Review

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Advancements in Blood Transfusion Therapy for Transfusion-Dependent Patients and Associated Clinical Manifestations

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Transfusion therapy has been proven a lifesaver for a variety of medical conditions, ranging from inherited haematological disorders like thalassemia and sickle cell disease, to acquired ailments like chemotherapy-induced anaemia and haematological malignancies. This review specifically aims to critically summarize the clinical, psychosocial, and safety-related dimensions of care in transfusion-dependent patients, with particular emphasis on the challenges of long-term transfusion support and the need for individualized management strategies. This detailed review introduces readers to the complex terrain of transfusion therapy required by these patients regularly by examining both the therapeutic benefits and the short- and long-term complications associated with repeated transfusion exposure, including the advantages and challenges associated with this vital medical treatment. Conventional transfusion therapy makes it possible to replace deficient blood components and prevent clinical deterioration, but they are also associated with important limitations and risks: they trigger allergic reactions, overload the patient with iron, are logistically demanding, and can impose a considerable psychological burden on trauma patients or people with chronic diseases. In addition to outlining these risks, the review compares the immediate life-sustaining value of transfusion therapy with its cumulative clinical burden, highlighting the need to balance efficacy, safety, and quality-of-life considerations in long-term care. Patients with transfusion dependence represent a unique group. Moreover, this population has individual requirements resulting in a customised approach as the treatment of each patient is not a straightforward task. The review thus reconfirms this important and necessary aspect of ongoing monitoring, careful patient evaluation, and substantial provision of support that will maximize clinical outcomes and enhance the quality of life for these individuals. Overall, the review argues that optimal management of transfusion-dependent patients requires not only haematological and transfusion expertise, but also integrated psychosocial care, risk mitigation, and patient-centered follow-up. The details of transfusion dependent patient care can be examined in depth and healthcare providers may hence redesign their strategy, guide patients to less dangerous scenarios, and address their individual specific needs through this process. This promotes the comprehensive, patient-oriented approach as a tool for clinical expertise integration, evidence-based practice and psychosocial support that makes transfusion practice safer and more effective. Moreover, it underscores the importance of sustained research, innovation and teamwork in driving forward transfusion medicine, safety protocols, and tailored treatment strategies to accommodate those who continually rely on transfusions. Future directions should focus on improving transfusion safety, minimizing transfusion-related complications, advancing personalized transfusion protocols, and exploring innovative therapeutic alternatives that may reduce long-term transfusion dependence.

Keywords: blood transfusion; transfusion-dependent patients; haematological malignancies; chemotherapy-induced anaemia; iron overload; transfusion reactions; individualized care; supportive care; quality of life; transfusion safety

Introduction

Transfusion therapy remains the key prerequisite of medical advancement; it may frequently be the only way to save the life of patients suffering from a variety of medical conditions [1]. Transfusion therapy has been an option in cases of inherited blood disorder like thalassemia and sickle cell disease [2,3], as well as acquired ailments such as the severe anaemia resulting from chemotherapy or bone marrow failure that greatly needs the therapeutic utility of transfusion therapy [4]. Even though the whole of the life-giving therapy rests on the foundation of multiple factors which require careful analysis, the transplant procedure itself can save thousands of lives each year.

Transfusions are not prestigious medical procedures but instead life-saving tools which offer patients the elements that they need to live to another day. Transfusion therapy enables one cure anaemia through the injection of healthy Red blood cells that aid in transport of Oxygen or prevent a person from bleeding to death due to the infusion of clotting factors [5]. Nevertheless, transfusions by blood are not devoid of their own difficulties and the risks [6]. One of the most critical problems is the activation of immunologic mechanism which is precipitated by transfusion and as a result of this; the recipient forms alloantibodies against the antigens of the donor [7]. The main problem for such cases is the development of alloimmunization with such patients; hence, the frequency of transfusion shows itself to be a huge obstacle to the further transfusion support, while the patient may need to search for compatible blood products or must even risk cross-transfusion reactions [8]. Transfusion-transmitted diseases constitute another grave hazard of the transfusion therapy, even though most of it has been averted through the advanced screening techniques and developing testing methods [9]. But in all occasions, the risk of transmissibility of the infectious diseases for instance, HIV, hepatitis B and C and emerging pathogens still remain a threat, pointing out the ongoing need for unceasing monitoring and stringent application of safety standards [10]. Furthermore, the clinical sequel from iron overload due to repetitive transfusions is another big challenge posed to transfusion-dependent people [11]. However, iron plays a crucial role as a part of hemoglobin and other biological processes, yet, excessive accumulation of excess iron may cause oxidative stress and tissue damage [12], particularly in organs like the heart, liver and endocrine glands [13]. Managing iron overload demands a multifaceted approach that involves both chelation therapy to eliminate excess iron and measures that are aimed at preventing further iron build up by controlling transfusions in a particular way [14]. In addition to the health constraints connected with those transfusion therapy, there are also organizational and emotional constraints which require our attention too [15]. The demanding nature of scheduling regular transfusions can place an entire set of different burdens be it on patients or their caregivers. These burdens vary from the disruption of their daily routines to the frequent visits to the health facilities [16,17]. Hence, the urgency of a multifaceted view of transfusion effects becomes more and more notable. The core reason of this assessment is to include knowledge from clinical practice, scientific research and patient experience in order to highlight complexities that are hidden in transfusion therapy [18]. We aim to do this by highlighting the benefits and dangers of transfusion therapy as well as indicating strategies for the maximization of transfusion practices so as to come up with improvement outcomes and high quality of life for the transfusion-dependent patients. Eventually, blood donation becomes some sort of a lifeline for patients battling with a range of health conditions [19]. It is a great promise that the donor will get well and live longer. Nonetheless, the administration of transfusion is not all smooth, and thus cautious to the risk and implications coming with this kind of intervention is advisable. Through unyielding research, innovation, and partnership we can endeavor for safer, and more excellent transfusion practices that preserve the life of the transfusion-dependent people and uphold the sanctity of life.

Transfusion-Dependent Patients

Transfusion-dependent patients are a heterogeneous group in which not only the people share a common issue having the same type of disease [20]. However, they express clinical pictures and the treatment courses different from each other with their own special cases [21]. Importantly, transfusion dependence does not arise from a single mechanism across all diseases; rather, it reflects distinct but overlapping pathological processes such as chronic haemolysis, ineffective erythropoiesis, bone marrow failure, treatment-related myelosuppression, immune-mediated peripheral destruction of blood cells, and coagulopathy-associated blood loss. Therefore, understanding the biological basis of transfusion dependence in each disease category is essential for appropriate clinical interpretation and individualized transfusion planning. This heterogeneous group is comprised of people suffering from hereditary diseases of blood, like thalassemia [22] and sickle cell anaemia [23], as well as those who are fighting with disorders that are acquired like hemopoietic malignancies [24], acquired anaemia [25], immunodeficiencies [26], chronic renal failure [27], liver diseases [28], and autoimmune diseases [29].

Treatment of haemoglobin or thalassemia and sickle cell disease is transfusion therapy to be repeated forever to prevent complications from chronic anaemia and haemolysis [30]. Although both thalassemia and sickle cell disease frequently require long-term transfusion support, the pathophysiological rationale differs significantly between them [31]. In thalassemia, transfusion dependence is mainly driven by ineffective erythropoiesis and severe chronic

anaemia resulting from defective globin chain synthesis, whereas in sickle cell disease, transfusions are often used not only to correct anaemia but also to reduce the proportion of sickled erythrocytes and prevent vaso-occlusive and ischemic complications [32]. This distinction has practical implications, as transfusion strategies in thalassemia are often scheduled and maintenance-based, while in sickle cell disease they may be episodic, prophylactic, or exchange-based depending on stroke risk, acute chest syndrome, or recurrent crises. Such patients can be considered as the endpoints of the connection between black important requirements in hemodynamics where meticulous monitoring and customized transfusion program is required to prevent aggravations of the diseases and keep a balance in hemoglobin level [33]. Accordingly, personalized care in hereditary transfusion-dependent disorders must also incorporate iron burden assessment, alloimmunization prevention, and extended antigen matching, particularly in patients expected to receive repeated lifelong transfusions.

On the other hand people suffering from various types of cancer having chemotherapy as remedy can experience such temporary or long term anemia which also demands transfusion support to ease symptoms and continue treatment permanently [34]. In contrast to hereditary disorders, transfusion dependence in malignancy-associated states is often secondary to treatment toxicity, marrow infiltration, inflammatory suppression of erythropoiesis, or disease progression itself [35]. Thus, the transfusion requirement in these patients is often dynamic rather than fixed, and may fluctuate according to chemotherapy intensity, remission status, infection burden, or marrow recovery [36]. This creates a different management model in which transfusions are frequently supportive and threshold-guided rather than chronically scheduled. The conditions of bone marrow and the ones like aplastic anaemia and myelodysplastic syndromes are presented as different challenges related to the impaired haematopoiesis and blood cytopenia among the stem cells and mature blood cells [37]. Among these patients, transfusion dependence results primarily from failure of marrow production rather than peripheral destruction or blood loss, and therefore management must balance symptom relief with long-term risks such as iron overload, transfusion refractoriness, and progression of marrow dysfunction [38]. In such settings, transfusion support is often integrated with disease-modifying therapies, including immunosuppressive treatment, hematopoietic growth factors, hypomethylating agents, or stem cell transplantation where appropriate.

To illustrate the diverse range of conditions contributing to transfusion dependence, refer to the Fig. 1. Rather than viewing these disorders as a simple list of indications for transfusion, they may be better understood as belonging to broader mechanistic categories: (i) disorders of defective red cell production, such as thalassemia, aplastic anaemia, and myelodysplastic syndromes; (ii) disorders of increased destruction or consumption, such as sickle cell disease and autoimmune haemolytic anaemia; (iii) treatment-related or disease-related marrow suppression, such as haematological malignancies and chemotherapy-induced cytopenias; and (iv) conditions associated with bleeding or coagulation abnormalities, such as chronic liver disease and immune thrombocytopenia. This mechanistic classification provides a more clinically meaningful framework for deciding when transfusions are required, what component should be administered, how frequently support is needed, and what complications are most likely to arise.

Some patients with liver environment transplant desired hematologic malignancies such as leukemia and lymphoma have cytopenias caused by bone marrow infiltration or allergic chemotherapy myelosuppression which will make them transfusion dependent [39]. Although both haematological malignancies and liver disease may lead to transfusion dependence, the mechanisms are fundamentally different. In haematological malignancies, dependence usually reflects impaired marrow function or cytotoxic treatment effects, whereas in liver disease, transfusion needs are more often linked to coagulopathy, thrombocytopenia, hypersplenism, and acute or procedural bleeding risk. Consequently, the goals of transfusion also differ: one focuses on restoring deficient cellular components over time, while the other often prioritizes short-term haemostatic stabilization. Chronic liver disease carries the risk of coagulopathy and bleeding complications, which can be life-threatening and therefore may require transfusion support during the acute situation of haemorrhage or antithesis when invasive procedures are conducted [40].

Subsequently, anaemia may be one of the chronic conditions in renal failure patients since they produce a decreased amount of red blood cells (erythropoietin), so they need transfusion therapy and erythropoiesis-stimulating agents [41]. Renal failure represents yet another distinct model of transfusion dependence, in which inadequate erythropoietin production rather than intrinsic marrow failure or haemolysis is the central mechanism [42]. For this reason, blood transfusion in chronic kidney disease is generally considered a supportive or rescue strategy rather than the primary long-term solution, and should ideally be complemented or reduced through erythropoiesis-stimulating agents and iron optimization whenever feasible [43]. On the other hand, autoimmune disease conditions such as autoimmune haemolytic anaemia and immune thrombocytopenia may need the use of immunosuppressive therapy and transfusion support means to control haemolysis and thrombocytopenia related complicated aspects of the disease [44]. In autoimmune conditions, transfusion support is particularly complex because the underlying problem is immune-mediated destruction, meaning that transfused cells may also be rapidly consumed or rendered less effective [45]. Therefore, management in these patients must not rely on transfusion alone, but instead combine carefully se-

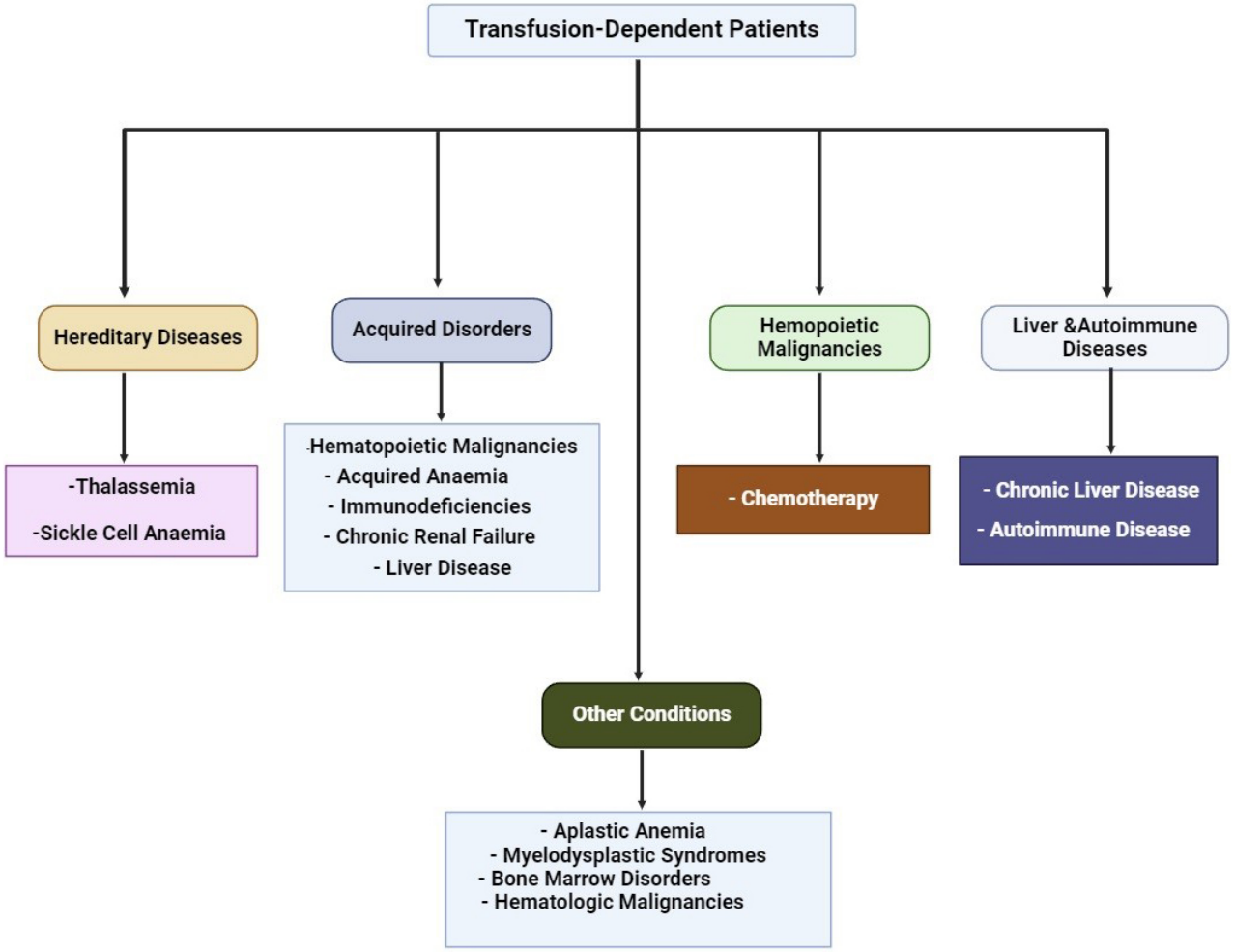

Fig. 1. The figure demonstrates the multitude of circumstances that characterize patient becoming dependent on blood transfusions. They get divided into diseases of the inheritance, acquired diseases, hemo malignancies, hepatological problems and immune diseases and other related pathologies. For each category there are particular examples that according to the situation may require transfusions.

lected blood component support with timely control of the immune process through corticosteroids, immunosuppressants, rituximab, or other disease-specific therapies. Analyze of the varying characteristics of the patients enduring blood transfusion due to various medical conditions is a precedence to formulating the transfusion management protocols specific to each individual, enhancing the level of care and improving the patient's prognosis [46]. Taken together, these comparisons show that "transfusion dependence" is not a uniform clinical state, but a final common manifestation of multiple disease-specific biological pathways. Recognizing these differences is essential for designing personalized transfusion strategies based not only on haemoglobin or platelet thresholds, but also on disease mechanism, expected duration of support, complication profile, iron burden, immunohematology risk, and patient quality-of-life considerations. Such an approach can improve both transfusion safety and long-term clinical outcomes.

Importance of Understanding the Needs of Transfusion Dependent Patients

The support of chronic patients requiring transfusions is a very diverse task requiring a complex methodical approach which combines medical, psyche-social, and logistic factors [47]. Transfusion dependent patient population is characterized by the heterogeneous group of medically diagnosed people, with the range of medications and individual circumstances [48]. Accordingly, healthcare providers shall embrace the concept of all-round patient experience to develop specific and effective care solutions [49]. We are now beginning an in-depth examination of the underlying issues involved in the care of this patient group. Outlined below in Table 1 are essential care considerations tailored for the diverse needs of transfusion-dependent patients.

Table 1. Care considerations for transfusion-dependent patients.

Aspect	Description
Treatment Efficacy	Regular transfusions to manage complications, maintain hemoglobin levels, and support treatment outcomes.
Complication Management	Monitoring for and addressing transfusion reactions, iron overload, and transfusion-transmitted infections.
Patient Safety	Pretransfusion assessments, continuous monitoring, and patient education to ensure safe transfusion practices.
Quality of Life	Pain management, psychosocial support, and shared decision-making to enhance overall well-being.
Healthcare Equity	Cultural competency, access to resources, and advocacy for equitable healthcare delivery.

Optimizing Treatment Efficacy

At the very core of meeting the needs of transfusion-dependent patients is the precisely aiming of treating efficacy. Such patients often need to receive transfusion after a short interval to manage the complication and sustain their vitality [11]. Such as individuals with inherited hematologic disorders such as thalassemia or sickle cell disease require red blood cell transfusions to maintain the sufficient levels of hemoglobin [50]. The transfusions avoid the complicatiors like anemia, vaso-occlusive crises and organ damage [51]. Therefore, transfusion support is also essential to the management of hematologic malignancies, chronic diseases like liver disease, and bone marrow failure syndromes which cause cytopenia, bleeding risk and other conditions related to treatment complications [52].

For higher treatment efficacy, healthcare providers should customize the plan of transfusion for each patient. Their needs must serve as a basis. Such a process incorporates the selection of the type and frequency of transfusions and based on the patient's diagnosis, the severity, the response to treatment, and the safety profile [53]. However, the issue is that transfusion therapies are closely evaluated to examine the efficiency of the treatment, identify any kind of adverse reactions or complications, and accordingly change treatment programs [54].

Minimizing Complications

Transfusion therapy may not be devoid of risks and awareness of needs of blood transfusion-dependent patients for further minimizing of possible issues is absolutely necessary. The donation of wrong type of a blood is definitely possible and it may result in the development of severe but less threatening reactions such as mild allergic or hemolytic reactions [55]. Transfusion therapy is another frequent complication for which number of recipients excessively has been transfused, most commonly with those who require regular or long-term transfusions [56,57]. Importantly, iron chelation therapy in transfusion-dependent patients is not routinely administered intravenously; rather, currently recommended chelators are predominantly oral or subcutaneous, depending on the agent used, patient tolerance, iron burden, organ involvement, and treatment adherence. According to the Thalassaemia International Federation (TIF) guidelines, the commonly used iron chelators include deferasirox (oral), deferiprone (oral), and deferoxamine, which is most commonly administered by subcutaneous infusion and may also be used intravenously in selected severe clinical situations, particularly intensive management of cardiac iron overload. Therefore, chelation therapy should be individualized and guided by regular monitoring of serum ferritin, liver iron concentration, and cardiac iron assessment where available Also, as far as transfusion-transmitted infections goes, these pose a danger to transfusion dependent patients and those prone to transfusion reactions [58]. Strict procedures of screening and testing, however, have been developed and introduced at the stage of screening and testing to prevent this occurrence, but doctors must constantly remain aware of pathogen emergence and the safety of blood products.

Enhancing Patient Safety

Providing patient safety is the cornerstone of understanding the requirements of transfusion-dependent patient's needs. These personnel frequently undergo close peri-procedural care and monitoring to avert complications and attain the best response. Pretransfusion assessments that include a full medical history, physical examination, and laboratory investigations are critical to determine any existing conditions or risk factors that may affect the safety of the blood transfusion [59]. As the healthcare providers are giving transfusion, they should follow the set protocols to securely identify patients and blood products, correctly use venous access, and appropriate infusion rates. Continuous monitoring of the vital signs and the patients' responses is a must to identify and manage immediately any adverse reaction or complication that may arise during transfusion [60]. Besides, patient education is a massive factor which improves safety and allows transfusion-dependent patients to be involved in their treatment process. Educating patients about the essence of transfusion therapy, possible risks and complications, and self-care approaches gives patients the opportunity to advocate for their health and recognize particular side effects [30].

Improving Quality of Life

Ensuring the welfare of transfusion-dependent patients goes beyond managing their medical conditions to include their general life quality as well. Such patients are confronted with many serious physical, emotional and psychosocial problems due to their clinical condition and their need for transfusion on a regular basis [61]. Consequently, the healthcare professionals have to adopt an in-

clusive approach towards care by addressing the medical aspects as well as the wider needs of the patients. Pain management for transfusion-dependent patients, particularly those suffering from sickle cell disease or bone marrow failure syndrome, is a primary concern [62]. Sufficient measures on pain control, including pharmacologic and non-pharmacologic interventions, are necessary to make people feel better and improve their quality of life [63]. The role of psychosocial support in improving the wellness of the transfusion-dependent patients is also very crucial. They can develop anxiety, depression, or social isolation resulting from their illness and the treatment they have to endure [64]. Recent evidence from meta-analyses and large cohort studies indicates that these psychosocial challenges are prevalent across transfusion-dependent populations, including patients with thalassemia, sickle cell disease, and bone marrow failure syndromes. Routine assessment using validated instruments, such as the SF-36, WHOQOL-BREF, and disease-specific tools like the Transfusion-Dependent Thalassemia Quality of Life (TDT-QoL) questionnaire, can quantify the impact of disease and treatment on physical, emotional, and social functioning [65]. Systematic evaluation enables identification of high-risk patients, facilitates early psychosocial interventions, and supports longitudinal monitoring. Interventions may include structured counselling, peer support groups, cognitive-behavioral therapy, and engagement with community resources to promote coping skills, resilience, and social reintegration. Incorporating these evidence-based psychosocial strategies as part of standard care has been shown to improve overall quality of life, reduce treatment-related anxiety, and enhance adherence to therapy. Hence, healthcare professionals have to tackle these psychosocial issues by providing support services, counselling and community resources that enable emotional resilience and problem-solving strategies.

Facilitating Shared Decision-Making

It is a must for the treatment team to practice collaboratively and patient-centred care to touch on the needs of patients who are always in need of transfusion and at the same time making sure that the patients are involved in the decision-making process. Clinical providers have to collaborate with patients and their close ones with the purpose of making them participants and permanent figures in this decision-making process because the treatment has to be in line with their values, preferences and care goals [66]. Shared decision-making is inclusive and requires open and transparent communication [67]. While healthcare providers explicate all treatment options, risks, benefits, and alternatives, the patients make their own diagnosis and have a greater voice in the process. Patients may make more rational choices because they are empowered to inquire about limitations and restrictions, communicate their worries, and advocate for their unique considerations and priorities [68]. However, they also need to be figured out the consideration of the cultural and lingual factors in ensuring that patients from diverse backgrounds are getting culturally competent care in which the belief, values, and traditions of theirs are respected. The major role that healthcare providers have to play is to find and address any cultural or language barriers that may arise leading to the misunderstanding of what should be carried out and decision making [69,70]. This will provide a forum for trust and working together between patients and providers.

Promoting Healthcare Equity

It is only after we learn what specific patient groups desire, that we may begin to advocate for healthcare equity and to neutralize the barriers to treatment and to improve outcomes. These people can be from different household income groups, different cultures, different locations as well as they can have particular challenges in accessing and using health care services. Hence, the healthcare providers need to assimilate a culturally responsive care plan that advocates for narrowing down the gaps of transfusion services access as well as provision of health care support services. Health equity care goes beyond to supporting social determinants of health which may affect the lives of patients who rely on transfusions and might life on street, be poor nutrition, without proper transport and some might not have medical facilities [71]. Through a holistic approach and the linkage of patients with their communities for social support services and needs, health professionals can help reduce the disparities and enhance the health outcome of transfusion-dependent patients [72]. Hence, it is highly critical to realize the needs of transfusion-dependant patients to maximize effectiveness of the treatment, avoid possible complication, assure the safety of the patient, promote better quality of life, facilitate informed decision-making between a physician and a patient, and create opportunities for access to healthcare. Through the process of the integrative approach and method, the notion that all the aspects of society are linked together can also be achieved.

Medical Considerations for Transfusion-Dependent Patients

Transfusion-dependent medical care requires appreciation of aspects completely different from care of other groups of patients. Such patients are on blood transfusion therapy to control their chronic medical condition and to avoid the development of complication. Throughout this in-depth inquiry, we will unravel such medical aspects that caregivers need to take into account as far as transfusion therapy, close monitoring for complications, management of underlying medical conditions, meeting psychosocial needs as well as educating the patients are concerned.

Transfusion Therapy

This is the main therapy option for the patients who are transfusion dependent [73]. Sufferers of these conditions must have regular or frequent transfusions of blood or blood components to make up for the reduced levels of essential ingredients such as red blood cells, platelets, or clotting factors [74]. Fundamentally, the objectives of transfusion therapy are to ameliorate manifestations, elevate the quality of life, and avert issues such as complications associated to the patient's underlying medical condition [75].

Types of Blood Products

The existing products administered to these transfusion-dependent patients are determined by their particular requirements. The most prevalent blood components are packed red blood cells (PRBCs), platelets, fresh frozen plasma (FFP), and cryoprecipitate [76]. Blood products are differentiated by their function in the body. It can be prescribed based on the diagnosis, laboratory results, and medical reasons for transfusion [77].

Indications for Transfusion

The question of transfusing a patient and the type of products must be based on medical necessity and laboratory variables. Indications for transfusion in the patients who are transfusion-dependent on a routine basis are covered by symptoms of anemia, platelet disorder in threat of bleeding, coagulation disorder and acute blood loss [78]. Medical labs work with hemoglobin levels, platelet counts, and coagulation profiles in transfusion scheduling and timing [79].

Transfusion Protocols

Transfusion protocols are part of clinicians' best practices involving rules and requirements for administering transfusion for safety and effective performance [80]. There are several protocols that are imperative during transfusion therapy products; these include pre-transfusion assessments, selection of blood products, transfusion techniques, monitoring for adverse reactions, and documentation of transfusion-related information [59]. In compliance with existing transfusion protocols, healthcare authorities have to strive for safety of patients and adequate treatment outcomes.

Pre-Transfusion Assessment

To begin the process of transfusion therapy, first, healthcare professionals carry out an upfront pre-transfusion assessment to evaluate the patient's appropriateness for transfusion and explore any risk factors or contraindications. Pre-transfusion assessment encompasses obtaining a detailed medical history, carrying out a physical examination, and performing haematological tests to asses haemoglobin levels, a blood type, and screening for transmissible infections [81]. However, this assessment may omit critical bedside safety checks, such as the re-confirmation of the patient's ABO and Rh blood group immediately prior to transfusion, as well as the mandatory two-person verification of the blood product against the patient's identification. These steps represent core safety standards established by the AABB and ISO, designed to prevent transfusion errors and ensure patient safety. Omission of these procedures can significantly increase the risk of haemolytic transfusion reactions and other preventable complications.

Patient Blood Typing and Crossmatching

Against compatibility of blood products with the recipient's blood type, patient blood typing and cross matching are the essential steps. The patient's blood type is determined to identify if he/she belongs to the ABO or Rh blood group, while a crossmatching is done to check whether the donor's blood is compatible with that of the patient [82]. Transfusion therapy can be extremely dangerous if the blood samples are not properly tested against the patient's blood type. Therefore, health care providers must verify the accuracy of blood typing and crossmatching results before administering transfusions.

Screening for Transfusion-Transmitted Infections

Detection of transmission transmitted infections (TTIs) during pre-transfusion assessment is one of the most important job done in order to make blood transfusion a safe process by minimizing transfer of infectious diseases through blood [83]. Typical TTIs represent, among other infectious agents' human immunodeficiency virus (HIV), Hepatitis B and C viruses (HBV and HCV), syphilis, and human T-cell lymphotropic viruses (HTLV) [84]. It is the responsibility of the healthcare providers to establish protocols and standards for the screening and testing of blood product for TTIs according to the currently existing rules and regulations.

The Table 2 (Ref. [48,61–72]) is highlighting the key points that deal with transfusion therapy for patients whose lifeline is regular transfusions serve to help maintain their medical condition in optimal health. It presents the knowledge about the common blood products used, the basic aspects of the transfusion protocols, the methods of pre-transfusion assessment, the patient blood-type assignments and the rules of crossmatching, and the infections with transfusion-transmitted route. Each Aspect plays an important role in enabling safe and effective transfusion therapy, thus enhanced patient outcomes and quality life.

Assessment of Transfusion Requirements

The patient's transfusion requirements must be evaluated by an expert in doing this the clinician should determine the transfusion indication, indicate the right blood product type and quantity in a correct volume and the treat-

Table 2. Key aspects of transfusion therapy for transfusion-dependent patients.

Aspect	Description	Reference
Transfusion Therapy	Main therapy option involving regular/frequent transfusions of blood/blood components to address reduced levels of essential ingredients.	[61–63]
Types of Blood Products	Includes packed red blood cells (PRBCs), platelets, fresh frozen plasma (FFP), and cryoprecipitate, prescribed based on diagnosis and medical reasons.	[64,65]
Indications for Transfusion	Based on medical necessity and laboratory variables such as anemia, platelet disorder, coagulation disorder, and acute blood loss.	[66,67]
Transfusion Protocols	Guidelines for safe and effective transfusion, encompassing pre-transfusion assessments, blood product selection, techniques, monitoring, and documentation.	[48,68]
Pre-transfusion Assessment	Evaluation of patient suitability, including medical history, physical examination, and hematological tests.	[69]
Patient Blood Typing & Crossmatching	Determines recipient's blood type (ABO/Rh) and checks compatibility with donor's blood to avoid adverse reactions.	[70]
Screening for TTIs	Identifying and minimizing transmission of infectious diseases like HIV, HBV, HCV, syphilis, and HTLV through blood products.	[71,72]

TTIs, transmission transmitted infections; HIV, human immunodeficiency virus; HBV, Hepatitis C viruses; HCV, Hepatitis C viruses; HTLV, human T-cell lymphotropic viruses.

ment timeline based on the patient's diagnosis, treatment response, and underlying condition. In this regard, healthcare professionals configure hemoglobin levels, blood cell counts, bleeding risk, allergies and clinical symptoms are taken into account in determining blood transfusion requirements [85] (Table 3, Ref. [13,43,46,73–81]).

Monitoring for Complications

Blood transfusion dependent patients run a high risk of possible complications that are related with the transfusion therapy like transfusion reactions and many infections that can be transmitted through this therapy [86]. Healthcare providers are obligated to monitor the patients constantly throughout and post the therapy course, so that they can immediately respond to any adverse events that may occur. Constant tracking of the vital signs, laboratory parameters, and clinical distinctions is central in the detection of the complications at an early stage and, therefore, far more adverse outcomes can be prevented [87].

Transfusion Reactions

Transfusion reactions can be through immune or non-immune mechanisms, and they may through the development of mild, moderate or severe symptoms [54]. Frequent transfusion reactions include the Febrile Non-Hemolytic Reactions (FNHHRs), Allergic Reactions (ARs), Acute Hemolytic Reactions (AHRs) and a serious transfusion-related complication, Transfusion-Related Acute Lung Injury (TRALI) [54]. Given that the healthcare workers must always be aware of the symptoms of transfusion disorders, they, also based on its severity and nature, should implement the necessary measures.

Iron Overload

Transfusion as a part of chronic therapy can give rise to the condition of iron overload as the excess of iron from transfused blood is accumulated [88] (Table 3). Overload of the organ via iron may cause liver dysfunction, endocrine and cardiac disorders if they are not treated in time [89]. However, besides these transfusion-dependent patients, iron chelation therapy can be also prescribed to those who suffer the excess of extra iron and the subsequent toxicity [57,90,91]. In turn, healthcare providers need to see the iron level through routine checkup as well as review adjust chelation therapy as necessary so that iron balance is maintained, and complications are avoided. The three vital blood tests including ferritin levels in serum, liver function tests, cardiac imaging studies should be done routinely as the main factors for monitoring of iron burden and decision making for the periods of management [14,92].

Transfusion-Transmitted Infections (TTIs)

While, there is a chance of transfusion-transmitted infections (TTIs) in spite of the stringent screening and testing procedures, it is quite rare and most of the time, errors happen to be there in the labs which have brought about such infections during the transfusions. Healthcare providers should regularly revolve around patients and watch them for signs and symptoms of TTIs, and, as they suspect an infection, they should do proper diagnostic testing that is appropriate. The transfusion therapy products can be avoided in many cases with the appropriately timed diagnosis of transfusion transmissible infections and adequate management, thereby minimizing the risk of transmission to the patients' receiving transfusions. Below is a concise sum-

Table 3. Essential factors in transfusion therapy management for transfusion-dependent patients.

Aspect	Description	Reference
Assessment of Transfusion Requirements	Evaluation of the patient's transfusion needs by determining indications, appropriate blood product type and quantity, treatment timeline, and consideration of diagnosis and response.	[73]
Monitoring for Complications	Continuous monitoring of patients during and after transfusion therapy to detect and respond promptly to potential complications such as transfusion reactions and infections.	[74,75]
Transfusion Reactions	Awareness and management of potential transfusion reactions, categorized by immune or non-immune mechanisms, and varying in severity from mild to severe.	[43]
Iron Overload	Recognition and management of iron overload, a consequence of chronic transfusion therapy, to prevent complications such as liver dysfunction, endocrine disorders, and cardiac issues. Monitoring should include clinically actionable thresholds such as serum ferritin >1000 ng/mL, liver iron concentration >7 mg/g dry weight, and cardiac T2 <20 ms, to guide initiation and adjustment of iron chelation therapy.	[13,46,76–80]
Transfusion-transmitted Infections (TTIs)	Vigilance for signs and symptoms of transfusion-transmitted infections (TTIs) and timely diagnostic testing to minimize the risk of transmission to transfusion-dependent patients.	[81]

mary of the essential factors in transfusion therapy management for transfusion-dependent patients, highlighting key considerations and references for further information.

Long-Term Complications

The role of chronic transfusion therapy continues to be essential in the treatment of haematological diseases; however, it exposes patients to long-term complications of transfusion. The potential health-related concerns that may arise as a consequence of prolonged transfusion dependence, are three significant complications: alloimmunization, transfusion-associated graft-versus-host disease (TA-GVHD), and delayed haemolytic transfusion reactions [86,93,94].

Alloimmunization, which involves formation of antibodies against the blood group antigens, is a major obstacle to administration of transfusion therapies, especially to regular recipients who always need blood transfusion [8,95]. Discovering alloantibodies can be problematic for finding venous blood products that are matched to the patient [8], leading to possible delay or improper treatment and being the attribution of increased sickness rates.

Transfusion-associated graft-versus-host disease (TA-GVHD), discernibly of a rare nature, with the condition having a high mortality rate, constitutes a fatal complication [is an indication of a mortal outcome] [96]. This condition happens when donor lymphocytes in blood that is infused, detect recipient's cells as problems and as a result, begin to mount an immune response that can give rise to an attack which leads to destruction of tissues and organ failure [97]. The effective surveillance and preventive steps are of utmost importance in noncompliance of TA-GVHD such as the use of irradiated blood products and practice of strict blood bank procedures is highly recommended [96,98].

Although the delayed-type hemolytic reactions do not show as obvious symptoms as Immune-Mediated Hemolytic Anemia (IMHA), still, they can develop within a couple of days to a couple of weeks after receiving the transfusion and the symptoms may be anemia and jaundice [99]. These responses indeed come about as bodily defences wage war against the infused red blood cells, leading to their brief life and potential consequences [100]. Recognition of early occurrence in response to transfusion as well as good management of delayed hemolytic transfusion reactions is thus a prerequisite to limit complications and improve patient outcomes.

Health delivery services providers need to constantly be keeping the risks related to chronic transfusion therapy as given extreme attention. Establishing accurate procedures by reviewing patient status frequently, selecting blood products effectively, as well as applying applicable guidelines decrease the chances of these complications. Therefore, these measures play a helpful role for patient safety and favorable results in the future.

Management of Underlying Medical Conditions

Transfusion-dependent subjects may actually suffer from diverse medical complications and this requires the use of treatment strategies that are aimed at relieving these complications (Table 4). The healthcare professionals have to adjunct their transfusion facility with the treatment of underlying conditions to compensate and enhance of patient's outcomes. Managing strategies includes medicinal interventions, disease-modifying drugs and caring practices that are aimed at controlling symptoms and halt disease (Table 4).

Hematologic Disorders

Transfusion-dependent people with diseases often worse into devastating hematologic abnormalities like thalassemia, sickle cell disease and myelodysplastic syndromes (MDS) [101,102]. Administration of such disorders may involve a drug therapy that is specific for each of the

Table 4. Strategies for managing underlying medical conditions in transfusion-dependent patients.

Medical condition	Management strategies
Hematologic Disorders	Disease-specific drug therapies (e.g., hydroxyurea, luspatercept)
	Bone marrow transplant (for eligible candidates)
Hematologic Malignancies	Integrated treatment approach combining chemotherapy, radiation therapy, and targeted therapy
Chronic Liver Disease	Drug therapies to reverse coagulation abnormalities
	Endoscopic procedures to stop bleeding from varices
	Liver transplantation (for eligible cases)
Renal Disease	Erythropoiesis-stimulating agents (ESAs) for stimulation of red blood cell production
	Iron supplementation
	Dialysis support measures

diseases, such as hydroxyurea for sickle cell disease [103], luspatercept & hydroxyurea for thalassemia [104,105] and Erythropoiesis-Simulating Agents (ESAs) for the anemia that is related to MDS [106] and bone marrow transplant [107] that is eligible for some candidates. Collaboration among healthcare providers with respect to hematologists and other specialties in surgery could be beneficial for creating tailored treatment programs for each patient.

Hematologic Malignancies

One of the most challenging problem encountered by the patients who are transfusion dependent with hematologic malignancy, such as leukemia, lymphoma and myeloma, is the adequate and integrated treatment approach which must combine chemotherapy, radiation therapy, and targeted therapy for the improvement of the patient condition [108]. Healthcare providers (HCPs) need to closely follow illness progress, provide medications for treatment side-effects, and give comfort care to ensure the best possible treatment outcomes and quality of life.

Chronic Liver Disease

Liver diseases that are chronic, including cirrhosis and hepatitis B or C, are usually complicated by the development of coagulopathy [109], thrombocytopenia [110] and hypersplenism [111], which lead to transfusion of platelets and others elements for the purpose of managing bleeding risk and the symptoms of thrombocytopenia [112]. The management strategy could include drug therapies to reverse coagulation abnormalities, endoscopic procedures to stop bleeding from varices, and liver transplantation in eligibility cases [113,114]. Coordination between healthcare provider, hepatologists, and transplant nurses is crucial to maximize patients' chances of successful transplantation and minimize post-transplant complications.

Renal Disease

The Transfusion-dependent patients with the chronic kidney disease (CKD) or the end-stage renal disease (ESRD) may develop anemia due to decreased erythropoietin production and the improper erythropoiesis [115]. The management decision can comprise of ESAs for stimulation of erythropoiesis, iron supplementations and dialysis support measures for improvement of hemoglobin concentration and relief from the deleterious impacts of anemia [116]. Healthcare providers need to ensure patients renal function is regularly monitored while treatment scheduling and adjustment are planned to match with the expected outcomes.

Addressing Psychosocial Needs

The psychosocial adjustments of transfusion-dependent patients may be quite overwhelming from the viewpoint of the medical conditions, treatment implementations and life routine issues as depicted in Fig. 2. Healthcare professionals must attend to these aspects of the care to ensure both patients' physical as well as mental health and offer the best quality of life they can. Psychosocial support programs can be counselling, support groups, and access to health psychiatry services, to enable patients to handle the psychological difficulties that accompany stress, anxiety, and depression [17].

Psychosocial Aspects of Care for Transfusion-Dependent Patients

Any blood medicine dependent person must cope with different obstacles that go beyond their disease, which could be related to their emotional status, social lifestyle and financial situation. In this multifaceted discussion of the psychosocial dimensions of care for the patients with transfusion dependency, we will discuss the mental and physiological effects of being dependent on transfusion, focus on measures of care and support that help the patients cope with transfusion dependence, all the while addressing the social and financial implications faced by patients who are not self-sufficient.

Emotional and Psychological Impact of Relying on Transfusions

Chronic disease at a time when transfusion therapy are needed routinely or frequently can have very deep implications on mental and emotional health of the patient. The feeling of being in a life and death situation may result into emotional effects which may include anxiety, depression,

and also, a loss of control [117]. Some typical experiences for the transfusion-dependent patients may be related to being unpleasant and fearful about the process of transfusion. Thus, they may be uneasy regarding the transfusion reaction, transfusion complications, or the overall condition of their health [118]. Constant interaction with a chronic disease that is here to stay with regular medical treatments can result in hopelessness, melancholy, and social disconnection. Patients could get bothered with mental impact of their disease in addition to the limitations it created for the patient in performing his/her routine activities and social interaction. Additional need for the number of times that people with the disease visit the medical center and hospitals can only add up to the feelings of loneliness and isolation [119]. Transfusion-dependent patients usually have an experience of feeling helpless and out of face with their bodies because they rely of regular medical treatment and intervention. This is destructive removal of control which eventually may results in impatience, frustration and expecting no possibility to change the destiny. The patients sometimes become helpless due to loss of agency over their lives and they also nay get very anxious or depressed at the load of maintenance of their medical conditions [73]. The chronic illness could be lived with mourning of one's lost health, autonomy, and future concerns. The diagnosis and treatment process could induce bitterness and loss as a symptom of the perception of disease, lifestyle change, and the disease effect on their quality of life. To cope with life acknowledged with a chronic illness is to experience different levels of feelings and become acquainted with a different world [120]. This figure summarizes the multilayered psychological and social aspects involved in caring for the transfusion-dependent patients. It highlights the emotional and mental consequences of transfusion reliability; ways of how supportive measures may help to tackle transfusion dependency and the social and financial obstacles patients experience because of this situation. It is through this detailed overview that it is shown that the feeling side of the issue should not be left out and that the well-being of the affected individuals should be holistically taken care of.

Supportive Care Strategies for Coping With Transfusion Dependency

To ensure emotional care of long-term transfusion dependent patients, clinicians should implement supportive treatment options, which will include, among others, resilience, coping strategies and overall positive psychosocial wellbeing (Fig. 2). These strategies may include patient information, counseling, peer groups support and mindfulness and relaxation techniques, and psychosocial interventions [121]. It is greatly important to be thorough in disclosing of medical issues, treatment alternatives, and strategies that the patient can take up in order to enable the patient to be well-rounded in his care and to make decisions that are informed. In addition to the listed above, the therapeutic sessions may be aimed at helping the patients to work through their emotions, learn effective coping skills, and adapt to their life style while suffering from a chronic illness [73]. Installing meditation-based stress reduction practices, relaxation exercises and guided imagery among patients can help decrease anxiety, promote relaxation, and improve the ability to bear pain and discomfort related to various medical treatments [122]. Psychosocial therapies such as cognitive-behavioural therapy (CBT), stress management, and problem-solving techniques can help patients learn how to cope with stress in an adaptive manner, how to manage their thoughts, and be prepared for the challenges life may present them with [123].

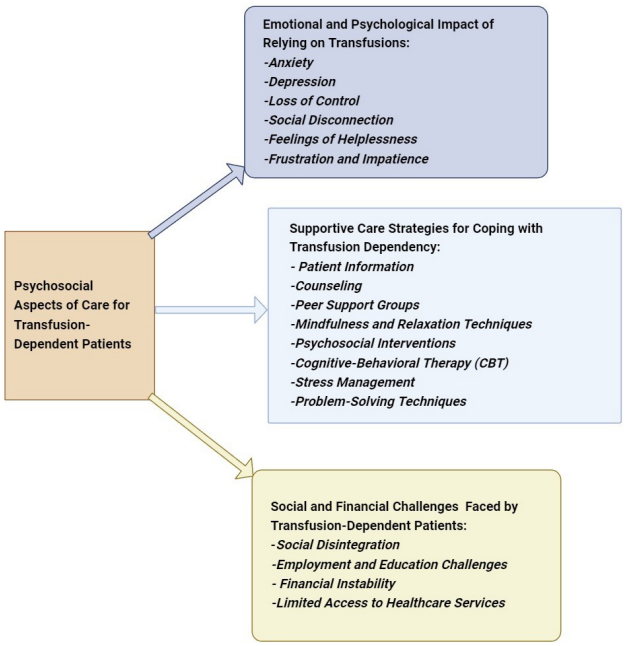

Fig. 2. Psychosocial dimensions of care for transfusion-dependent patients.

Addressing Social and Financial Challenges Faced by Transfusion-Dependent Patients

Along with the emotional and psychological influence, transfusion-dependent patients may be subject to some social and financial obstacles which their condition brings. Such problems can worsen stress and convergence the overall load of diseases. Long-term and frequent visits to the hospital may interfere with their social activity, relationships and integration into their community. Social disintegration causes loneliness, aloofness, and detachment from society [124]. Employment or a tertiary education may be challenging for transfusion-dependent patients because of their delicate health condition and complicated treatment schedule. It can thus cause financial instability, income loss, and limited access to health care and supporting services as well [125].

Table 5. Emerging alternatives to traditional transfusion therapy.

Alternative	Description
Artificial Blood Substitutes	Manmade solutions designed to mimic the function of red blood cells in transporting oxygen. Offers benefits such as donor safety, longer shelf life, and independence from blood type [116].
Stem Cell Therapies	Hematopoietic stem cell transplantation involves infusing donor stem cells into the recipient's bloodstream, offering curative potential for hematological disorders [117].
Erythropoiesis-Stimulating Agents (ESAs)	Synthetic hormones stimulating red blood cell production, commonly used to treat anemia in chronic kidney disease and cancer chemotherapy [118].
Oxygen Therapeutics	Synthetic oxygen carriers engineered for delivering oxygen to tissues and organs, providing alternatives in emergency and critical care settings [119].

Advancements in Transfusion Therapy for Transfusion-Dependent Patients

The progressive development of transfusion therapy for patients with transfusion dependency has become a crucial aspect. Transfusion therapy has been a precious ally of clinical stances improving the patients with various medical conditions, maintaining the adequate oxygen delivery and replenishment of the deficient blood components, as well as ensuring the preservation of critical physiological functions [126]. Although traditional transfusions have some drawbacks and risks like transfusion reaction, infectious complications, and donor dependency [127], the cell therapy is a booming solution for blood disorders. To combat these issues and improve patient prognoses, transfusion researchers and clinicians have been identifying future-forward strategies. Here we will discuss in detail the most recent breakthroughs in transfusion drug therapy for patients who depend on transfusions to survive, including promising alternatives to transfusion therapy and gene therapy as potential tools that can lead to the improvement of the management of hematologic disorders.

Emerging Alternatives to Traditional Transfusion Therapy

Traditional transfusion therapy have long been the primary method of treating anemia and other blood-related disorders. But in spite of progress with medical tech, and research that showed how complicated and sometimes inferior traditional donor transfusions might be, there has been revealed the alternatives having the potential of greater result. New alternatives to blood transfusion are being discovered every day, and such alternatives include artificial blood substitutes [128], stem cell therapies [129], erythropoiesis-stimulating agents (ESA) [130], and oxygen therapeutics [131].

Artificial Blood Substitutes

Synthetic replacement for blood is the manmade solution designed to stand up for the function of red blood cells to transport oxygen (Table 5, Ref. [116–119]). These alternatives offer several possible benefits as compared to the traditional blood transfusion: the donors' safety is guaranteed with no dangers of the infectious diseases spreading, the shelf life of the product is longer, and it is blood type independent [132]. Researchers are exploring various formulations of artificial blood substitutes, including perfluorocarbon-based emulsions [133] and hemoglobin-based oxygen carriers [134], to address the critical need for safe and effective blood alternatives.

Stem Cell Therapies

The approach of using stem cell therapies instead of standard process of transfusion therapy is an answer for patients suffering from hematological disorders. In the process of hematopoietic stem cell transplantation (HSCT), donor stem cells are infused into the blood circulation of the recipient [135]. The cells then develop into all the formed blood parts, which include red blood cells, white blood cells, and platelets. HSCT can become a pacemaker of curative therapies for such fatal illnesses like thalassemia, sickle cell disease, and aplastic anemia, the chance of remission and betterment of the quality of life is high [136].

Erythropoiesis-Stimulating Agents (ESAs)

ESAs partake of synthetic hormones that stimulate the production of more red blood cells being formed in the bone marrow. These agents are chosen mostly to substitute anemia in chronic kidney disorder, cancer chemotherapy and so on [137]. An easy-to-use alternative of ESAs for transfusions in which the frontiers are drawn is also the treatment of anemia, as this reduces the use of transfusions [138]. It has in turn been seen that the symptoms of fatigue, weakness, and shortness of breath are improved [116].

Oxygen Therapeutics

Oxygen Therapeutics are a special type of synthetic oxygen carriers engineered for delivery of oxygen to tissues and organs in the absence of red blood cells [139]. Such agents have the possibilities of use in emergencies, trauma situations and critical care settings that could require alternate products or are forbidden [140]. The use of oxygen therapeutics replaces the need for transfusions which are costly, limits the availability due to their lifespan and many factors can make blood transmission risky [141].

Gene Therapy and Its Potential Impact on Transfusion-Dependent Patients

Gene therapy has got a great potential to cure hematologic patients by fixing the inheritable gene, which are responsible to create blood problems. This innovative mechanism comprises of dividing therapeutic genes into patient cells and replacing of defective genes with them to restore the normal cellular function and relieving the symptoms of the disease [142] as depicted in Fig. 3.

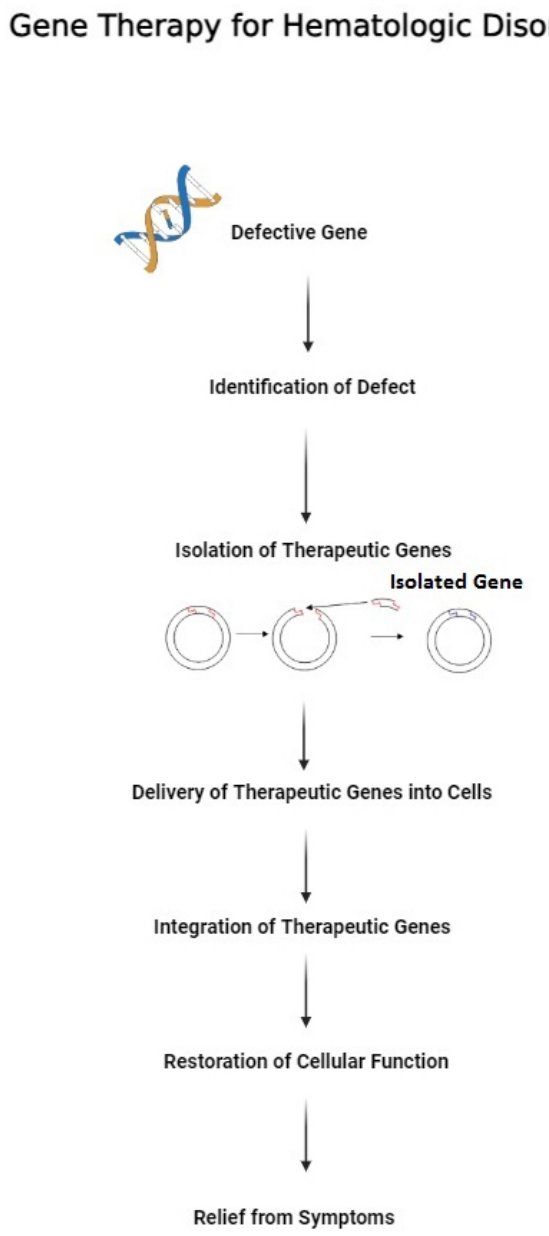

Fig. 3. Sequential steps in gene therapy for hematologic disorders. The figure represents the sequential steps involved in gene therapy for hematologic disorders, starting from identifying the defective gene, isolating therapeutic genes, delivering them into patient cells, integrating them into the genome, restoring cellular function, and ultimately resulting in relief from symptoms.

The subject of transfusion-dependent treatments is being studied by a few different gene therapy techniques, namely, gene editing technology, gene addition therapy, autologous therapy, and gene therapy with hematopoietic stem cells as depicted in Table 6 (Ref. [133,134,136–138]).

Gene Editing Technologies

In cases of gene editing, the technologies are enabled by CRISPR-Cas9, which provides high-level precision modifications of the patients' genetic code [143]. If these modifications are done at the DNA-level they enable correction of mutations associated with hematologic diseases [144]. Researchers may achieve red cell production facilitation through focus on a small number of genes, thereby attaining the remedy of diseases of thalassemia and sickle cell conditions, which will not require long time transfusion therapy any more [145,146] as depicted in Table 6.

Gene Addition Therapy

The gene addition therapy involves passage of intact copies of defective/defective genes into the patient's cells to substitute for such deficiencies [147]. Application of this method can return to normal proteins synthesis and cellular activities that will ultimately bring about a higher red blood cell production and hemoglobin levels among patients who have had to depend on transfusion in the long term [148].

Autologous Gene Therapy

Autologous gene therapy entails removal of the own cells from the patient, genetic modification outside the body, and readministration through intravenous route [149]. On top of that such an individualized treatment minimizes the risk of immune rejection and transplant rejection, which makes it an appealing therapy for those who are patients which need transfusions [149].

Hematopoietic Stem Cell Gene Therapy

Genetic correction in hematopoietic stem cells (HSCs) is the main target in the gene therapy therapy for hematopoietic stem cells, which are the cells that make all types of blood cells. These valuable stem cells may be modified genetically to reproduce responsible and healthy blood cells that could then eliminate the need for transfusions in transfusion severe cases [150].

Conclusion

On the whole, it is possible to assert that the clinical background of transfusion medicine of transfusion-dependent patients is characterized by impressive achievements and difficult issues. Throughout this review, we have considered the complicated circumstance of the Transfusion-dependent Patient, by embracing medical considerations, psychological aspects, and emerging therapies.

Table 6. Gene therapy techniques for transfusion-dependent patients.

Gene therapy technique	Description
Gene Editing Technologies	Utilizes CRISPR-Cas9 for precise modifications of genetic code at the DNA level, correcting mutations associated with hematologic diseases. Offers potential remedy for thalassemia and sickle cell conditions, reducing the need for long-term transfusion therapy [133,134].
Gene Addition Therapy	Involves transferring intact copies of defective genes into patient's cells to substitute for deficiencies, enabling normal protein synthesis and cellular activities, resulting in higher red blood cell production and hemoglobin levels [136].
Autologous Gene Therapy	Patient's own cells are removed, genetically modified *ex vivo*, and then re-administered intravenously. Offers individualized treatment with reduced risk of immune and transplant rejection, appealing for transfusion-dependent patients [137].
Hematopoietic Stem Cell Gene Therapy	Focuses on genetic correction in hematopoietic stem cells (HSCs) to produce healthy blood cells, potentially eliminating the need for transfusions in severe cases [138].

Transfusion treatment has been the building block of many medical treatments for replacing many blood components, maintaining homeostasis, and preventing problems. Undoubtedly, for many years the use of blood transfusion has been lifesaving in different cases; however, there are some disadvantages and risks associated with it, particularly in patients requiring repeated or lifelong support. Importantly, this review highlights that transfusion dependence should not be approached as a uniform clinical condition, but rather as a multifactorial and disease-specific state requiring individualized therapeutic planning and longitudinal care.

Acknowledging the complex picture of these patients, with their multiple concomitant clinical issues and variations is an important aspect of optimization of outcomes for these patients. Therapeutic approaches, made by in-depth patient assessment, long-term monitoring, and careful choice of blood products, should be an essential element of patient care. In practical clinical terms, this includes disease-specific transfusion thresholds, extended antigen matching where appropriate, regular surveillance for alloimmunization and iron overload, and timely integration of adjunctive therapies such as iron chelation, erythropoiesis-stimulating agents, immunomodulatory treatment, or disease-modifying interventions. Moreover, managing psychosocial care components of treatment should be among the goals in order to promote patient welfare and improve quality of life. Organizing psychosocial support groups, making the patients aware by educating and counselling them, and facilitating peer relations can relieve the emotional tolls caused by transfusion. These measures should not be considered optional additions, but rather integral components of high-quality transfusion care, particularly for patients facing long-term treatment dependence and repeated healthcare exposure.

However, there is a transformation of paradigm in transfusion medicine field due to the emergence of novel therapeutic interventions that are meant to address the physiological deficiencies that bind the patient hand and foot with traditional blood transfusion. Newer alternatives for instance red-cell substitutes, stem cell therapy, erythropoietin growing factors, hypoxic therapy, and gene therapy provide attractive routes for ameliorating patient status and the entire treatment picture. Such innovations unquestionably contribute to the reduction of existing threats in classic transfusion procedures and offer promise to patients with chronic transfusion conditions. At the same time, these approaches should be evaluated critically with regard to long-term efficacy, accessibility, safety, affordability, and their ability to reduce or replace transfusion burden in different disease settings. Future clinical practice will likely depend on how successfully these therapies can be integrated into conventional transfusion programs rather than viewed as isolated replacements.

In the future, there is a need for more research, innovation, and partnership to bring about higher standards, better and more effective treatments as well as refine transfusion practice. Future research should move beyond general safety concerns and focus more specifically on: (i) developing personalized transfusion algorithms for different disease groups; (ii) improving prediction and prevention of alloimmunization and iron overload; (iii) optimizing patient blood management strategies; (iv) evaluating long-term psychosocial and quality-of-life outcomes; and (v) expanding access to emerging curative or transfusion-sparing therapies. In addition, multicentre and longitudinal studies are needed to generate stronger evidence for individualized transfusion thresholds, supportive care pathways, and cost-effective models of long-term monitoring. Through the adoption of a comprehensive, patient-centered model of care that blends clinical competency, evidence-based medicine, and psychosocial support, healthcare providers can meet the challenges of transfusion-dependent patients with more understanding, precision, and success. Ultimately, the future of transfusion medicine lies not only in making transfusion safer, but also in making it smarter, more personalized, and where possible, less necessary. Collectively then, we can embark on a journey of safer, better transfusions considering patient safety as well as respecting life with the aim of improving global outcomes for transfusion dependent people.

Abbreviations

TTIs, transmission transmitted infections; HIV, human immunodeficiency virus; HBV, Hepatitis B viruses; HCV, Hepatitis C viruses; HTLV, human T-cell lymphotropic viruses.

Availability of Data and Materials

The authors confirm that the data supporting the results of this study are available within the manuscript.

Author Contributions

Conceptualization: RM, MAAlt, BMA, UJ, MMM, JA, UM, SKM. Writing: JB, MMJ, MM, ZMA, MAAlt, FJT, FHA. Important revising: RM, MAAla, BMA, UJ, MMM, JA, UM, SKM. Methodology: RM, MAAla, JB, MMJ, MM, ZMA. Tables and Figures: MMM, JA, UM, SKM, ZMA, MAAlt, FJT, FHA, BMA, UJ. Validation and software: MAAlt, FJT, FHA, BMA, UJ, MMM, JA, UM, SKM. All authors approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

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Conflict of Interest

The authors declare no conflict of interest.

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