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REVIEW ARTICLE

Impact of Blood Transfusion on Bone Healing and Regeneration in Orthopaedic Surgeries

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ABSTRACT

Blood transfusion is often required during major orthopaedic surgery due to excessive blood loss, especially with joint arthroplasty, spinal fusion, and fracture repair. Despite the medical importance of transfusion in saving lives, new knowledge indicates that transfusion could have adverse effects on bone healing and bone regeneration. Physiological effects of blood transfusions on bone repair, particularly potential delays in inflammatory responses, impaired oxygen delivery, prolonged inflammation, and increased bone resorption, are the foci of this article. Understanding how transfusion-related immunomodulation and changed cytokine activity disrupt bone regeneration is essential for optimizing post-operative outcomes. Strategies to reduce the need for transfusion-inclusive blood-conserving techniques and pharmacological agents such as tranexamic acid and erythropoietin are presented. This article reviews the available literature to offer comprehensive understanding regarding how blood transfusions might influence bone healing in orthopaedic surgeries while simultaneously presenting potential alternative strategies to improve the outcomes for the patients.

KEYWORDS

• Blood Transfusion • Bone Regeneration • Orthopaedic Procedures • Wound Healing • Fracture Healing

INTRODUCTION

Massive blood loss is common in orthopaedic surgeries, especially those involving joint replacement, spinal fusion, and fracture repair; blood transfusion may be necessary to maintain hemodynamic stability and oxygenation.[1] Although transfusion can prevent complications from blood loss, such as hypovolemic shock, there are risks associated

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with this method that might interfere with bone healing. The aim of this article is to discuss the effects of blood transfusions during the bone healing process focusing on remedial measures to be taken in orthopaedic patients.

Bone Healing Process

Bone healing is a multi-phase process: inflammation, followed by soft callus formation, hard callus formation, and finally remodelling. In the initial inflammatory stage, macrophage and neutrophil cells clean up debris and secrete cytokines to enhance the following healing processes.[2] A break at this stage can cause a delay in healing due to soft and hard callus formation and also the final remodelling of bone.[3] Hence, conditions that impair oxygen delivery, result in prolonged inflammation, or alter cytokine profiles directly impact the success of bone healing.[4]

The Role of Blood Transfusion in Orthopaedic Surgeries

Blood transfusion is often required during orthopaedic surgeries to replenish lost blood, ensure proper oxygen delivery, and maintain hemodynamic stability.[1] However, transfusion may also introduce factors that negatively affect bone healing, including altered immune responses, impaired oxygenation, and cytokine disturbances.

1. Immunomodulation and Delayed Healing

Transfusion-related immunomodulation is a widely described condition, where the immune response is suppressed after transfusion.[5] Transfusion-induced immunosuppression can therefore delay the inflammatory response essential for bone repair.[6] The early inflammatory response plays an essential role in attracting immune cells and messenger molecules such as IL-1 and TNF-α, which are central to the soft callus formation and subsequent bone remodeling processes.[7] A delayed or suppressed immune response may slow the pace of recruitment of osteoprogenitor cells, necessary for regeneration.[8]

2. Oxygen Delivery and Bone Regeneration

Although blood transfusions are carried out for the purpose of tissue reoxygenation, transfused red blood cells (RBCs) usually have decreased oxygen-carrying capacity as a result of storage-related changes.[9] The terms "storage lesions" reflect decreased efficacy in the delivery of oxygen to tissues.[10] Because adequate oxygenation is required for osteoblast function and new bone matrix formation, compromised RBC performance may result in delayed healing of bone.[11] Furthermore, the reduced microcirculation after blood transfusion might add to slower bone healing.[12]

3. Inflammatory Response and Cytokine Activity

Blood transfusions introduce exogenous inflammatory mediators, which, due to the prevailing inflammatory environment, raise the levels of pro-inflammatory cytokines at the injury site.[13] Elevated concentrations of cytokines such as IL-6 and CRP extend the inflammatory phase, throwing off the delicate balance required for effective healing of bone.[14] Prolonged inflammation has been demonstrated to blunt the process of soft callus formation, and it delays hard callus formation.[15]

4. Transfusion-Related Complications

Transfusion-associated complications, including transfusion-related acute lung injury (TRALI), transfusion-associated circulatory overload (TACO), and infection, can be detrimental to the postoperative recovery of orthopaedic patients.[16] Infection, especially at the surgical site, is a significant risk factor for delayed union or non-union of fractures.[17] The patients receiving transfusions are more likely to suffer from infections, thereby making the risk of poor bone healing outcomes worse.[18]

5. Bone Resorption and Osteoclast Activation

Other fresh studies indicated that blood transfusions will enhance the activity of osteoclasts, causing an increase in bone resorption at fracture sites.[19] This effect is likely mediated by the receptor activator of nuclear factor kappa-B ligand (RANKL), which promotes osteoclastogenesis and accelerates bone resorption.[20] Excessive bone resorption can compromise structural integrity during healing and delay the transition from soft to hard callus, ultimately affecting long-term recovery.[21]

Alternatives to Blood Transfusion

Given the potential adverse effects of blood transfusions on bone healing, alternative

strategies should be employed to minimize the need for transfusions in orthopaedic surgeries.

1. Blood Conservation Techniques

Intraoperative blood conservation techniques, such as acute normovolemi chaemodilution, controlled hypotension, and intraoperative cell salvage, can significantly reduce the need for transfusions by limiting intraoperative blood loss.[22] These techniques help maintain adequate circulation while avoiding the negative effects associated with transfusions.[23]

2. Pharmacological Agents

Pharmacological agents, especially tranexamic acid (TXA), have been shown to reduce blood loss during orthopaedic procedures by inhibiting fibrinolysis.[24] TXA is effective in minimizing the need for transfusions without compromising bone healing, making it a valuable tool in orthopaedic surgery.[25]

3. Erythropoietin

Preoperative administration of erythropoietin (EPO) has been used to stimulate endogenous RBC production, reducing the likelihood of transfusion during surgery.[26] EPO is particularly useful for elective surgeries where blood loss is anticipated, and it does not interfere with the bone healing process.[27]

CONCLUSION

Although blood transfusion is inevitable in managing blood loss during orthopaedic surgeries, it has adverse effects on bone healing and bone regeneration. These include immunosuppression, decreased oxygen delivery, prolonged inflammation, and increased osteoclast activity, all delaying or impairing bone regeneration. Proper alternatives are blood conservation techniques, pharmacological interventions by administering tranexamic acid, and erythropoietin. Further studies are necessary to establish optimized protocols that reduce blood transfusions yet promote more effective bone healing in the patients who require Orthopaedic procedures.

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