Supplementary material Supplementary data

Detailed operational procedures for VPPS.VPPS was designed with a specialized purification circuit that integrated c-TPE with PDFA. The treatment protocol comprised two distinct phases: 2 h of c-TPE followed by 4 h of PDFA treatment.

Step 1: 2-h c-TPE

Blood samples were drawn from the antecubital vein utilizing the Spectra Optia Blood Separation System (Spectra Optia, Terumo BCT, Colorado, USA) at a flow rate of 60 mL/min. The plasma was separated through centrifugation and transferred into a circulation bag, then directed into a waste plasma collection bag at a rate of 30 mL/min. Simultaneously, a replacement fluid pump delivered fresh frozen plasma (FFP) to the patient at the same rate. The total volume exchanged during the plasma exchange procedure was 2200 mL.

Step 2: 4-h PDFA

In this stage, a minimum of 6 L of waste plasma was gradually separated for subsequent purification. Throughout the plasma purification process, waste plasma was extracted from a circulation transfer bag using KM8900a (KURARAY, Japan) or DX-10 (Jafron, China) hemodialysis equipment at a flow rate of 150 mL/min. This waste plasma was mixed with plasma extracted from the Spectra Optia Blood Separation System at a flow rate of 30 mL/min and subsequently pumped through a high-throughput blood filtration column (ABH-18F; Asahi Kasei Medical Co., Ltd., Tokyo, Japan) at a cumulative flow rate of 180 mL/min. The flow rate of the plasma dialysate was maintained at 50 mL/min. Concurrently, the diluted plasma was filtered at a flow rate of 40 mL/min. The system included a neutral resin column (HA330-II; Jafron Biomedical Co. Ltd.) and a bilirubin adsorber (BS330; Jafron Biomedical Co. Ltd.); both operating at a flow rate of 180 mL/min. However, the remaining purified plasma was directed into the circulation transfer bag at a flow rate of 150 mL/min and subsequently mixed with freshly separated waste plasma at a flow rate of 30 mL/min. Consequently, all separated waste plasma underwent multiple purification processes. This design exhibits enhanced efficiency in plasma purification, as the flow rate of the PDFA is several times faster than that of plasma

separation. This ensures that the centrifuged plasma undergoes more extensive *in vitro* purification prior to reintroduction into the body. The maintenance and monitoring of the extracorporeal circuit are performed through a combination of the Spectra Optia Blood Separation Device and the DX-10 Hemodialysis Device.