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## RESEARCH ARTICLE

# Improving Apheresis Inlet Flow With a Novel Double-Draw Vascular Access Technique

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## ABSTRACT

Peripheral intravenous catheters (PIVCs) are the preferred vascular access for apheresis; however, veins that initially appear suitable may develop venous spasms, resulting in poor inlet flow and frequent pressure alarms. Ports used for apheresis can also experience inlet pressure alarms due to catheter or venous occlusion. When conservative measures failed, we implemented a novel double-draw technique in which a second draw line was connected via a four-way stopcock and male-to-male adapter to the initial draw access (either a PIVC or port) to improve inlet flow. The double-draw technique was performed in 26 procedures (therapeutic plasma exchange [TPE],  $n = 10$  and lipoprotein apheresis [LA],  $n = 16$ ) in 8 patients. During TPE, median negative inlet pressure improved from  $-179$  mmHg (IQR  $-218$  to  $-69$ ) with single-draw access to  $-71$  mmHg (IQR  $-78$  to  $-62$ ) following placement of a second draw line ( $p = 0.0162$ ). Inlet flow rate during TPE improved from median  $47$  mL/min (IQR,  $40$ – $58$  mL/min) with single-draw access to  $70$  mL/min (IQR,  $60$ – $75$  mL/min) ( $p = 0.008$ ). During LA, median negative inlet pressure improved from  $-136$  mmHg (IQR  $-193$  to  $-109$ ) to  $-59$  mmHg (IQR  $-66$  to  $-47$ ) ( $p < 0.0001$ ). Median inlet flow rate during LA improved from  $70$  mL/min (IQR  $59$ – $71$  mL/min) with single-draw access to median  $80$  mL/min (IQR  $70$ – $80$  mL/min) ( $p = 0.023$ ). Overall 25 of 26 procedures (96.2%) demonstrated an improvement in inlet pressure following implementation of the double-draw technique. All procedures were completed successfully without abandonment of the original access site. The double-draw technique is a novel option for managing inlet pressure alarms during apheresis when conservative measures fail.

## 1 | Introduction

Apheresis procedures, including therapeutic plasma exchange (TPE), lipoprotein apheresis (LA), extracorporeal photopheresis, and red blood cell exchange, play an important role in the management of a variety of acute and chronic conditions [1]. The success of a therapeutic apheresis procedure is dependent upon establishing and maintaining adequate vascular access to ensure sufficient blood flow throughout the treatment. Vascular access options include peripheral intravenous catheters (PIVCs), temporary or tunneled dialysis-type catheters, certain

implantable ports and midline catheters, and surgically created arteriovenous fistulas or grafts [2, 3]. The choice of vascular access depends on factors including vein suitability, procedure frequency and urgency, nursing expertise, and the blood flow requirements of the apheresis device [4].

PIVCs are the preferred vascular access for apheresis because of their favorable safety profile compared with central venous access and their ease of placement [5, 6]. Although discontinuous systems allowing a single access point are available, most apheresis procedures use two separate access points,

commonly referred to as the “draw” and “return” lines. In adults, PIVC gauge typically ranges from 17 to 19, while smaller gauges (19–22) are generally used in children. Larger-gauge catheters permit higher blood flow rates, up to 80 mL/min or greater, whereas smaller gauges typically support flow rates less than 60 mL/min [7, 8]. The draw line is placed in larger veins in the antecubital fossa or in the brachial or cephalic veins, while smaller, more distal veins may be used for the return line. Dialysis-type steel needles or plastic intravenous catheters can be used for inlet and outlet routes.

Veins that initially appear suitable for PIVC placement may develop venous spasms during apheresis, resulting in poor inlet flow and frequent inlet pressure alarms. Standard interventions include warming the extremity, relaxation techniques, administration of intravenous fluids, adjustment of catheter position, repositioning of the arm, and reduction of the inlet flow rate. When these measures fail, removal of the existing line and cannulation of a new vein, or even central venous catheter placement, may be required, resulting in patient discomfort, prolonged treatment times, reduced treatment efficiency, and additional procedural risks. Implantable ports are also susceptible to inlet pressure alarms, which may result from venous or intraluminal occlusion and require patient or needle repositioning, frequent flushing, or administration of thrombolytics, potentially increasing procedure time and cost [9].

To address this challenge, we implemented a novel “double-draw” technique to improve inlet flow without abandoning the original access site. This technique involves placement of a second draw line connected to the original draw access, either a PIVC or port, thereby combining flow from two separate access points into a single inlet line.

## 2 | Materials and Methods

### 2.1 | Study Design and Population

This was a single-center retrospective analysis of all patients who received the double-draw technique over a 12-month period (January 2025 through December 2025) in the outpatient apheresis unit at the University of California San Diego.

### 2.2 | Study Population

The double-draw technique was performed during 26 apheresis procedures in 8 patients (Table 1). Procedures were initiated with a single draw access (PIVC,  $n = 19$ ; implanted port,  $n = 7$ ), with placement of a second draw access when negative inlet pressures could not be corrected with conservative measures. The double-draw technique was employed during TPE on the Optia device (Terumo BCT) and Amicus (Fresenius Kabi), and during lipoprotein apheresis on the MA-03 system (Kaneka).

Patients undergoing TPE were prescribed an exchange volume of  $1.0\text{--}1.2 \times$  total plasma volume. Anticoagulation with acid citrate dextrose solution A (ACD-A) was used for regional circuit anticoagulation at a ratio of incoming whole blood to ACD-A of 10:1–14:1. Prophylactic calcium gluconate was routinely administered via the return line (2 g in 100 mL of normal saline) at a rate of 80–120 mL/h. Patients undergoing LA were prescribed processing of  $1.5 \times$  the total plasma volume (range 3–5 L), with systemic heparin used for anticoagulation at an initial bolus of 25 units/kg followed by 25 units/kg hourly.

### 2.3 | Double-Draw Technique

At our institution, approximately 80% of outpatient apheresis procedures are performed using PIVCs, with flexible 18-gauge BD Angiocatheters used for the draw access and 20-gauge for return access. When no suitable vein is available for draw access and a patient requires chronic apheresis therapy, an implantable port may be used (AngioDynamics SmartPort). Ports are accessed with high-flow, straight, noncoring 16 or 18 gauge needles (AngioDynamics and Norfolk Medical, respectively) and locked with heparin 1000 units/mL (5 mL) after the procedure.

During procedures using PIVCs or ports, when inlet pressure alarms failed to improve with conservative measures, the double-draw technique was employed in patients with another suitable vein for cannulation. The configuration consists of two draw lines connected via extension tubing (Smiths Medical) to a four-way stopcock (Medline) and male-to-male adaptor (Edwards Lifesciences), which is then connected to the apheresis inlet line (Figure 1). When both draw accesses were PIVCs,

**TABLE 1** | Patient characteristics.

| Patient | Age | Sex | BMI | Diagnosis                     | Procedure | Access | Treatment frequency         |
|---------|-----|-----|-----|-------------------------------|-----------|--------|-----------------------------|
| 1       | 65  | M   | 22  | CIDP                          | TPE       | PIVC   | $2 \times$ a week           |
| 2       | 48  | M   | 28  | Transverse myelitis           | TPE       | PIVC   | $2\text{--}3 \times$ a week |
| 3       | 59  | M   | 27  | CAD, High Lp(a)               | LA        | PIVC   | Q2 weeks                    |
| 4       | 61  | M   | 36  | CAD, High Lp(a)               | LA        | PIVC   | Q2 weeks                    |
| 5       | 73  | F   | 25  | CAD, High LDL & Lp(a)         | LA        | PIVC   | Q2 weeks                    |
| 6       | 45  | M   | 25  | PAD, High Lp(a)               | LA        | PIVC   | Q2 weeks                    |
| 7       | 58  | F   | 28  | Familial hypercholesterolemia | LA        | Ports  | Q2 weeks                    |
| 8       | 79  | M   | 17  | CAD, PAD, high LDL            | LA        | PIVC   | Q2 weeks                    |

Abbreviations: CAD: coronary artery disease, CIDP: chronic inflammatory demyelinating polyradiculoneuropathy, LA: lipoprotein apheresis, LDL: low density lipoprotein, Lp(a): lipoprotein a, PAD: peripheral arterial disease, PIVC: peripheral intravenous catheter, TPE: therapeutic plasma exchange.

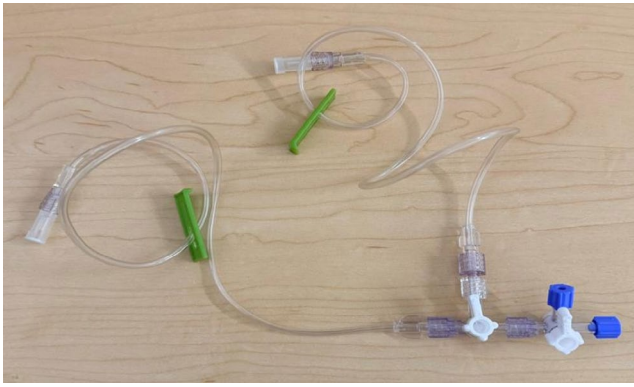


**FIGURE 1** | Double-draw set up: Both lines are connected via extension tubing to a four-way stopcock and male-to-male adapter, which are then attached to the apheresis inlet line. This configuration allows for either simultaneous or alternating blood flow from the two venous access points, helping to reduce resistance and stabilize inlet pressures.

two venous access sites were placed on the same extremity (Figure 2). When the double-draw configuration consisted of a port and a PIVC, the additional draw-line PIVC was placed in the arm ipsilateral to the port (Figure 3).

During procedures, draw sites were routinely flushed with saline to maintain patency. Closure of each draw access was alternated via the stopcock during machine operation, and inlet pressures were closely monitored as an early indicator of access compromise.

## 2.4 | Statistical Analysis

Inlet pressures are routinely documented in the electronic medical record and were compared before and after placement of the second draw line using paired, two-tailed Student's *t*-tests. A *p* value <0.05 was considered statistically significant.

## 2.5 | Ethical Considerations

The study protocol met institutional review board (IRB) exemption criteria at our institution. Given the retrospective nature of the study and use of de-identified patient data, a waiver of informed consent was granted.

## 3 | Results

Between January and December of 2025, the double-draw technique was performed during 26 apheresis procedures in 8 patients, including 10 TPE procedures and 16 LA procedures (Table 1). All procedures were initiated with a single draw access (PIVC, *n* = 19; implanted port, *n* = 7), with placement of a second draw line when negative inlet pressures could not be adequately corrected with conservative measures. Inlet pressures, inlet flow rates, and treatment times were routinely recorded in the electronic health record per unit protocol (Table 2). During TPE (*n* = 10), median negative inlet pressure improved from −179 mmHg (IQR −218 to −69) with single-draw access to −71 mmHg (IQR −78 to −62) following placement of a second draw line (*p* = 0.0162) (Figure 4A). Median



**FIGURE 2** | Double-draw configuration using two PIVC (return access in right arm not pictured).



**FIGURE 3** | Double-draw configuration using a port and a PIVC (return access in right arm not pictured).

inlet flow rate during TPE improved from 47 mL/min (IQR, 40–58 mL/min) with single-draw access to 70 mL/min (IQR, 60–75 mL/min) (*p* = 0.008) (Figure 5A). Flow rate improved in 7 of 10 procedures (70%). During LA (*n* = 16), median negative inlet pressure improved from −136 mmHg (IQR −193 to

**TABLE 2** | Treatment data.

| Patient | Procedure | Initial draw access | Inlet flow before placing double-draw access (mL/min) | Inlet pressure before placing double-draw access (mmHg) | Inlet flow after placing double-draw access (mL/min) | Inlet pressure after placing double-draw access (mmHg) | Total treatment time (min) | Procedure completed |
|---------|-----------|---------------------|-------------------------------------------------------|---------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------|----------------------------|---------------------|
| 1       | TPE       | PIVC                | 40                                                    | -225                                                    | 75                                                   | -69                                                    | 121                        | Yes                 |
| 1       | TPE       | PIVC                | 40                                                    | -224                                                    | 55                                                   | -80                                                    | 150                        | Yes                 |
| 1       | TPE       | PIVC                | 44                                                    | -29                                                     | 75                                                   | -73                                                    | 120                        | Yes                 |
| 1       | TPE       | PIVC                | 40                                                    | -93                                                     | 60                                                   | -60                                                    | 136                        | Yes                 |
| 1       | TPE       | PIVC                | 50                                                    | -222                                                    | 80                                                   | -231                                                   | 149                        | Yes                 |
| 1       | TPE       | PIVC                | 40                                                    | -157                                                    | 75                                                   | -68                                                    | 150                        | Yes                 |
| 1       | TPE       | PIVC                | 50                                                    | -61                                                     | 65                                                   | -40                                                    | 116                        | Yes                 |
| 1       | TPE       | PIVC                | 70                                                    | -205                                                    | 60                                                   | -90                                                    | 135                        | Yes                 |
| 1       | TPE       | PIVC                | 60                                                    | -60                                                     | 60                                                   | -41                                                    | 133                        | Yes                 |
| 2       | TPE       | PIVC                | 80                                                    | -201                                                    | 80                                                   | -72                                                    | 113                        | Yes                 |
| 3       | LA        | PIVC                | 70                                                    | -192                                                    | 70                                                   | -60                                                    | 262                        | Yes                 |
| 3       | LA        | PIVC                | 75                                                    | -199                                                    | 80                                                   | -53                                                    | 248                        | Yes                 |
| 4       | LA        | PIVC                | 50                                                    | -141                                                    | 80                                                   | -67                                                    | 340                        | Yes                 |
| 5       | LA        | PIVC                | 60                                                    | -49                                                     | 60                                                   | -25                                                    | 250                        | Yes                 |
| 6       | LA        | PIVC                | 60                                                    | -118                                                    | 80                                                   | -47                                                    | 280                        | Yes                 |
| 6       | LA        | PIVC                | 70                                                    | -185                                                    | 80                                                   | -95                                                    | 265                        | Yes                 |
| 6       | LA        | PIVC                | 70                                                    | -106                                                    | 70                                                   | -21                                                    | 290                        | Yes                 |
| 7       | LA        | Port                | 80                                                    | -222                                                    | 80                                                   | -62                                                    | 198                        | Yes                 |
| 7       | LA        | Port                | 80                                                    | -130                                                    | 70                                                   | -63                                                    | 223                        | Yes                 |
| 7       | LA        | Port                | 70                                                    | -100                                                    | 80                                                   | -58                                                    | 210                        | Yes                 |
| 7       | LA        | Port                | 80                                                    | -125                                                    | 80                                                   | -65                                                    | 205                        | Yes                 |
| 7       | LA        | Port                | 50                                                    | -197                                                    | 80                                                   | -78                                                    | 230                        | Yes                 |
| 7       | LA        | Port                | 70                                                    | -182                                                    | 70                                                   | -53                                                    | 235                        | Yes                 |
| 7       | LA        | Port                | 65                                                    | -110                                                    | 80                                                   | -75                                                    | 218                        | Yes                 |
| 8       | LA        | PIVC                | 45                                                    | -240                                                    | 50                                                   | -45                                                    | 304                        | Yes                 |
| 8       | LA        | PIVC                | 55                                                    | -102                                                    | 55                                                   | -15                                                    | 230                        | Yes                 |

Abbreviations: LA: lipoprotein apheresis, PIVC: peripheral intravenous catheter, TPE: therapeutic plasma exchange.

-109) to -59 mmHg (IQR -66 to -47) following placement of a second draw line ( $p < 0.0001$ ) (Figure 4B). Median inlet flow rate during LA improved from 70 mL/min (IQR 59–71 mL/min) with single-draw access to median 80 mL/min (IQR 70–80 mL/min) ( $p = 0.023$ ) (Figure 5B). For LA, while the change in median inlet flow rate is statistically significant, it is relatively modest as the procedures were already running at a relatively high flow rate before the intervention. Overall, 25 of 26 procedures (96.2%) demonstrated an improvement in inlet pressure following implementation of the double-draw technique. All procedures were completed successfully without abandonment of the original access site. One patient subsequently requested the double-draw technique at the start of six additional procedures during the study time frame; these procedures were not included in the analysis.

## 4 | Discussion

When suitable veins are available, PIVCs are the preferred vascular access for therapeutic apheresis procedures due to their superior safety profile, availability, and lower cost compared to central venous access. Complications associated with PIVCs are uncommon but include infection, venous infiltration, patient discomfort, thrombosis, multiple venipuncture attempts, hematomas, and potential venous sclerosis over time [5]. Despite their widespread availability and familiarity, peripheral intravenous catheterization can be challenging, and success rates for therapeutic apheresis vary [10, 11]. Reported risk factors for difficult PIVC placement include older age, female sex, higher body mass index (BMI), previous chemotherapy, vein characteristics, and health-care professional experience [12, 13]. Ultrasound-guidance of

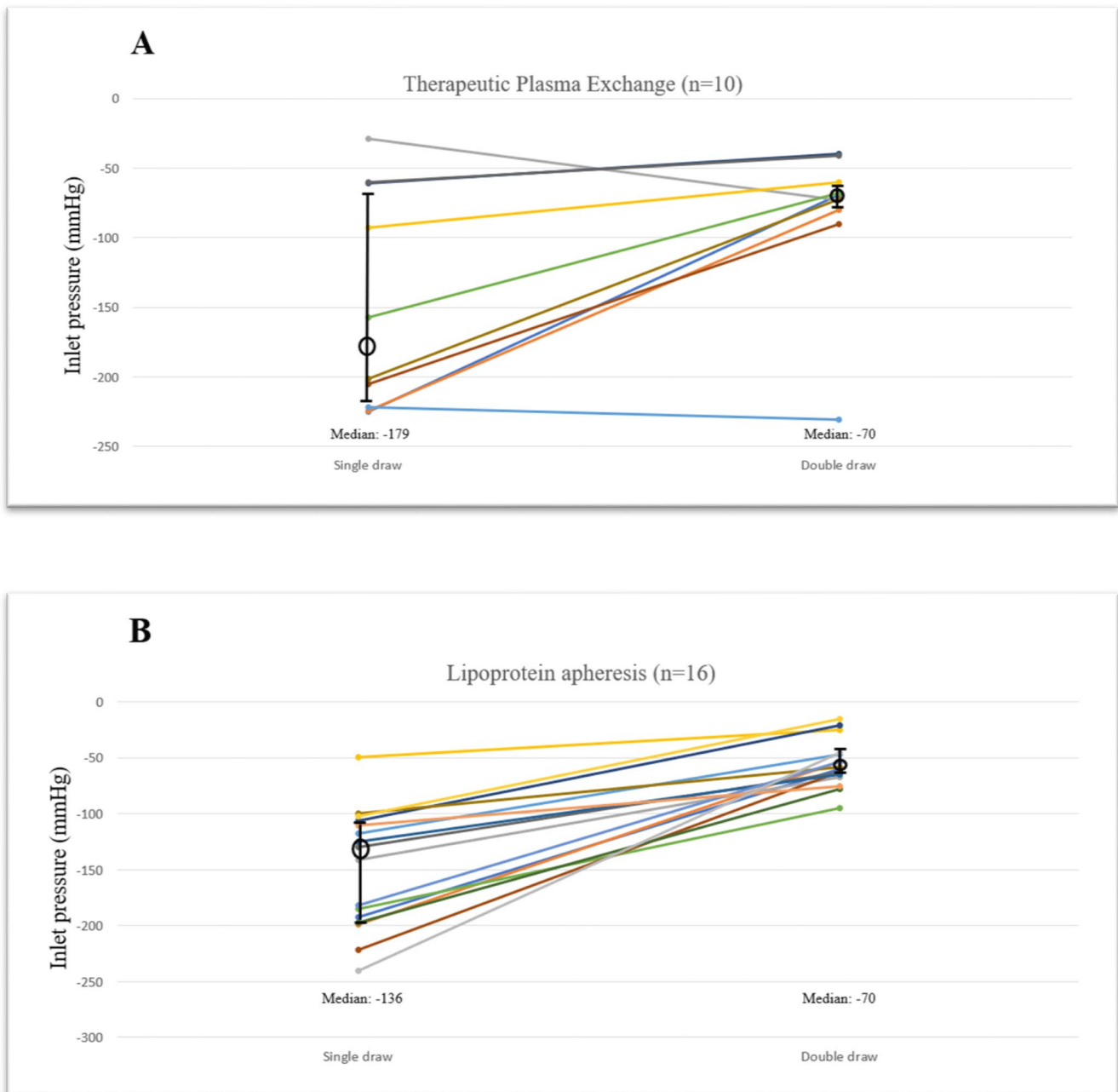


**FIGURE 4** | Effect of double-draw vascular access on inlet pressure during apheresis. (A) Paired inlet pressures before and after placement of a second draw line during therapeutic plasma exchange (TPE,  $n = 10$ ). (B) Paired inlet pressures before and after placement of a second draw line during lipoprotein apheresis (LA,  $n = 16$ ). Each dot represents an individual apheresis procedure, with lines connecting paired measurements from the same procedure. Open circles and error bars indicate the median and interquartile range, respectively. Inlet pressure became significantly less negative following placement of the second draw line during both TPE ( $p = 0.016$ ) and LA ( $p < 0.001$ ).

PIVC has been shown to improve success rates for apheresis procedures [14].

When veins are unsuitable for PIVC, certain ports can be used for chronic therapeutic apheresis procedures [15]. Ports can be an appealing alternative because they impose less burden on patients' lifestyles than conventional apheresis catheters and have a lower risk for infection; however, they can also pose challenges to inlet flow during procedures [16, 17]. Poor flow can be a result of mechanical obstruction, such as catheter migration, kinking, or malposition within the vessel, or from intraluminal or catheter-tip

thrombosis or fibrin sheaths. Interventions to improve port flow during apheresis include saline flushing, patient repositioning, and administration of thrombolytic agents, which may increase the procedure costs and result in procedural delays [9, 17].

## 5 | Conclusions

The optimal vascular access device for a successful apheresis procedure minimizes complications, provides adequate flow rates, requires little maintenance during treatment, and minimizes the

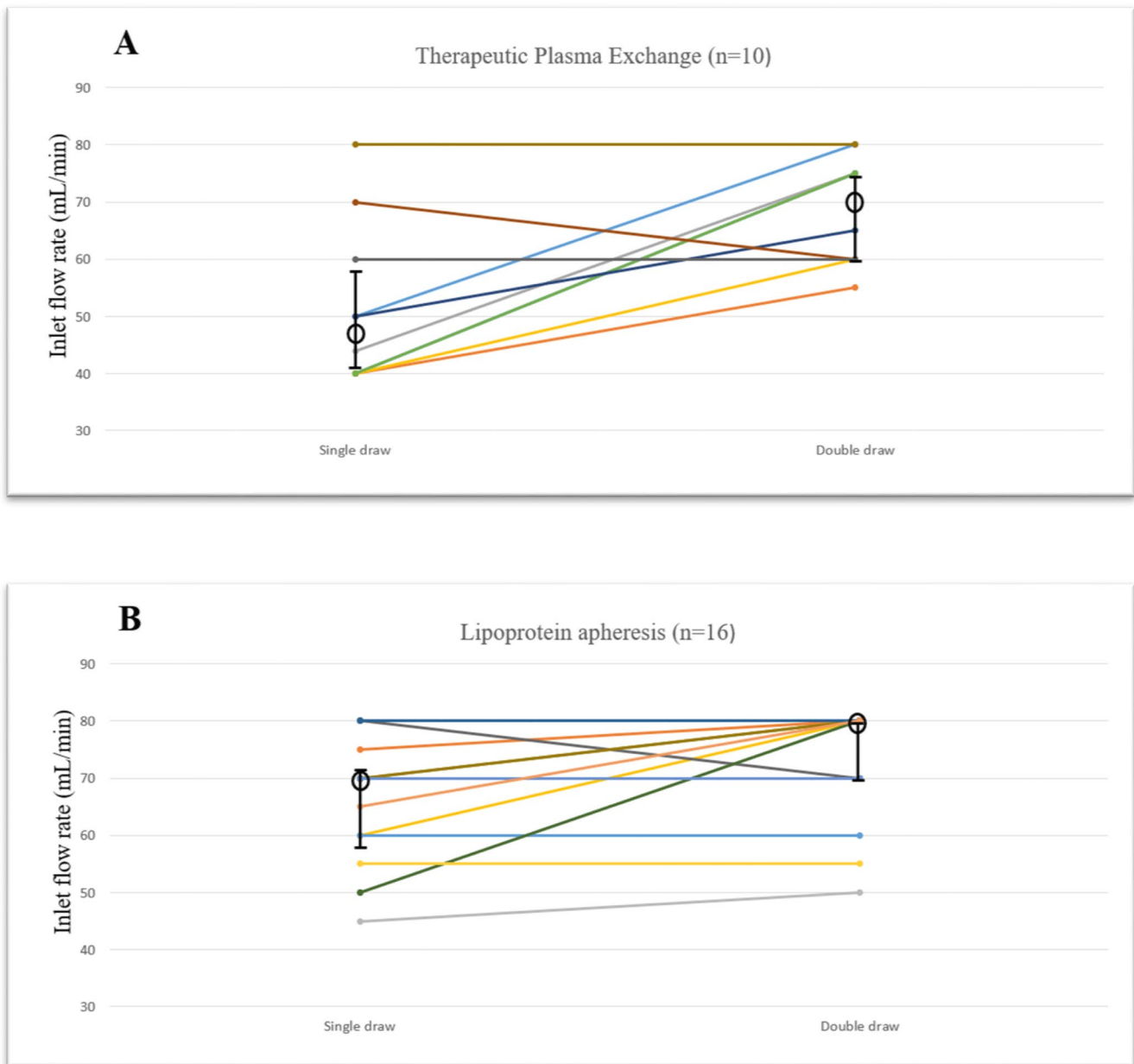


**FIGURE 5** | Effect of double-draw vascular access on inlet flow rate during apheresis. (A) Paired inlet flow rates (mL/min) before and after placement of a second draw line during therapeutic plasma exchange (TPE,  $n = 10$ ). (B) Paired inlet flow rates before and after placement of a second draw line during lipoprotein apheresis (LA,  $n = 16$ ). Each dot represents an individual apheresis procedure, with lines connecting paired measurements from the same procedure. Open circles and error bars indicate the median and interquartile range, respectively. Inlet flow rates increased following placement of the second draw line during both TPE ( $p = 0.008$ ) and LA ( $p = 0.023$ ).

impact on quality of life, including procedure duration, access visibility, and discomfort [9]. PIVCs are recommended as first-line access for apheresis because of their favorable safety profile compared with traditional apheresis catheters, while ports are increasingly used for patients requiring chronic apheresis when PIVCs are difficult to maintain. Given both PIVCs and ports can experience increased inlet pressure during apheresis procedures as a result of venous or catheter-related obstruction, the double-draw technique provides a novel, previously undescribed option when conservative measures such as warming or repositioning fail. By distributing flow across two venous access points, the double-draw technique may reduce the negative venous pressure required to maintain inlet flow, allowing treatment to continue without

abandoning the original access. In this series, the technique was associated with improved inlet pressure and successful completion of all procedures. Although placement of a second access requires an additional venipuncture and may potentially increase patient discomfort, it can allow continuation of treatment without the delays associated with repeated attempts at the original access site, placement of new access, or transition to central venous access.

Ongoing monitoring of both access sites is important to minimize the risk of clot formation within the extension tubing. We recommend periodic saline flushing to assess patency, alternating closure of each draw access via the stopcock during machine operation, and monitoring rising inlet pressures as an indicator

of access failure. Supportive measures, including extremity warming and repositioning, should be continued concurrently.

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## Disclosure

Amber P. Sanchez MD has received consulting fees from Terumo BCT.

## Ethics Statement

The study protocol met institutional review board (IRB) exemption criteria at our institution. Given the retrospective nature of the study and use of de-identified patient data, a waiver of informed consent was granted.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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