuit with regional citrate. Blood flow rates through the HD circuit can reach 350 mL/min with plasma removal rates in the TPE circuit up to 60 mL/min. Ninety-two patients received a total of 621 treatments between December 1993 and July 2011. All treatments were completed within 4 hours. No major treatment-related adverse events occurred and less than 10% of treatments were complicated by minor events. Main indications for treatment were ANCA (anti-neutrophilic cytoplasmic antibody) vasculitis (n = 25), Goodpasture’s/antiglomerular basement membrane disease (n = 24), adult thrombotic thrombocytopenic purpura/hemolytic uremic syndrome (n = 24), and acute antibody-mediated renal transplant rejection (n = 8). Overall rates of renal recovery, in-hospital mortality, and overall mortality at 18-year follow-up were 45% (41/92), 2% (2/92), and 21% (19/92), respectively, compatible with published literature. Combination HD and TPE is safe, efficient, and requires less human resources and time than conventional sequential therapy. It should be considered in patients whose treatment regimen includes HD and TPE.

Key words: Apheresis, combination, hemodialysis, plasmapheresis, therapeutic plasma exchange

INTRODUCTION
Apheresis is a procedure during which whole blood is processed to separate plasma from blood cells. It allows selective removal of any of the blood cell lines or plasma. Plasma separation (plasmapheresis) can be performed through membrane filtration or centrifugation.1 When a large amount of plasma is removed and replaced with a substitution solution, the process is referred to as therapeutic plasma exchange (TPE). Since its pioneer years in the early 1910s,2 TPE has emerged as an important extracorporeal therapy used in the treatment of complex conditions. In recent years, the proposed indications for TPE have broadened and include systemic diseases such as thrombotic thrombocytopenic purpura/hemolytic uremic syndrome (TTP/HUS), ANCA (anti-neutrophilic cytoplasmic antibody) vasculitis, and Goodpasture’s disease. These conditions often cause renal failure resulting in the requirement for hemodialysis (HD).
Traditionally, HD and TPE treatments are administered separately, with a typical HD treatment requiring 4 hours and TPE treatment requiring 2–3 hours. Thus, provision of sequential treatments would demand a time commitment of approximately 7–8 hours from patients and nursing staff. The simultaneous performance of both procedures would permit a reduction in time, human, and physical resources.

Over the last decade, isolated case reports of combined TPE and HD procedures have been published.\(^5\)\(^6\)\(^9\) Despite slight variation in technique, all methods involve running both circuits simultaneously, either in parallel or in series with one another. Most of these reports describe combination HD with membrane filtration plasmapheresis.\(^8\)\(^9\) Although centrifugal TPE is more widely available and utilized, reports of its combination with HD are rare.\(^5\)\(^6\)\(^7\)

This report describes the technical details of combination HD and centrifugal TPE therapy. It also describes patient- and treatment-related outcomes over an 18-year period. To our knowledge, this is the largest published series of patients who have received combination therapy.

MATERIALS AND METHODS—TECHNICAL REPORT

Setting and staffing

St. Paul's Hospital is a tertiary care hospital located in downtown Vancouver, Canada. It is one of three hospitals within the province to provide TPE. All HD and TPE treatments are prescribed by trained nephrologists or in collaboration with a specialized hematologist (L. V.). Combination treatments are provided by nursing staff and technicians with special competency in dialysis and TPE procedures, and performed within the HD unit or inpatient wards.

Space and structural requirements

The physical location of combination treatments must allow for enough space to fit both the HD machine and TPE machine, with display and treatment monitors of both machines being visible and accessible (Figure 1a). Technical, hygienic, and emergency procedures must conform to regulatory standards for provision of dialysis and TPE.

Vascular access and machines

A single vascular access is used during combination treatments. Double-lumen dialysis catheters or arteriovenous fistulas (or grafts) can be used. The choice of HD machine and dialyzer membrane is unaffected during combination treatments. Our center currently uses the B. Braun Dialog HD machine (B.Braun Medical Inc., Melsungen, Germany), the Asahi Reexed high-flux polysulfone dialyzer membrane (Asahi Kuraray Medical Co. Ltd., Tokyo, Japan), and the centrifugal COBE Spectra Apheresis System (Caridian BCT, Lakewood, USA).

Connection of HD and TPE circuits

During combination treatments, a portion of freshly dialyzed whole blood is siphoned off the HD circuit, processed through the TPE circuit, and returned to the patient (Figure 1b). This requires insertion of an extension blood line (‘Hemodialysis Combo line’, HP-100, Medionics International Inc., Markham, Canada) between the HD venous return line and the venous limb of the patient’s vascular access. This extension line is 50 cm long and has two access ports, which are placed 12 cm apart and are used to connect the TPE circuit to the HD circuit (Figure 2a,b). A standard Y-connector can be added to the venous limb of the patient’s vascular access to allow for administration of fluids or intravenous medications.

HD prescription

No parameters of the initial HD prescription require alteration. Anticoagulation of the HD circuit is via infusion of unfractionated heparin into the HD arterial line as per routine local practice, unless contraindications are present. After a few sessions of combination therapy, minor modifications to the dialysate bicarbonate and calcium concentration may be necessary in response to changes in serum bicarbonate or calcium levels due to the use of citrate in the TPE circuit.

Initiation of TPE during HD

The HD circuit is primed and initiated as per routine practice. When ready to initiate TPE, the HD blood pump speed is reduced to 200 mL/min to avoid venous pressure alarms. The TPE circuit is attached to the HD circuit through the ports on the extension line. The port most distal to the patient (TPE inlet) is used to deliver a portion of blood from the HD venous bloodline to the TPE circuit (TPE inlet), and the port most proximal to the patient (TPE outlet) is used to deliver processed blood from the TPE circuit back to the HD circuit.

Once the TPE circuit has been attached to the HD circuit, the TPE inlet flow rate is gradually increased until the target plasma removal rate is reached. The HD circuit
Figure 1 (a) Combination treatment machine set up. The centrifugal therapeutic plasma exchange machine and hemodialysis (HD) machines are both set up side-by-side or one in front of the other, as long as treatment and display monitors are visible accessible. (b) Schematic diagram of combination circuit setup. The HD circuit is modified by attaching the HD venous return line to an extension line. Two ports on this extension line allow whole blood to be withdrawn from the HD venous return line, circulated through the therapeutic plasma exchange (TPE) circuit, and subsequently returned to the patient. The TPE circuit is regionally anticoagulated with citrate, infused at the TPE inlet line. Replacement fluid is infused at the TPE outlet line. Calcium is infused into the venous limb of patient’s vascular access.
blood flow rate is then sequentially increased within limits of the arterial and venous vascular access pressures. Whole blood flow rate through the HD circuit is not compromised and can safely reach 350 mL/min. The TPE circuit and procedure are primed, performed, and disconnected without any interruption to the HD circuit.

TPE prescription

During a typical TPE prescription, the total exchange volume is dependent on the patient’s plasma volume, as determined by the patient’s body weight and hematocrit (plasma volume = 0.07 × weight [kg] × [1-hct!]). The usual practice is to prescribe an exchange volume of 1.5× plasma volume for the first three treatments and 1× plasma volume for subsequent treatments. This standard approach may be modified based on clinical and bloodwork parameters as well as patient tolerability of treatments. TPE treatment time is dependent on the volume of plasma to be exchanged, but allows for high volumes of plasma (up to 5 to 6 L) to be exchanged within 1.5 to 3 hours.

The composition of the exchange fluid is determined by the rationale for providing TPE. When replacement of defective or deficient plasma constituents is the aim, fresh frozen plasma is used (e.g., HUS/TTP). When removal of an offending plasma constituent is the aim, a combination of albumin and crystalloid (normal saline or Ringer’s lactate) is used. During combination treatments, replacement volumes are set at 100% and the patient’s overall fluid balance is controlled through adjustments of the ultrafiltration volume during HD.

Anticoagulation of TPE circuit

The TPE circuit is anticoagulated regionally using ACD-A solution (Anticoagulant Citrate Dextrose Solution Formula A, Baxter Healthcare Corporation, Canada), which is infused into the inlet TPE line. Depending on machine specifications, the ACD-A to inlet blood flow ratio can range from 1:1.5 to 1:4.5, and the ACD-A infusion rate can range from 0.8 mL/min/L to 1.2 mL/min/L exchange volume. We use a default ACD-A to inlet blood flow ratio of 1:2.5 and ACD-A infusion rate of 0.8 mL/min/L of exchange volume, unless clinical context warrants modification, as outlined in Table 1.

Prophylactic intravenous calcium is infused either peripherally or into the venous limb of the vascular access (using a port on the Y-connector) to prevent symptomatic hypocalcemia (Figure 2). Our default calcium infusion rate is 1 g/h, which is increased to 2 g/h only if clinical symptoms of hypocalcemia develop. Ionized calcium levels are measured to monitor for citrate-induced hypocalcemia.
<table>
<thead>
<tr>
<th>Hemodialysis circuit</th>
<th>Therapeutic plasma exchange circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment time</td>
<td>4 h</td>
</tr>
<tr>
<td>Whole blood flow rate</td>
<td>As per routine orders (usually 300–350 mL/min)</td>
</tr>
<tr>
<td>Plasma removal rate</td>
<td>—</td>
</tr>
<tr>
<td>Fluid removal rate</td>
<td>As per patient clinical status</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>Unfractionated heparin</td>
</tr>
<tr>
<td></td>
<td>• infused into arterial HD line</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.25–1.5 mmol/L in dialysate</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>28–35 mmol/L in dialysate</td>
</tr>
<tr>
<td>Plasma volume (PV)</td>
<td>—</td>
</tr>
<tr>
<td>Exchange volume (EV)</td>
<td>—</td>
</tr>
<tr>
<td>Replacement volume</td>
<td>—</td>
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<tr>
<td>Exchange fluid</td>
<td>—</td>
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</tbody>
</table>

Dependent on exchange volume
Typically 1.5–3 h
Determined by target plasma removal rate (up to 120 mL/min)
Maximum 60 mL/min

—
Citrate (ACD-A)
• infused into TPE inlet line
• ratio to inlet blood flow rate
1.25 (standard)
1.35 (if using FFP as replacement)
1.45 (if hypocalcemic)
• infusion rate range
0.8–1.2 mL/min/L of EV
Calcium gluconate 1–2 g/h peripheral intravenous infusion

—
0.07 × weight (kg) × (1-hematocrit)
1.5 × PV (first 3–5 treatments), then
1.0 × PV (subsequent treatments)
100%
100% plasma (if HUS/TTP)
or
75% albumin (5%) + 25% Ringer’s lactate or normal saline

ACD-A = Anticoagulant Citrate Dextrose Solution-Formula A; EV = exchange volume; FFP = fresh frozen plasma; HD = hemodialysis; HUS = hemolytic uremic syndrome; TPE = therapeutic plasma exchange; TTP = thrombotic thrombocytopenic purpura.

The HD circuit is anticoagulated per routine practice using unfractionated heparin in most cases (unless clinical contraindications are present), without need for reversal of anticoagulation. Our default heparin protocol specifies a 500-unit loading dose and 500 units/h maintenance dose. Efficacy and safety of anticoagulation is monitored clinically based on appearance of the extracorporeal circuit tubing, prevention of clotting episodes, and avoidance of prolonged bleeding from the vascular access site. We do not perform laboratory monitoring of the anticoagulant effect.

Nursing care and monitoring

Safety and technique monitoring is carried out according to dialysis and TPE policies and guidelines. Combination treatments are carried out at a 1:1 patient to nurse ratio. In addition to disease-specific bloodwork, routine bloodwork including serum electrolytes, coagulation parameters, ionized calcium, and magnesium levels are measured at the beginning of each treatment in order to monitor for complications related to therapy, such as metabolic alkalosis, hypocalcemia, hypomagnesemia, abnormal coagulation parameters, or hypernatremia.

Documentation and monitoring

Monitoring and documentation are performed according to local HD and TPE policies and guidelines. In addition to the usual documentation of HD treatment parameters, data capturing TPE treatment parameters are recorded on a separate log sheet. These include machine specifications, treatment time, real-time volume of plasma removed and replaced, composition of exchange fluid, rates of anticoagulant and intravenous calcium infusion, and overall fluid balance.

Any adverse effects encountered during the combined procedure require notification of the supervising physician and documentation on an Adverse Event form. All data are annually submitted in de-identified format to a national registry (Canadian Apheresis Group) for purposes of quality assurance and accountability.
RESULTS—PATIENT OUTCOMES

Patient selection
A total of 92 patients have received combination treatments between December 1, 1993 and July 31, 2011. The average age of patients was 51.3 years (range 18 to 87 years), with 51 male and 41 female patients. Indications for combination treatments were ANCA vasculitis (n = 25 patients), Goodpasture’s disease/antiglomerular basement membrane (anti-GBM) disease (n = 24 patients), adult TTP/HUS (n = 24 patients), acute antibody-mediated renal transplant rejection (n = 8 patients) and a limited number of other indications as detailed in Table 2.

Treatment course
A total of 621 combination treatments were performed in the 92 patients between December 1993 and July 2011. These numbers exclude any isolated TPE or HD runs, which the patient may have received, as can occur when daily HD is required while daily TPE is not. The average number of combination treatments per patient was 5.9, with a range 1 to 24 runs per patient. All patients received additional medical therapy including immunosuppression according to disease-specific indications under the direction of the treating physicians. All drugs were dosed after combination treatments when possible.

Renal recovery
Forty-one of ninety-two patients (45%) recovered kidney function, while the remaining 51 patients (55%) remained dialysis-dependent (Table 2). Of these, 10 patients eventually received a renal transplant. Disease-specific rates of renal recovery were highest in patients treated for acute renal transplant rejection (7 of 8 patients, 88%) and lowest in Goodpasture’s/anti-GBM disease (3 of 24 patients, 13%).

Patient survival
Two of ninety-two patients (2%) died during the course of their hospitalization, none of whom died of complications attributable to combination treatment. One patient was being treated for TTP and died in-hospital from hospital-acquired pneumonia and septic shock. The second patient was being treated for ANCA vasculitis and died in-hospital after withdrawal of care prompted by a diagnosis of metastatic adenocarcinoma. During the 18-year follow-up, an additional 17 of the original 92 patients had died (overall mortality 19 of 92 patients, 21%). Long-term mortality

Table 2 Clinical patient outcomes of combination treatments. Baseline characteristics of patients and indications for combination treatments performed between December 1993 and July 2011. Renal recovery defined as independence from dialysis. In-hospital death defined as death during same hospitalization when patient was receiving combination treatments. Overall death defined as death at last follow-up in July 2011.

<table>
<thead>
<tr>
<th>Indication for therapeutic plasma exchange</th>
<th>Total patients (n)</th>
<th>Males (n/total) (%)</th>
<th>Age in years (avg/range)</th>
<th>Total number treatments (n)</th>
<th>Renal recovery (n/total) (%)</th>
<th>In-hospital death (n/total) (%)</th>
<th>Overall death (n/total) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodpasture’s/anti-GBM disease</td>
<td>24</td>
<td>14/24 (58)</td>
<td>55.5 (28-78)</td>
<td>228</td>
<td>3/24 (13)</td>
<td>0/24 (0)</td>
<td>6/24 (25)</td>
</tr>
<tr>
<td>TTP/HUS</td>
<td>24</td>
<td>11/24 (46)</td>
<td>54.8 (17-81)</td>
<td>123</td>
<td>14/24 (58)</td>
<td>1/24 (4)</td>
<td>8/24 (33)</td>
</tr>
<tr>
<td>Vasculitis</td>
<td>25</td>
<td>13/25 (52)</td>
<td>60.1 (30-80)</td>
<td>191</td>
<td>12/25 (48)</td>
<td>1/25 (4)</td>
<td>1/25 (4)</td>
</tr>
<tr>
<td>Renal transplant</td>
<td>8</td>
<td>6/8</td>
<td>44.1 (30-65)</td>
<td>18</td>
<td>7/8 (88)</td>
<td>0/8 (0)</td>
<td>3/8 (38)</td>
</tr>
<tr>
<td>Multiple myeloma</td>
<td>4</td>
<td>2/4</td>
<td>67.8 (54-87)</td>
<td>26</td>
<td>2/4 (50)</td>
<td>0/4 (0)</td>
<td>0/4 (0)</td>
</tr>
<tr>
<td>Other or unknown</td>
<td>7</td>
<td>4/7</td>
<td>26.0 (18-33)</td>
<td>35</td>
<td>2/7 (29)</td>
<td>0/7 (0)</td>
<td>1/7 (14)</td>
</tr>
<tr>
<td>Overall</td>
<td>92</td>
<td>51/92 (55)</td>
<td>51.3 (18-87)</td>
<td>621</td>
<td>41/92 (45)</td>
<td>2/92 (2)</td>
<td>19/92 (21)</td>
</tr>
</tbody>
</table>

anti-GBM = antiglomerular basement membrane; HUS = hemolytic uremic syndrome; TTP = thrombotic thrombocytopenic purpura.
rates were similar in patients with Goodpasture's disease/anti-GBM disease, HUS/TTP, and renal transplant rejection (between 25% to 38%), but lower in patients with vasculitis (5%).

RESULTS—TREATMENT-RELATED OUTCOMES

Procedure outcomes

Vascular access in all combination treatments was through a temporary HD catheter in either the internal jugular or femoral vein. No significant vascular access complications were noted during any combination treatments. All combination therapies were completed within 3-4 hours.

Procedural adverse events

There were no serious adverse events (SAE), as defined by either death during combination treatment or any event requiring interruption or cessation of further treatments. Performance of TPE did not lead to clinically significant falls in blood pressure requiring nursing or physician intervention. There were no episodes of circuit clotting, hemorrhage, or hemolysis. Individual patient fluid balance goals were attained in all cases.

Minor adverse events were defined as any event attributable to the combination treatment but not meeting criteria for SAE. Given that combination therapy was initiated in 1993 and machine, disposable, and technical details have been refined since early years of inception, the rate of minor adverse events has improved and plateaued at least 10% over the last 18 years. A retrospective review of the last consecutive 100 treatments revealed six treatments during which minor adverse events were recorded. The most common adverse events were urticaria or pruritus (two of six patients) and mild perioral tingling (four of six patients). All urticarial or pruritic symptoms resolved with the administration of a standard dose antihistamine. All perioral tingling resolved with an increase in the intravenous calcium gluconate infusion from 1 g/h to 2 g/h.

No episodes of clinically significant metabolic alkalosis or hypernatremia requiring intervention were reported. On rare occasions, a transient coagulopathy was observed in some patients (maximum international normalized ratio 1.6), which resolved either spontaneously by the next day, or with the substitution of fresh frozen plasma for the crystallloid portion of the exchange fluid used during subsequent treatments.

DISCUSSION

The goal of TPE is to replenish a missing or defective plasma constituent (e.g., ADAMTS-13 in idiopathic thrombotic thrombocytopenic purpura) or to remove an offending plasma constituent (e.g., antglomerular basement membrane antibody in anti-GBM disease/Goodpasture's disease). Indications for TPE take into account the pathophysiology of the disease process and the pharmacokinetics of the target plasma constituent. Official guidelines are published and updated regularly to guide clinicians with regards to initiation, continuation, and discontinuation of TPE. There is a specific group of patients with specific disease entities which require both TPE and HD during the course of treatment, thereby making simultaneous treatment an attractive option.

Isolated case reports about combination HD and plasma exchange therapy began to emerge in the 1980s. But only two centers have published their institutional longitudinal experience with combination therapy, both of which utilized membrane filtration plasmapheresis in addition to HD (Table 3). A Spanish group described their 12-year experience with 36 patients who underwent 287 procedures between 1998 and 2010. The indications for therapy were similar to those reported herein and included HUS/TTP, rapidly progressive glomerulonephritis, antibody-mediated humoral renal transplant rejection, and Goodpasture's disease/anti-GBM disease. They too report minor adverse event rate of 10.5%, with more events in cases where plasma was the predominant exchange fluid. The authors report similar renal recovery rates as those reported herein, but higher in-hospital mortality rates. Long-term survival data were not reported.

Similarly, a German group described their 16-year experience with 82 patients who underwent 483 procedures between 1993 and 2009. The indications for therapy were again similar to our report: thrombotic microangiopathy, vasculitis, humoral renal transplant rejection, and Goodpasture's disease. Rates of renal recovery and mortality were slightly higher than in our study and the Spanish study. Major adverse event rate and long-term survival data were not reported.

Several points are noteworthy about the technical setup of combination therapy at our center:

1. The HD prescription is unaltered, with the whole blood flow rate through the HD membrane reaching maximum desired rates (usually 350 mL/min).
2. Only a portion of blood that has already undergone HD is diverted into the centrifugal TPE circuit and
<table>
<thead>
<tr>
<th>Type of TPE</th>
<th>Centrifugal TPE</th>
<th>Membrane plasma filtration</th>
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<tbody>
<tr>
<td>Reference</td>
<td>Yorgin et al., 2000&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Bhowmik et al., 2001&lt;sup&gt;8&lt;/sup&gt;</td>
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<td>Mahmood et al., 2006&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Denneberg et al., 1982&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Number of patients (total)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Number of sessions (total)</td>
<td>16</td>
<td>125</td>
</tr>
<tr>
<td>TPE circuit connection inflow</td>
<td>Arterial limb of dialysis catheter</td>
<td>Arterial HD bloodline</td>
</tr>
<tr>
<td></td>
<td>Arterial HD drip chamber</td>
<td>n/a</td>
</tr>
<tr>
<td>TPE circuit connection outflow</td>
<td>Venous limb of HD catheter</td>
<td>Arterial HD drip chamber</td>
</tr>
<tr>
<td></td>
<td>Venous HD drip chamber</td>
<td>n/a</td>
</tr>
<tr>
<td>HD blood flow rate (mL/min)</td>
<td>200 (not stated)</td>
<td>200</td>
</tr>
<tr>
<td>TPE blood flow rate (mL/min)</td>
<td>330–400 (not stated)</td>
<td>200</td>
</tr>
<tr>
<td>Anticoagulation of HD circuit</td>
<td>Heparin</td>
<td>Heparin</td>
</tr>
<tr>
<td>Anticoagulation of TPE circuit</td>
<td>Citrate</td>
<td>Citrate</td>
</tr>
<tr>
<td>Reported TPE efficiency (volume exchanged in specified time period)</td>
<td>“1.5 × plasma volume in 60–90 min”</td>
<td>“2–2.5 L in 50–60 min”</td>
</tr>
<tr>
<td></td>
<td>“Max 4 L, time period unknown”</td>
<td>“900 mL in 42 min”</td>
</tr>
</tbody>
</table>

HD = hemodialysis; HF = hemofiltration; TPE = therapeutic plasma exchange.
then returned back to the venous HD return line. This avoids a negative impact on solute clearance during dialysis.

3. Minor modifications are made to the HD dialysate calcium, bicarbonate, and potassium concentrations depending on the frequency of treatments, exchange volume, and exchange fluid composition.

4. TPE can be performed efficiently with plasma removal rates as high as 60 mL/min. This allows for TPE to be completed within the time frame of regular HD.

5. Each circuit is anticoagulated separately, allowing for modifications in either circuit without impacting the other.

Rates of minor events during combination therapy are similar to those reported during isolated TPE treatments.\(^\text{13}\) Rates of renal recovery, in-hospital mortality, and long-term mortality were 45% (41 of 92 patients), 2% (2 of 91 patients), and 21% (19 of 92 patients), respectively. Rates of overall renal recovery and in-hospital death were similar to those described by other centers performing combination treatments for similar indications.\(^\text{13}\) Disease-specific rates of renal recovery and long-term mortality compared well to previously published reports of patients who presented with similar conditions and received isolated TPE and HD treatments.\(^\text{14-17}\)

Pooled center experience with combined membrane plasma filtration and HD has been reported in a total of 121 patients (783 procedures).\(^\text{3,6,8,9}\) However, reports on combined centrifugal TPE and HD have been rare, with a total of only five patients (159 procedures) represented in the literature.\(^\text{4,5,7}\) Given the more widespread use of centrifugal TPE, this report of 92 patients with 621 procedures, using combination centrifugal TPE and HD is important.

In an era of resource constraint and patient-centered care, we would recommend that use of conventional HD machines in combination with centrifugal TPE apparatus be considered as safe and efficient.

ACKNOWLEDGMENTS

We wish to credit Ms. L. Mauw for her technical expertise and innovative initiatives during the initial developments of combination therapy at our center. We also wish to thank the nursing and technician staff at the hemodialysis unit at St. Paul’s Hospital for their endless commitment to the TPE program, in particular Ms. L. Frank, Ms E. Davidson, Mr. D. Morrison, Ms. L. Ocampo, and Mr. A. Cruz. We thank Mr. T. Gee for providing the pictures used in this report.

DECLARATION OF CONFLICTS OF INTEREST

None to declare. The results presented in this paper have not been published previously in whole or part. Full institutional and clinical research ethics approval for this study was obtained.

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REFERENCES


