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THE USE OF BIOSORBENTS IN HEMATOLOGY AND THEIR EFFECTS ON CARDIAC FUNCTION

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Abstract

This article provides a comprehensive study of the use of biosorbents in hematology and their effects on cardiac function. Biosorbents, which can be natural or synthetic materials, possess the ability to adsorb toxins, excess lipids, and other harmful substances from the blood. These properties contribute to blood purification, stabilization of hemoglobin levels, and improvement of red and white blood cell function. Furthermore, biosorbents help regulate lipid profiles, reduce cholesterol and triglyceride levels, and support cardiovascular health. The article analyzes various research findings, highlighting the positive effects of biosorbents on heart function and circulatory system by reducing toxic load in the blood. Long-term use of biosorbents is shown to be effective in stabilizing hematological parameters and decreasing the risk of cardiovascular diseases. These findings suggest potential applications of biosorbents in clinical practice for both hematological and cardiological preventive strategies.

Introduction:Biosorbents, as innovative adsorptive materials, have garnered increasing attention in the management of hematological disorders and cardiac complications. These materials, which include activated carbon, chitosan, and functionalized polymer resins, are capable of selectively removing toxins, cytokines, and other harmful metabolites from the bloodstream [1,3,7]. In hematology, the accumulation of inflammatory mediators and metabolic by-products can exacerbate anemia, leukocyte dysfunction, and platelet abnormalities, thereby increasing the risk of systemic complications.Cardiac function is closely linked to blood composition. Elevated levels of cytokines and circulating toxins can induce endothelial dysfunction, increase vascular resistance, and place additional stress on the myocardium [1,2,4]. Therefore, biosorbents serve a dual purpose: they not only improve hematological parameters but also contribute to hemodynamic

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stability and myocardial protection [2,5,8]. Clinical studies on hemoadsorption during cardiopulmonary bypass (CPB) operations, complex cardiac surgery, and post-cardiac arrest care have demonstrated reductions in IL 6, IL 1β, and TNF α, along with improved vasopressor requirements and cardiac output [1,2,7,8].

Despite these encouraging results, significant challenges remain. Most clinical trials are limited by small sample sizes, heterogeneity in patient populations, and variability in treatment protocols such as duration, timing, and frequency of hemoadsorption [4,6,9]. Furthermore, there is a paucity of long-term data evaluating the effects of biosorbents on cardiac remodeling, myocardial recovery, and overall survival. Current evidence predominantly focuses on short-term inflammatory modulation rather than comprehensive cardiovascular outcomes. These limitations highlight the need for larger multicenter trials and standardized treatment protocols.Critical gaps in the current literature include:Limited understanding of the molecular interactions between biosorbents and specific blood components in different hematological disorders [3,5].Insufficient data on the long-term effects of repeated hemoadsorption sessions on cardiac function and systemic homeostasis [2,4].Need for personalized treatment protocols considering the type of hematological disorder, cardiac risk profile, and individual patient response [6,9].

Biosorbents are prepared from various materials and exert their therapeutic effects by selectively adsorbing harmful substances from the blood. They are divided into natural and synthetic types [3,7].Natural biosorbents include activated carbon, chitosan, and glycoprotein-bound biological polymers. These materials have a high surface area and remove molecules from the blood primarily through physical adsorption. For example, chitosan possesses immunomodulatory properties that help reduce inflammatory mediators [3,7]. Natural biosorbents minimally affect erythrocytes, leukocytes, and platelets, making them suitable for maintaining stable blood composition in hematology.Synthetic biosorbents consist of polymer resins, biomimetic coatings, and surface-functionalized materials. Their main advantage is high selectivity and the ability to target cytokines, endotoxins, and other harmful substances in the blood [1,2,8]. For example, CytoSorb® polymer resins can adsorb molecules ranging from 5–60 kDa, effectively reducing inflammatory mediators. Furthermore, the functional groups on their surface minimize undesired protein binding, ensuring the safety of blood cells and platelets.

The primary mechanism of biosorbents is physical and chemical adsorption, which captures harmful substances from the bloodstream. Natural materials rely mostly on physical adsorption, while synthetic polymers work through selective chemical binding and molecular interactions [3,5,7]. As a result of these mechanisms:

- Cytokine levels (IL 6, IL 1β, TNF α) decrease [1,2,7],
- Stability of erythrocytes and leukocytes is maintained [3,5],
- Blood viscosity and myocardial load are reduced [2,8].
- The effectiveness of biosorbents depends on their material, surface functionalization, size, and treatment protocol. However, certain limitations exist:
- Individual patient responses to biosorbents are not fully studied across diverse patient groups [6,9],
- Long-term safety and cardiac effects of repeated sessions have not been adequately evaluated [2,4],
- Some cytokines have beneficial roles, and their adsorption may impair certain immune functions [3,5].
- Considering these factors, the selection of biosorbents should take into account the patient's condition, blood toxin and cytokine profile, and cardiac risk. This approach enables their safe and effective application in integrated hematology and cardiology care.

Biosorbents have a significant impact on hematological parameters due to their ability to remove inflammatory mediators, metabolic toxins, and other harmful substances from the bloodstream [1,3,5]. These effects are particularly relevant in conditions such as anemia, leukocyte dysfunction, thrombocytopenia, and hemolytic disorders, where the accumulation of cytokines and toxic metabolites can exacerbate disease progression.Biosorbent therapy has been shown to stabilize erythrocyte counts and hemoglobin levels during systemic inflammatory responses. By removing oxidative stress-inducing molecules and free radicals, biosorbents prevent premature erythrocyte destruction and maintain adequate oxygen-carrying capacity [3,7]. Clinical trials in cardiac surgery patients undergoing hemoadsorption reported minimal hemolysis, indicating the safety of these materials for red blood cells [1,2,8].One of the key hematological benefits of biosorbents is their ability to modulate immune cell activity. Elevated cytokines such as IL 6 and TNF α can impair leukocyte function and promote systemic inflammation. By reducing these mediators, biosorbents help restore normal leukocyte activity, improve phagocytic function, and reduce excessive inflammatory responses [2,5,7]. This is particularly important in hematologic disorders associated with chronic inflammation or sepsis.Biosorbents generally have minimal adverse effects on platelet count and function, although careful monitoring is recommended. Their selective adsorption mechanism ensures that platelet integrity is preserved while reducing pro-inflammatory factors that may trigger coagulation abnormalities [3,5,8]. Studies have demonstrated that hemoadsorption does not significantly increase bleeding risk in cardiac surgery patients or in critically ill hematology patients [1,4,7].

Despite these benefits, several limitations exist:

- Individual responses vary based on underlying hematologic conditions and the specific type of biosorbent used [6,9].
- Long-term impacts of repeated biosorbent therapy on hematopoiesis and immune homeostasis remain under-investigated [2,4].
- Excessive removal of cytokines may inadvertently suppress beneficial immune responses, necessitating careful treatment monitoring [3,5].

Biosorbents offer a promising approach to stabilizing hematological parameters while simultaneously addressing systemic inflammation. Integrating these therapies into hematology care requires tailored protocols considering the patient's disease profile, inflammatory status, and overall risk of hematologic complications [1,2,5,7]. Biosorbents not only modulate hematological parameters but also play a critical role in maintaining cardiovascular stability. The cardiovascular system is highly sensitive to systemic inflammation and circulating toxins, which can impair endothelial function, increase vascular resistance, and elevate myocardial stress [1,2,4]. By selectively removing these harmful mediators, biosorbents contribute to both direct and indirect cardiovascular protection.Clinical studies have shown that biosorbent therapy reduces the need for vasopressors during complex cardiac surgeries and in critically ill patients [2,5,8]. By decreasing circulating levels of pro-inflammatory cytokines such as IL 6, IL 1β, and TNF α, vascular tone improves, systemic vascular resistance decreases, and cardiac output stabilizes [1,2,7]. This effect is particularly important during cardiopulmonary bypass (CPB) or post-cardiac arrest care, where hemodynamic fluctuations are common.Inflammatory mediators and circulating toxins contribute to myocardial injury and dysfunction. Biosorbents help mitigate these effects by reducing oxidative stress and inflammatory signaling in cardiac tissues [1,3,5]. Studies have reported improved left ventricular function, decreased myocardial edema, and lower troponin levels in patients undergoing hemoadsorption therapy during cardiac procedures [2,7,8].

Biosorbent therapy has been associated with improved endothelial function through the reduction of circulating endotoxins and pro-inflammatory cytokines [2,4,7]. Enhanced endothelial health leads to better vascular compliance, reduced arterial stiffness, and lower risk of ischemic complications. These effects are particularly beneficial for patients with combined hematologic and cardiovascular disorders, where systemic inflammation often exacerbates endothelial dysfunction.

Despite the cardiovascular benefits, several limitations should be considered:

- Most clinical trials have small sample sizes and short-term follow-up, making long-term cardiac outcomes unclear [4,6,9].
- Individual variability in cytokine response and myocardial tolerance may affect efficacy [2,5].
- Excessive cytokine removal might potentially blunt necessary immune responses, which could indirectly affect cardiac repair and adaptation [3,5].

Biosorbents offer a dual therapeutic effect: they stabilize hematological parameters while providing measurable cardiovascular benefits. Proper patient selection, timing, and protocol optimization are essential to maximize these benefits and ensure both hematologic and cardiac safety [1,2,5,7,8].The hematologic and cardiovascular systems are closely interconnected. Hematologic abnormalities, such as anemia, leukocyte dysfunction, and thrombocytopenia, can directly and indirectly affect cardiac function, while cardiac dysfunction can exacerbate hematologic imbalances. Biosorbents, by modulating blood composition and inflammatory mediators, help stabilize this interplay.Systemic inflammation serves as the primary link between hematologic disorders and cardiac complications. Elevated cytokines, including IL 6, TNF α, and IL 1β, can impair endothelial function, increase vascular resistance, and trigger myocardial stress. By selectively adsorbing these cytokines, biosorbents reduce systemic inflammation, which simultaneously improves hematologic stability and cardiac performance.

Hematologic disorders often lead to increased oxidative stress due to the accumulation of free radicals, damaged erythrocytes, and metabolic by-products. This oxidative stress contributes to myocardial injury, arrhythmias, and decreased cardiac output. Biosorbents remove reactive oxygen species and other harmful metabolites, thereby reducing myocardial load and preserving cardiac function.Blood viscosity and cellular composition play a crucial role in cardiac hemodynamics. An imbalance in erythrocytes, leukocytes, and platelets can increase vascular resistance and myocardial work. Biosorbents help maintain optimal blood rheology by stabilizing cell counts and reducing inflammatory mediators, improving microcirculation and overall cardiac efficiency.The integrated effect of biosorbents on hematology and cardiac function is particularly valuable in patients undergoing cardiac surgery, intensive care treatment, or suffering from combined hematologic and cardiovascular disorders. Appropriate application of biosorbents can reduce systemic inflammation and oxidative stress, stabilize hematologic parameters, prevent excessive hemolysis, and improve cardiac output and vascular compliance.Despite these benefits, gaps remain. Long-term cardiovascular outcomes related to repeated biosorbent therapy are not well studied, individual patient variability may affect therapeutic efficacy, and optimal timing, duration, and selection of biosorbent types require further standardization. Understanding these mechanisms highlights the dual therapeutic potential of biosorbents in simultaneously addressing hematologic abnormalities and cardiovascular risks, making them a promising adjunct in integrated care [1,2,5,7,8]. Biosorbents have emerged as a promising adjunct therapy in various clinical scenarios where hematologic and cardiovascular systems are compromised. Their ability to selectively remove inflammatory mediators, endotoxins, and other harmful substances allows for improved patient outcomes in both acute and chronic conditions [1,2,5].In cardiac surgery, hemoadsorption has been used to stabilize hemodynamics during cardiopulmonary bypass. Elevated cytokines and inflammatory mediators during surgery can lead to vasoplegia, myocardial dysfunction, and postoperative complications. Biosorbents reduce IL 6, IL 1β, and TNF α levels, decreasing the need for vasopressors and improving cardiac output [2,4,7].In critical care and sepsis, systemic inflammation often leads to multiorgan dysfunction. Biosorbents can reduce the inflammatory burden, stabilize hematologic parameters, and improve tissue perfusion, thereby preventing progression to severe cardiac complications. Clinical trials have demonstrated improved survival rates, reduced ICU stays, and stabilization of laboratory markers such as lactate and troponin levels [1,2,5,8].

In hematology, patients with severe anemia, leukocyte dysregulation, or hyperinflammatory states can benefit from biosorbent therapy. By modulating blood composition and removing excessive cytokines, these patients experience improved erythrocyte survival, normalized leukocyte function, and reduced risk of thrombotic events [3,5,7].Despite these benefits, proper patient selection, timing, and monitoring are critical. Individual variability in cytokine profiles, underlying comorbidities, and treatment duration must be considered to avoid unintended immunosuppression or hemodynamic instability [2,4,6] Protocol optimization based on patient-specific factors enhances both safety and efficacy.Biosorbents provide a versatile tool in integrated care, offering both hematologic and cardiovascular benefits. Their clinical applications span cardiac surgery, critical care, and hematology, establishing them as an important adjunct in managing patients with combined inflammatory, hematologic, and cardiovascular challenges [1,2,5,7,8].

While biosorbents offer significant therapeutic benefits in both hematology and cardiology, their clinical use is not without limitations and safety considerations. Understanding these factors is essential for optimizing treatment outcomes and minimizing potential adverse effects [1,2,5].Biosorbents are generally well-tolerated, with minimal direct toxicity to blood cells. However, some potential complications include unintended removal of beneficial cytokines, alterations in electrolyte balance, and, rarely, mild thrombocytopenia or hemolysis [3,4,7]. These effects are often transient and manageable with careful monitoring, but they highlight the need for individualized therapy.Another limitation is the variability in patient response. Factors such as baseline hematologic status, cardiac function, severity of inflammation, and comorbidities can significantly influence therapeutic efficacy. Consequently, biosorbent therapy must be tailored to each patient, including the selection of material type, duration, and frequency of hemoadsorption sessions [2,6,8].Furthermore, clinical data on long-term outcomes are still limited. Most studies focus on short-term improvements in inflammatory markers, hemodynamics, and blood parameters. The long-term impact on cardiac remodeling, immune system function, and overall survival requires further investigation [4,5,9].Biosorbents remain a promising adjunct therapy when applied judiciously. Close monitoring of hematologic and cardiac parameters, along with protocol optimization, ensures both safety and maximum therapeutic benefit. Continued research and larger clinical trials are necessary to fully establish standardized guidelines and long-term safety profiles [1,2,5,7,8].The therapeutic potential of biosorbents in integrated hematology and cardiology care continues to expand, driven by advances in material science, nanotechnology, and clinical research. Emerging biosorbent designs aim to enhance selectivity, biocompatibility, and adsorption efficiency, enabling more precise removal of harmful mediators while preserving beneficial molecules [1,3,5].Future developments may include personalized biosorbent therapy, tailored to individual patient profiles based on cytokine levels, hematologic parameters, and cardiovascular risk factors. This approach could maximize efficacy while minimizing potential adverse effects and immunosuppression [2,4,7].Integration of biosorbents with advanced monitoring systems and point-of-care diagnostics is another promising direction. Real-time feedback on cytokine removal, hemodynamics, and blood composition could allow dynamic adjustment of therapy, improving both safety and clinical outcomes [2,5,8].Combining biosorbents with other therapeutic modalities, such as pharmacologic interventions or extracorporeal support devices, may provide synergistic benefits in critically ill patients. This integrated approach can effectively address complex conditions involving systemic inflammation, hematologic dysregulation, and cardiovascular compromise [1,2,6].Several challenges remain. Long-term clinical data, standardized protocols, and large-scale trials are required to establish efficacy, safety, and cost-effectiveness. Continued interdisciplinary research involving hematology, cardiology, and material science will be essential to fully realize the potential of biosorbent therapy [1,2,5,7,8].The future of biosorbents is closely linked to precision medicine, targeting hematologic and cardiovascular complications in a patient-specific, dynamic, and safe manner.

Recommendations for Clinical Practice:Biosorbents have demonstrated therapeutic benefits in managing hematologic and cardiovascular complications, and their application in clinical practice requires careful consideration of patient-specific factors. Clinicians should evaluate baseline hematologic status, cardiac function, inflammatory markers, and comorbidities before initiating therapy to optimize outcomes [1,2,5].Treatment protocols should be tailored according to the type of biosorbent, session duration, and frequency of hemoadsorption. Monitoring blood parameters, cytokine levels, and hemodynamic status during and after therapy is essential to ensure efficacy and detect potential adverse effects promptly [2,4,7].

Education and training of healthcare personnel are crucial for the safe and effective use of biosorbents. Proper handling, device setup, and troubleshooting during therapy minimize complications and enhance patient safety [3,5,8].Integration of biosorbent therapy with other medical interventions, including pharmacologic management and supportive care, may enhance clinical outcomes, particularly in patients with severe systemic inflammation or combined hematologic and cardiovascular disorders [1,2,6].Finally, clinicians should maintain a record of therapy outcomes and participate in clinical studies whenever possible. Collecting real-world evidence contributes to refining protocols, understanding long-term effects, and establishing standardized guidelines for biosorbent use in diverse patient populations [2,5,7,8].

Conclusion:Biosorbents have emerged as a valuable adjunct therapy in integrated hematology and cardiology care. By selectively removing inflammatory mediators, toxins, and metabolic by-products, they contribute to stabilizing hematologic parameters, improving cardiovascular function, and reducing systemic inflammation [1,2,5,7,8].Their dual therapeutic effects make them particularly suitable for patients with combined hematologic and cardiac complications, including those undergoing cardiac surgery, intensive care treatment, or experiencing severe inflammatory states. Careful patient selection, individualized treatment protocols, and close monitoring of hematologic and cardiovascular parameters are essential to maximize benefits and minimize potential adverse effects [2,4,6].Advances in material science, nanotechnology, and personalized medicine are expected to enhance the selectivity, biocompatibility, and efficacy of biosorbents. Integration with real-time monitoring systems and combination with other therapeutic modalities may further improve patient outcomes in complex clinical scenarios [1,3,5,7].Biosorbents hold significant promise as a therapeutic tool capable of addressing the intertwined challenges of hematologic disorders and cardiovascular dysfunction. Continued research, standardized protocols, and large-scale clinical trials will be critical in establishing their long-term safety, efficacy, and role in routine clinical practice [2,5,7,8].

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