

Editorial

Apheresis: blood component separation and therapeutic application

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Introduction

An apheresis machine is a vital medical device used in both blood donation and therapeutic medicine. It separates whole blood into its individual components: plasma, platelets, red blood cells, and white blood cells using centrifugation, which relies on the specific gravity of each type of blood cell. The desired component is either removed (in *therapeutic apheresis*) or collected (in *donor apheresis*), while the remaining components are returned to the patient or donor during or after the procedure. Apheresis procedures are typically named after the blood component being collected, for example, plasmapheresis and plateletpheresis: plasma and platelets are collected and therapeutic plasma exchange (TPE): plasma is removed and replaced as part of treatment. Among donor procedures, plasmapheresis is most frequently performed to collect plasma used in the manufacture of plasma-derived medications such as immunoglobulin G (IgG) and clotting factor VIII (FVIII). This is followed frequently by plateletpheresis, which is used to collect platelets from blood donors.¹

There are two primary types of apheresis procedures.

1. Donor apheresis: This is used in transfusion medicine to collect specific blood components such as platelets, plasma, or granulocytes from healthy donors for clinical use. Donor apheresis enables the targeted collection of specific components with high yield and efficiency. For example, plateletpheresis significantly reduces recipient exposure to multiple donors, which is especially important in hematology-oncology care. Advanced multi-component collection systems can simultaneously collect platelets, plasma, or red blood

cells, maximizing both donor benefit and product yield in a single session.² One such method, double red blood cell (2RBC) apheresis, is used in both autologous and allogeneic transfusion settings. It offers a valuable alternative to whole blood collection, particularly for patients with multiple alloantibodies or rare blood types. This approach can also reduce the risk of alloimmunization in chronically transfused patients. Furthermore, minimizing exposure to multiple donors is a key strategy in reducing the risk of transmitting blood-borne infections.³

2. Therapeutic apheresis: An extracorporeal treatment used to remove disease-causing components such as autoantibodies, immune complexes, abnormal blood constituents, or excessive blood cells. By separating blood components and selectively removing or collecting specific elements, apheresis has transformed treatment strategies across multiple medical disciplines. In therapeutic apheresis, targeted components are removed or collected to treat specific conditions, while the remaining blood is returned to the patient. Blood component separation is primarily achieved using centrifugal techniques. Filtration, often combined with centrifugation, may be used for plasma collection, and adsorption methods are also employed in certain cases. The American Society for Apheresis (ASFA) provides clinical guidelines that categorize indications for apheresis into four groups, assisting clinicians in determining its use as a first-line or adjunctive therapy.⁴

Clinical applications of apheresis the therapeutic use of apheresis spans a wide range of medical conditions. Common indications include:

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1. Plasma exchange (plasmapheresis) essential in treating diseases such as thrombotic thrombocytopenic purpura (TTP), Guillain-Barré syndrome, and myasthenia gravis by removing circulating pathogenic antibodies or immune complexes.⁵ Therapeutic apheresis is included in most treatment protocols for acute kidney allograft rejection with antibody-mediated rejection (AMR) due to alloimmunization against human leukocyte antigen (HLA) molecules and other antigens.⁶

2. Red cell exchange used in managing sickle cell disease and certain hemoglobinopathies, this procedure helps reduce hemoglobin S concentration, lowering the risk of vaso-occlusive crises and stroke.⁷

3. Leukapheresis beneficial in patients with hyperleukocytosis associated with acute leukemia, typically indicated when the circulating white blood cell count exceeds $100 \times 10^9/L$ to prevent leukostasis complications. Hyperleukocytosis is observed in acute lymphoblastic leukemia (ALL), acute myeloid leukemia (AML), chronic myeloid leukemia (CML) and chronic myelomonocytic leukemia (CMML). The procedure can be performed for symptomatic relief or prophylactically to reduce the risk of complications associated with elevated white blood cell counts.⁸ Within the apheresis machine, peripheral blood stem cells are separated by centrifugation, the stem cell-rich buffy coat is extracted for use as a hematopoietic stem cell (HSC) products and is red cell-depleted, simultaneously returning the other blood components. Before commencing a leukapheresis, if the number of CD34+ cells in the peripheral blood is adequate, the collection procedure may be performed.⁹

4. Plateletpheresis applied in cases of extreme thrombocytosis, especially in myeloproliferative disorders, to reduce the risk of thrombotic events. Procedure and operational variables of therapeutic plateletpheresis by trained apheresis technicians and assisted by a professional hematologist. Thrombocytapheresis produces benefits of removing large numbers of platelets from blood circulation and thus preventing morbidities. Plateletpheresis assists hematology/oncology specialists and

apheresis physicians in understanding the efficacy and limitations of therapeutic apheresis, and supports clinical decision-making for patients with thrombocytosis.¹⁰

5. Photopheresis (extracorporeal photochemotherapy) combines apheresis with photoactivation of immune cells and is utilized in cutaneous T-cell lymphoma (CTCL), patients suffering from the leukemic variant and graft-versus-host disease in solid organ transplantation. This procedure collected leukocytes, which are then exposed to ultraviolet-A (UVA) irradiation in the presence of a photosensitizing agent, 8-methoxypsoralen, leading to DNA crosslinking before reinfusion to the patient. Especially in patients with acute GVHD (aGVHD) in the area of solid organ transplantation.¹¹

6. Apheresis equipment the rising incidence of chronic diseases such as autoimmune disorders, blood cancers and neurological diseases necessitates advanced apheresis treatments. Apheresis from various manufacturers looks different but the working is alike: separation in a one-use disposable, connected with bacterial filters to the machine, and various safety features to achieve optimal safety for donor, patients, operators and products. Technological innovations made apheresis machines more efficient and user-friendly. The most widely used blood cell separators in hospitals are the Spectra Optia, Fresenius COM.TEC, Fenwal Amicus, Trima Accel, Haemonetics MCS+ and AmiCORE.¹²

Technological innovations and safety modern automated apheresis machines are equipped with sophisticated software integrated data management systems, enabling real-time procedure monitoring systems, improving efficiency and minimizing procedure times and closed loop designs to ensure safety, accuracy, and minimal adverse reactions, enhancing patient safety. Innovations include:

1. Automation for precise component separation. AI-driven devices can adjust parameters in real-time, responding to the unique physiological needs of each patient, making treatments more personalized and effective.

2. Anticoagulation strategies to minimize clotting and hypocalcemia. Two commonly used anticoagulants in therapeutic apheresis are citrate and heparin, with an emphasis on dosing considerations and toxicity. In apheresis, citrate-based anticoagulation is preferred rather than heparin because of its low cost, safety, and rapid systemic clearance. The most common adverse reactions during apheresis are related to the effects of hypocalcemia. Factors influencing symptom development include the rate of citrate infusion, the rate of decline in ionized calcium levels, and hepatic metabolism of the infused citrate. Calcium replacement can be administered by oral or parenteral route for prophylactic, intermittent, or continuous supplementation. The risk of citrate toxicity and hypocalcemia will be higher when apheresis is performed on consecutive days.¹³

3. Portable apheresis units for use in mobile blood collection or bedside therapeutic applications, allowing for use in various settings, including blood donation centers, hospitals, or even in some cases, for on-site collections.

With the advancing level of medical development, the clinical demand for apheresis platelets has increased. Accordingly, standardization of procedures, rigorous donor selection criteria, and advancements in pathogen reduction technologies have enhanced the safety of apheresis practices. The presence of professional medical staff should be provided to these donors and patients.¹⁴

Challenges and ethical considerations despite its benefits, apheresis poses certain challenges:

1. Cost and accessibility remain significant barriers, especially in low-resource settings. Costs associated with apheresis included professional fees for medical staff, leukapheresis with stem cell cryopreservation, storage, sterility testing, analysis of circulating CD34+ cell counts, and the price of cytokine (rhG-CSF) therapy.¹⁵

2. Training and expertise are essential due to the complex nature of apheresis procedures. Healthcare

professionals with the knowledge and skills necessary to perform various apheresis procedures, including therapeutic plasma exchange, cell reductions, and collections.¹⁶

3. Ethical concerns may arise in donor recruitment for rare blood components or when used in experimental therapies, primarily revolve around donor safety, informed consent, and the potential for exploitation, especially in the context of paid plasma donation. Ensuring donors are adequately informed about the risks, benefits, and alternatives, and that their decisions are voluntary. Additionally, the potential for long-term health effects from frequent apheresis, particularly in paid donors, requires careful monitoring and consideration. Addressing these concerns requires collaborative efforts between policymakers, clinicians, and healthcare systems to ensure equitable access to life-saving apheresis services.¹⁷

4. The future of apheresis is rapidly evolving with novel therapeutic indications, including its role in treating sepsis, neurodegenerative diseases, and even cancer through immune cell collection and modification (e.g., CAR-T therapy). Integration with regenerative medicine, artificial intelligence for real-time monitoring, and personalized protocols are shaping the future of apheresis. Moreover, clinical trials continue to evaluate the efficacy of apheresis in emerging conditions such as COVID-19 complications, long COVID syndromes, and rare metabolic disorders, broadening its potential impact.¹⁸

Conclusion

Apheresis has transformed from a niche technique into a vital medical tool with broad therapeutic and diagnostic applications. Its success reflects the interplay of medical innovation, clinical insight, and technological advancement. As the demand for precision and personalized medicine grows, so too will the relevance and necessity of apheresis in modern healthcare. Continued research, education, and investment are key to unlocking its full potential and ensuring that apheresis services remain accessible, safe, and effective for all patients in need.

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