Review of Contemporary Philosophy
ISSN: 1841-5261, e-ISSN: 2471-089X
Vol 22 (1), 2023
Pp 5115 - 5123

Transfusion Reactions: Pathophysiology, Clinical Manifestations, Diagnosis, Management Strategies, Nursing Interventions, And Preventive Approaches in Blood Transfusion Therapy

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Abstract:

Background: Transfusion reactions are adverse events that occur during or after blood transfusion and can range from minor discomfort to severe, life-threatening complications. These reactions are classified into acute and delayed types, with various underlying causes, including immunologic and non-immunologic mechanisms. While mild reactions can be managed with minimal intervention, severe reactions can result in significant morbidity and mortality. Effective identification, diagnosis, and management of these reactions are crucial to improving patient outcomes.

Aim: This article aims to review the pathophysiology, clinical manifestations, diagnosis, management strategies, nursing interventions, and preventive measures related to transfusion reactions.

Methods: A comprehensive literature review was conducted, synthesizing data from studies on transfusion reactions, focusing on their classification, etiology, epidemiology, and management. Clinical manifestations, diagnostic approaches, and nursing interventions were explored to provide a holistic understanding of the subject.

Results: Transfusion reactions manifest in various forms, including mild allergic reactions, febrile non-hemolytic reactions, and more severe forms like acute hemolytic reactions, anaphylaxis, and transfusion-related acute lung injury (TRALI). Diagnosis often requires distinguishing transfusion reactions from other

medical conditions. Management strategies involve halting the transfusion, supportive care, and targeted interventions depending on the type of reaction. Nursing interventions, including vigilant monitoring and communication, play a critical role in early detection and management.

Conclusion: Transfusion reactions remain a significant challenge in clinical practice. Early recognition and prompt management are essential to minimizing adverse outcomes. Preventive strategies, including improved screening and blood handling practices, are key to reducing the incidence of severe reactions. Healthcare providers must remain vigilant in identifying reactions and provide timely interventions to ensure patient safety.

Keywords: Transfusion reactions, pathophysiology, diagnosis, management, nursing interventions, preventive measures, acute hemolytic reactions, TRALI, transfusion therapy.

Received: 07 October 2023 **Revised**: 22 November 2023 **Accepted**: 06 December 2023

Introduction:

Transfusion reactions are classified as adverse events occurring as a result of the transfusion of whole blood or its components. These reactions can vary significantly in severity, from minor discomfort to life-threatening complications. Reactions may manifest either during the transfusion (acute transfusion reactions) or in the days or weeks following the procedure (delayed transfusion reactions), with a distinction between immunologic and non-immunologic origins. Diagnosing a transfusion reaction can be challenging due to the non-specific and often overlapping nature of its symptoms. Common clinical manifestations include fever, chills, urticaria (hives), and itching. While some of these symptoms may be resolved with minimal intervention, more serious reactions are indicated by respiratory distress, high fever, hypotension (low blood pressure), and hemoglobinuria (red urine). The classification of transfusion reactions encompasses various types: acute hemolytic, delayed hemolytic, febrile non-hemolytic, anaphylactic, simple allergic, septic (due to bacterial contamination), transfusion-related acute lung injury (TRALI), and transfusion-associated circulatory overload (TACO). In the event of any suspected reaction, it is critical to immediately halt the transfusion, notify the blood bank, and consult the treating clinician [1][2][3].

Etiology:

Immune-mediated transfusion reactions typically arise from the incompatibility or mismatch between the transfused product and the recipient. Such reactions involve naturally occurring antibodies in the recipient's blood (e.g., anti-A or anti-B antibodies, which are primarily responsible for acute hemolytic reactions) as well as antibodies produced in response to foreign antigens (alloantibodies). These alloantibodies are implicated in a variety of reactions, including mild allergies, febrile non-hemolytic, acute hemolytic, and anaphylactic responses. Additionally, antibodies present in the donor's blood may contribute to reactions, particularly in the case of transfusion-associated lung injury (TRALI) [4][5][6]. Non-immunologic reactions often stem from the physical effects of the blood components themselves or the transmission of infectious diseases. Septic transfusion reactions, for example, result from bacterial or endotoxin contamination of the blood product. This contamination can occur at the time of collection due to insufficient disinfection of the donor's arm, the presence of bacteria in the donor's circulation during collection, or improper handling of the product after collection. Furthermore, transfusion reactions can also arise from factors unrelated to the intrinsic properties of the blood. Notable examples include transfusion-associated circulatory overload (TACO) and hypothermia.

Epidemiology:

The occurrence of transfusion reactions spans a broad spectrum, from relatively common events (such as mild allergic and febrile non-hemolytic reactions) to rare but severe occurrences (including anaphylaxis, acute hemolytic reactions, and sepsis). The most frequent fatal events are associated with TRALI, whereas long-term or delayed complications are typically linked to disease transmission. The severity and incidence of transfusion reactions depend on the specific type of reaction, the prevalence of particular diseases in the

donor population, and the extent of follow-up care received by the patient. However, with advances in donor screening, improved testing methods, and the implementation of automated data systems, the risks and fatality rates associated with blood transfusions continue to decline [7][8].

Pathophysiology:

The pathophysiological mechanisms underlying transfusion reactions vary depending on the type of reaction [9][10][11].

- **Acute Transfusion Reactions:**

- **Mild allergic reactions** are typically caused by hypersensitivity to foreign proteins in the donor product.
- **Anaphylactic reactions** are more severe forms of allergic reactions, often occurring in patients with IgA deficiency who produce alloantibodies against IgA and then receive blood products containing IgA.
- **Febrile non-hemolytic reactions** are thought to result from the release of cytokines from leukocytes (white blood cells) in the donor's blood.
- **Septic reactions** arise from bacterial contamination or bacterial byproducts, such as endotoxins, present in the transfused blood.
- **Acute hemolytic transfusion reactions** may lead to either intravascular or extravascular hemolysis, depending on the underlying cause. Immune-mediated reactions are often due to the presence of recipient antibodies against blood group antigens in the donor's blood. Non-immune reactions can also occur when red blood cells are damaged prior to transfusion due to factors such as heat or incorrect osmotic conditions.
- **Transfusion-associated circulatory overload (TACO)** results from the volume of the transfused product overwhelming the recipient's circulatory system, leading to hypervolemia (volume overload).
- **Transfusion-related acute lung injury (TRALI)** is caused by antibodies in the donor product reacting with recipient antigens, prompting an immune response that results in pulmonary edema. Conditions such as infection, recent surgery, or inflammation may contribute to the development of TRALI.

- **Delayed Transfusion Reactions:**

- **Delayed hemolytic transfusion reactions** typically arise from an anamnestic response to a foreign antigen to which the patient has been previously exposed, often through prior transfusions or pregnancy.
- **Transfusion-associated graft-versus-host disease (GVHD)** occurs when donor lymphocytes, typically found in cellular blood products, engraft in an immunocompromised recipient's bone marrow. The donor lymphocytes recognize the recipient's tissues as foreign and initiate an immune response against the recipient's body. The recipient's immune system is unable to clear the foreign lymphocytes, leading to severe, often fatal outcomes.

History and Physical Examination:

A thorough understanding of the patient's medical history and health status is essential before initiating a transfusion. During the transfusion, vital signs are closely monitored, typically recorded at 15-minute intervals. Minor fluctuations in vital signs are generally considered normal and include changes such as a ±0.5°C variation in temperature, ±5 breaths per minute in respiratory rate, ±10 beats per minute in heart rate, and ±20 mm Hg in blood pressure. It is important to note that changes exceeding these thresholds do not necessarily indicate a transfusion reaction but should prompt heightened vigilance from the bedside nurse. Abnormal responses that may suggest a transfusion reaction include the development of hives, itching, a fever exceeding 1°C above baseline, chills, hypotension, and dyspnea.

Evaluation:

The diagnosis of acute transfusion reactions is initiated by recognizing the clinical signs and symptoms at the bedside. Key manifestations such as urticaria, fever, chills, respiratory distress, hypotension, and hypothermia require careful assessment, as they can indicate a variety of reactions. Urticaria or itching, which may initially appear as a mild allergic response, can also signal the onset of a more severe anaphylactic reaction, which can be life-threatening. In these instances, it is critical to immediately halt the transfusion and monitor the patient for any progression of symptoms. Fever and chills, commonly associated with febrile non-hemolytic reactions, can sometimes indicate the onset of more serious complications like acute hemolytic reactions, transfusion-related acute lung injury (TRALI), or septic transfusion reactions. A rise in temperature of 1°C or more from baseline should prompt immediate cessation of the transfusion, and further investigation is necessary to rule out acute hemolytic reactions or bacterial contamination if a significant temperature increase or other severe symptoms, such as rigors, are present. Respiratory distress, or dyspnea, is another critical symptom that may arise during severe reactions like anaphylaxis, TRALI, or transfusion-associated circulatory overload (TACO). This can sometimes occur in isolation without any additional symptoms, making early recognition challenging. Hypotension can be observed in a variety of reactions, including acute hemolytic reactions, septic transfusion reactions, anaphylaxis, and TRALI. It is also possible for hypotension to develop without any other signs of a transfusion reaction, requiring heightened vigilance. Lastly, hypothermia can occur with large-volume transfusions of refrigerated products and generally requires simple warming of the patient and/or the blood product.

Treatment / Management

Upon the suspicion of a transfusion reaction, immediate cessation of the transfusion is essential, followed by keeping the intravenous line open with appropriate fluids, usually 0.9% saline. A thorough clerical check is critical, involving verification of the product bag and confirming the patient's identification to rule out any human errors that may have led to an incompatible transfusion. Once the transfusion is halted, the patient’s vital signs should be closely monitored and recorded at 15-minute intervals to ensure that any signs of deterioration are promptly identified. A post-transfusion blood sample must be drawn and sent to the laboratory for further investigation, along with the blood bag and tubing if possible. This process allows for additional testing and clerical checks by the blood bank, which may help confirm the occurrence of an incompatible transfusion. The treatment of transfusion reactions typically revolves around supportive care tailored to the specific reaction. For example, mild allergic reactions can often be managed with antihistamines such as diphenhydramine to alleviate symptoms like itching or hives. For febrile non-hemolytic transfusion reactions, an antipyretic may be administered to reduce fever. In the case of more severe reactions, additional interventions may be necessary based on the type of reaction. For example, patients experiencing anaphylaxis may require epinephrine administration, while those with septic transfusion reactions may need antibiotics and other supportive therapies. In all cases, rapid identification and management are critical to prevent adverse outcomes. Maintaining close communication between the healthcare team, blood bank, and transfusion services is essential for optimal patient care.

Differential Diagnosis

When diagnosing transfusion reactions, it is important to consider a broad differential diagnosis, as many of the symptoms associated with these reactions overlap with other serious conditions. Anaphylaxis, a severe allergic reaction, is one of the primary conditions that must be differentiated from transfusion reactions. This condition can present symptoms such as urticaria, respiratory distress, and hypotension, similar to those seen in severe transfusion reactions like anaphylactic reactions to blood products. Disseminated intravascular coagulation (DIC) is another condition that should be considered, particularly when there is evidence of clotting abnormalities or bleeding following a transfusion. DIC is a pathological condition that results in widespread clotting and subsequent bleeding, and it may be triggered by severe transfusion reactions. Hemolytic anemia, which involves the premature destruction of red blood cells, is another important differential diagnosis. Hemolysis can occur as a result of transfusion reactions,

particularly in cases of acute hemolytic transfusion reactions, and it may present symptoms such as jaundice, fatigue, and dark urine. Septic shock, which can occur due to bacterial contamination of blood products, is also a critical condition that must be ruled out when fever, chills, and hypotension are present. Bacterial or endotoxin contamination of the blood product can lead to sepsis, a life-threatening systemic response to infection. While these conditions are distinct from transfusion reactions, their overlapping symptoms require careful clinical assessment and diagnostic testing to ensure the appropriate management. By considering these differential diagnoses, clinicians can accurately identify the cause of the patient's symptoms and provide timely, effective treatment.

Complications

Transfusion reactions can lead to various serious complications, which can have significant impacts on patient outcomes if not promptly identified and managed. Disseminated intravascular coagulation (DIC) is one such complication that can occur following transfusion reactions, particularly those involving bacterial contamination or severe hemolytic reactions. In DIC, there is an abnormal activation of the clotting cascade, leading to widespread clot formation throughout the vasculature, followed by excessive bleeding due to the consumption of clotting factors. This can result in severe hemorrhaging and organ dysfunction, requiring immediate intervention with anticoagulation therapy and supportive measures. Lung injury is another potential complication of transfusion reactions, particularly transfusion-related acute lung injury (TRALI). TRALI is a condition in which the transfused blood product contains antibodies that react with the recipient's immune system, causing pulmonary edema and respiratory distress. TRALI is a life-threatening condition that requires intensive management, including respiratory support and, in some cases, mechanical ventilation. Renal failure is another complication that may arise as a result of transfusion reactions, especially in the context of acute hemolytic reactions, where the release of hemoglobin from destroyed red blood cells can lead to kidney damage. If left untreated, renal failure can progress to complete kidney failure, necessitating dialysis. Hemolysis, the breakdown of red blood cells, can occur during both acute and delayed transfusion reactions and can lead to complications such as anemia, jaundice, and renal impairment. Finally, in the most severe cases, transfusion reactions can result in death, particularly when the reaction is not quickly identified or managed. The mortality rate is highest in cases of TRALI and septic transfusion reactions, which can cause rapid systemic organ failure. Ensuring prompt recognition and appropriate management of transfusion reactions is crucial to minimizing the risk of these complications and improving patient outcomes. Close monitoring and early intervention are essential for preventing these potentially fatal outcomes.

Other Issues

Transfusion reactions are influenced by a variety of factors, including the specific type of blood component being transfused, the storage conditions of the product, and the patient's underlying co-morbid conditions at the time of transfusion. It is essential to recognize that these factors can play a significant role in determining the severity and type of reaction that may occur. For instance, reactions to red blood cell transfusions may differ from those observed with platelet or plasma transfusions due to differences in the components' storage requirements and the patient's immune response. Additionally, the presence of co-morbidities such as cardiovascular disease, diabetes, or immunosuppressive conditions can increase the risk of more severe transfusion reactions or complicate the management of any reaction that does occur. Therefore, a comprehensive understanding of these contributing factors is crucial for healthcare providers to rapidly identify potential transfusion reactions, intervene promptly, and ensure that the patient receives appropriate care. Early recognition of symptoms, accurate diagnosis, and effective treatment are critical to managing transfusion reactions and optimizing patient outcomes. The healthcare team must remain vigilant throughout the transfusion process, ensuring that proper protocols are followed and that the patient's condition is closely monitored for any signs of adverse effects. By doing so, healthcare providers can reduce the likelihood of complications, minimize the risks associated with transfusion, and enhance overall patient safety.

Enhancing Healthcare Team Outcomes

Blood transfusions are a fundamental component of modern medicine, and it is essential that all healthcare professionals are familiar with transfusion reactions and their management. Any patient, regardless of the ward or specialty they are in, may require a blood transfusion, and nurses, in particular, must be knowledgeable about the potential complications associated with transfusions. Understanding the different types of reactions, from benign to severe, is critical for ensuring that staff can appropriately address any adverse events that arise. While most transfusion reactions are not life-threatening, some can be severe and result in fatalities. For example, anaphylactic reactions to blood transfusions are exceedingly rare but are often fatal when they do occur. Similarly, transfusion-related acute lung injury (TRALI), though not common, affects between 1% and 9% of transfusions and can lead to respiratory failure, requiring intensive pulmonary support to prevent a fatal outcome. Although the incidence of bacterial contamination in blood products is rare, it remains a significant concern and can involve both gram-negative and gram-positive organisms, posing serious risks of sepsis. To reduce the morbidity and mortality associated with transfusion reactions, vigilance is required from the nursing staff, who play a critical role in monitoring patients throughout the transfusion process. During patient intake, a thorough medical history should be taken, including inquiries about previous transfusions and any complications that may have occurred. Furthermore, if there is any uncertainty about the patient's blood group or the blood product being administered, it is imperative to request that the laboratory reconfirm this information to avoid potential errors. Ensuring this level of attention to detail is essential in preventing adverse outcomes and improving the overall safety and effectiveness of blood transfusions [16][17-18].

Nursing Diagnosis and Interventions:

In the context of transfusion reactions, nursing diagnoses are formulated based on the signs and symptoms presented by the patient. Common diagnoses include "Risk for Hypovolemic Shock," which may arise from acute blood loss or hemolytic reactions. "Ineffective Breathing Pattern" is another diagnosis, often associated with fluid overload or pulmonary complications like transfusion-related acute lung injury (TRALI) and anaphylaxis. Additionally, "Acute Pain" can be diagnosed when the patient experiences discomfort from hemolysis, immune responses, or tissue damage, while "Impaired Skin Integrity" may be identified in response to allergic reactions, such as urticaria or anaphylaxis. "Risk for Infection" is another common diagnosis, especially in cases where bacterial contamination of the transfused blood occurs. Finally, "Anxiety" is frequently observed as patients experience fear or discomfort related to transfusion reactions. These diagnoses guide the formulation of specific nursing interventions aimed at stabilizing the patient and minimizing further complications during a transfusion reaction.

Effective nursing interventions play a vital role in the management of transfusion reactions, with the primary objective being to halt the progression of the reaction and stabilize the patient. The first step in managing a suspected transfusion reaction is to immediately stop the transfusion. This prevents further exposure to the blood product and allows for quick identification and intervention. The intravenous line should remain open with appropriate fluids, such as 0.9% saline, to maintain circulation and avoid complications like clotting in the IV line. Vital signs should be closely monitored, especially blood pressure, pulse, temperature, and respiratory rate, to identify any changes that might indicate the severity of the reaction, such as fever, hypotension, or respiratory distress. If any significant changes are noted, further interventions should be implemented to address the underlying cause of the reaction, such as initiating oxygen therapy for respiratory distress or administering antihistamines for mild allergic reactions.

In addition to halting the transfusion and monitoring the patient, it is critical for nurses to promptly notify the healthcare provider and the blood bank. This ensures that the appropriate tests are conducted to confirm the cause of the reaction, such as identifying hemolysis or bacterial contamination, and to investigate the possibility of an incompatible transfusion. Coordination with the blood bank allows for a detailed investigation into the compatibility of the transfused blood, which may prevent similar incidents in the future. In cases of severe reactions like anaphylaxis, immediate administration of medications such as epinephrine, corticosteroids, and antihistamines is essential to mitigate symptoms and prevent life-

threatening complications. Oxygen therapy should be initiated for patients exhibiting signs of dyspnea or respiratory distress, and if necessary, further respiratory support, such as mechanical ventilation, may be required to ensure adequate oxygenation.

Moreover, after halting the transfusion and initiating treatment, post-reaction monitoring is crucial. The patient should be observed closely for delayed reactions or complications, and vital signs should be checked frequently to assess recovery or further deterioration. Documentation of all actions taken, including the time of transfusion stoppage, medications administered, and the patient's response to treatment, is essential for maintaining accurate medical records. Nurses should also provide emotional support to the patient and their family members, explaining the situation clearly and offering reassurance. This helps alleviate anxiety and enhances the overall patient experience during a stressful time. Furthermore, educating the patient and their family about the signs and symptoms of transfusion reactions is vital to prevent future occurrences and to ensure that they are well-prepared in case of a similar event. These interventions collectively contribute to improved patient outcomes and ensure that transfusion reactions are managed promptly and effectively.

Conclusion:

Transfusion reactions encompass a broad spectrum of adverse events that can occur during or after blood transfusion. The pathophysiology of these reactions varies depending on their classification, which includes acute and delayed reactions. Acute reactions, such as mild allergic responses, anaphylaxis, febrile non-hemolytic reactions, and transfusion-related acute lung injury (TRALI), typically occur during the transfusion process. Delayed reactions, including delayed hemolytic reactions and transfusion-associated graft-versus-host disease (GVHD), can develop in the days or weeks following transfusion. The underlying mechanisms of these reactions are either immunologic, caused by incompatibility between donor and recipient blood, or non-immunologic, which involve factors like bacterial contamination and circulatory overload. Accurate diagnosis of transfusion reactions can be challenging due to the non-specific nature of their clinical manifestations. Symptoms such as fever, chills, urticaria, and respiratory distress may overlap with those of other conditions, making it essential for healthcare providers to carefully evaluate the patient's medical history and closely monitor vital signs during the transfusion process. Early recognition of a transfusion reaction is critical to ensure prompt intervention and prevent further complications. Management strategies for transfusion reactions involve halting the transfusion immediately, providing supportive care, and administering specific treatments based on the type of reaction. For example, antihistamines may be used for mild allergic reactions, while more severe reactions like anaphylaxis require epinephrine administration. In cases of bacterial contamination or sepsis, antibiotics and other supportive therapies are essential. Additionally, transfusion-related lung injuries require intensive respiratory support. Nurses and other healthcare professionals play a key role in monitoring patients, recognizing early signs of reactions, and communicating effectively with the blood bank and clinical team to manage these events. Preventive measures to reduce transfusion reactions include improved donor screening, better blood product handling, and the use of advanced technologies in blood typing and crossmatching. By implementing these strategies, healthcare providers can reduce the incidence of severe reactions, ensuring that blood transfusion therapy remains a safe and effective treatment option. Furthermore, education and training for healthcare professionals on recognizing and managing transfusion reactions are essential to improve patient safety and outcomes.

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ردود الفعل الناتجة عن نقل الدم: الفيزيولوجيا المرضية، الأعراض السريرية، التشخيص، استراتيجيات العلاج، التدخلات التمريضية، والطرق الوقائية في علاج نقل الدم

الملخص:

الخلفية: ردود الفعل الناتجة عن نقل الدم هي أحداث غير مرغوب فيها تحدث أثناء أو بعد نقل الدم، ويمكن أن تتراوح من الإزعاج البسيط إلى المضاعفات الشديدة المهددة للحياة. تصنف هذه الردود إلى نوعين حاد ومتأخر، مع وجود أسباب مختلفة أساسية، بما في ذلك الآليات المناعية وغير المناعية. في حين يمكن إدارة ردود الفعل الطفيفة بتدخل بسيط، فإن ردود الفعل الشديدة يمكن أن تؤدي إلى مرضية ووفيات كبيرة. إن تحديد هذه الردود، وتشخيصها، وإدارتها بشكل فعال أمر بالغ الأهمية لتحسين نتائج المرضى.

الهدف: يهدف هذا المقال إلى مراجعة الفيزيولوجيا المرضية، والأعراض السريرية، والتشخيص، واستراتيجيات العلاج، والتدخلات التمريضية، والإجراءات الوقائية المتعلقة بردود الفعل الناتجة عن نقل الدم.

الطرق: تم إجراء مراجعة شاملة للأدبيات، مع تلخيص البيانات من الدراسات المتعلقة بردود الفعل الناتجة عن نقل الدم، مع التركيز على تصنيفها، وأسبابها، وعلم الأوبئة، وإدارتها. تم استكشاف الأعراض السريرية، وأساليب التشخيص، والتدخلات التمريضية لتوفير فهم شامل للموضوع.

النتائج: تظهر ردود الفعل الناتجة عن نقل الدم بأشكال مختلفة، بما في ذلك ردود الفعل التحسسية الطفيفة، وردود الفعل الحموية غير التحللية، والأشكال الأكثر شدة مثل ردود الفعل التحللية الحادة، والحساسية المفرطة (التأق)، وإصابة الرئة الحادة المرتبطة بنقل الدم .(TRALI) غالبًا ما يتطلب التشخيص التمييز بين ردود الفعل الناتجة عن نقل الدم وحالات طبية أخرى. تشمل استراتيجيات الإدارة إيقاف النقل، والرعاية الداعمة، والتدخلات المستهدفة حسب نوع الرد الفعلي. تلعب التدخلات التمريضية، بما في ذلك المراقبة الدقيقة والتواصل، دورًا حاسمًا في الكشف المبكر والإدارة.

الخلاصة: تظل ردود الفعل الناتجة عن نقل الدم تحديًا كبيرًا في الممارسة السريرية. إن التعرف المبكر والإدارة السريعة أمران أساسيان لتقليل النتائج السلبية. تعد الاستراتيجيات الوقائية، بما في ذلك تحسين فحص الدم وممارسات التعامل مع الدم، أمرًا حيويًا لتقليل حدوث الردود الشديدة. يجب على مقدمي الرعاية الصحية أن يظلوا يقظين في التعرف على ردود الفعل وتقديم التدخلات في الوقت المناسب لضمان سلامة المرضى.

الكلمات الرئيسية: ردود الفعل الناتجة عن نقل الدم، الفيزيولوجيا المرضية، التشخيص، العلاج، التدخلات التمريضية، الإجراءات الوقائية، ردود الفعل التحللية الحادة، TRALI، علاج نقل الدم.