THE IMPACT OF LIQUID PLASMA IN MASSIVE AND EMERGENCY BLOOD TRANSFUSION

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A Dissertation

Submitted to Franklin University in partial fulfillment of

the requirements for the degree of

DOCTOR OF HEALTHCARE ADMINISTRATION

October 2023

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Abstract

Massive bleeding remains one of the leading potentially preventable causes of death in the United States, accounting for more than 50% of mortality rates (Marietta, Marco et al., 2011). Massive transfusion protocol (MTP) is a rapid transfusion of a large amount of blood and blood products (more than ten units of red blood cells in twenty-four hours, or four units of red blood cells in an hour, or any four blood components in 30 minutes) in a short period of time (Thurn et al., 2019). The blood products' ratios included in the massive transfusion protocol are distinct and composed of red blood cells, fresh frozen plasma, and platelets. Developing and establishing electronic records for massive transfusion protocols may improve patient outcomes (Broxton et al., 2017)**.** Using liquid plasma during a massive transfusion protocol may improve patient survival rate by decreasing the blood product delivery time to the patient's bedside and reducing healthcare costs by lowering blood product waste (Beckermann et al., 2022). In this quantitative study, the researcher analyzed retrospective medical records from a Level One Medical Trauma Center in the Southwest United States to answer the research question. Data regarding using liquid plasma in massive blood transfusion outcomes were collected from the hospital records for pre- and post-liquid plasma usage implementation. The study investigated the following research question: For patients who require emergency and massive transfusion, what is the impact of using liquid plasma compared to fresh frozen plasma on blood product wastage and plasma-saving cost one year before and after using liquid plasma?

Keywords: Massive transfusion protocol, massive bleeding, trauma patients, blood transfusion, Liquid plasma.

Dedication

In the name of Allah, the Most Gracious, the Most Merciful,

To the Prophet Muhammad (peace be upon him), whose life and teachings continue to illuminate our path with wisdom and compassion, guiding us toward the pursuit of knowledge, justice, and mercy.

To my beloved children, Amir, Ziad, and Fayrouz,

Your unwavering love and support have been the driving force behind my journey. You inspire me with your curiosity, resilience, and steadfast belief in the power of education. This dissertation is a testament to the bright futures that await you, filled with endless opportunities and the potential to impact the world profoundly.

To my dear wife, Hind,

Your love, patience, and unwavering encouragement have been my anchor in the stormy seas of academia. Your sacrifices and understanding have allowed me to pursue this path with dedication. This dissertation is a tribute to your enduring support and the beautiful life we continue to build together.

To my loving parents,

Your guidance, sacrifices, and unwavering belief in my abilities have shaped me into who I am today. Your faith in my potential has been my constant motivation. This dissertation is a token of my gratitude for everything you have done to nurture my dreams.

This work represents the culmination of our shared journey—the culmination of the values instilled in me by the Prophet Muhammad, the hopes I have for my children, the love I share with my wife, and the gratitude I hold for my parents. May it serve as a testament to the power of love, faith, and dedication in pursuing knowledge and improving humanity.

Acknowledgments

I begin by expressing my profound gratitude to Allah (God), the source of all knowledge and wisdom, for granting me the strength, resilience, and guidance to embark on this academic journey. Your divine blessings have illuminated my path and sustained my determination throughout this endeavor.

I extend my heartfelt appreciation to my esteemed Dissertation Committee:

Dr. Alex Akulli: Your insightful guidance, unwavering support, and scholarly expertise have been invaluable throughout my research. Your mentorship has left an indelible mark on my academic journey.

Dr. Gail Frankle: Your expertise and feedback have greatly enriched the quality of this dissertation. Your dedication to the pursuit of knowledge has been a true inspiration.

Dr. Jesse Florang: Your critical insights and constructive feedback have been instrumental in shaping this work. Your commitment to academic excellence is commendable.

I am deeply thankful to Dr. Hue Shan, Stanford's Medical Director, and Wei Cai, for their invaluable assistance and support. Your contributions have significantly enriched the depth and quality of this dissertation.

To my family and friends,

Your unwavering support, encouragement, and understanding have been the cornerstone of my journey. Your belief in my abilities and your sacrifices have made this achievement possible. I cherish the moments we have shared and the strength you have provided during the challenging times.

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Chapter 1: Introduction

Background of the Study

Massive bleeding is one of the primary avoidable death reasons following trauma, childbirth, and surgery (Quintana-Díaz & García Erce, 2016). Massive bleeding is defined as the loss of the whole-body blood volume in twenty-four hours or four units of red blood cells in four hours. Massive hemorrhage can be a life threaten and require an immediate blood transfusion (Allen et al., 2015). Massive blood transfusion is defined as the transfusion of more than ten units of packed red blood cells (pRBCs) in twenty-four hours (McDaniel et al., 2014). Massive transfusion protocols (MTP) allow for efficiently delivering large quantities of blood components to the rapidly exsanguinating patient (Malone et al., 2006). MTPs are required in complex medical scenarios, and the considerations for MTP activation are often constrained by limited time and information (Meyer & David E, 2017). While many hospitals have established a massive blood transfusion protocol, many gaps can still be harmonized and standardized to improve clinical outcomes and decrease blood product wastage (Smith et al., 2020). Massive and emergency transfusion is often life-saving for trauma and actively bleeding patients (Patil & Shetmahajan, 2014).

Blood components must be ready to use due to the unexpected nature of bleeding patients. Plasma is frequently frozen and must be thawed before usage, which can take up to 30 minutes (Bates et al., 2021). The transfusion service faces logistical challenges in keeping ready-to-issue plasma for the institution's MTP while preventing plasma wastage. Smith et al. (2020) examined implementing liquid plasma usage in an academic medical center through a retrospective review of all trauma patients before and after introducing liquid plasma. Smith et al. (2020) found that it was associated with decreased plasma waste from 13.5% to 10.3% post-liquid plasma implementation on overall plasma waste and from 13.5% for thawed plasma waste to 2.9% for liquid plasma waste (Smith, et al., 2020).

Statement of the Problem

Massive bleeding is the most common cause of death in trauma patients (Akaraborworn et al., 2021). Massive blood transfusion is a life-saving procedure to control and manage massive bleeding. MTP is a set of orders of predetermined blood product ratio that is transfused to massively bleeding patients in a specific order to replace the lost blood (Broxton et al., 2017). The ideal blood product ratio for massive transfusion protocol is 1:1:1 packed red blood cell (RBC): fresh frozen plasma (FFP): platelet (PLT), which is the best possible alternative to fresh whole-blood transfusion (Saleh, 2015). Massive transfusion with a high plasma-to-red blood cell ratio reduces mortality rates (Oliveros Rodríguez et al., 2020). Balanced resuscitation strategies require increased usage of plasma to improve patient survival rates. Fresh frozen plasma is in the frozen state and takes an average of 30 minutes to thaw and be ready for transfusion (Butler, 2020)

The delay in thawing and initiating FFP transfusion results in a critical limitation: timing to commence and attain the high FFP: RBC ratio as early formula-driven resuscitation advises that FFP begins early, ideally with the first RBC unit at the commencement of resuscitation (Nascimento et al., 2010). The shelf life of thawed plasma (FFP) is only five days expiration after being thawed (Rapaille et al., 2021). Transfusing pre-thawed FFP along with the first RBC units to reach the 1:1 ratio can lead to a significant source of blood component wastage(Smith et al., 2020). Plasma waste results in substantial financial loss and increases the cost of healthcare; according to Smith et al. (2020), it was US $39,376 (US $107/unit) of wasted healthcare expenses.

Purpose of the Study

This quantitative retrospective comparative study explored the impact of using liquid plasma in massive and emergency transfusions of trauma patients on plasma waste, blood product delivery time, and initiating the first unit of plasma transfusion. The study analyzed secondary data from medical records obtained from a Level One Medical Trauma Center in the Southwest United States.

Significance of the Study

Massive bleeding accounts for more than 50% of all trauma-related deaths within the first 48 hours following a hospital admission (Akaraborworn et al., 2021). It can significantly raise the mortality rate of any surgery (Sim et al., 2020). Although fatality rates of 0.1% are seen during surgical operations, they can be as high as 5% to 8% during elective vascular surgery and as high as 20% when there is significant bleeding (Marietta, M. et al., 2006). According to the American College of Surgeons Trauma Quality Improvement Program (ACS TQIP), performance quality indicators for the process of massive blood transfusion protocol should include 1) Time from calling MTP to infusion of first unit RBC, 2) Time from calling MTP to infusion of first unit plasma, 3) Wastage rates for blood products and 4) Patient survival rate. Liquid plasma (LQP) is never frozen and is generally stored for 26 days (Meledeo et al., 2021a). Liquid plasma is immediately available for massive and emergency transfusion as it is already in the liquid state and will not require the thawing time as the thawed FFP.

Using liquid plasma during a massive transfusion may decrease blood product waste, improve the blood product delivery time, and decrease mortality by achieving a balanced resuscitation (Meyer, M. J. et al., 2018). Massive blood transfusion outcome measures include patient mortality and morbidity, blood product delivery time, and waste (Camazine et al., 2015).

The result will impact the field of transfusion medicine because the findings could potentially be used as an effective plasma transfusion strategy in massive and emergency transfusions for trauma patients. After all, it achieves an early and high FFP: RBC resuscitation transfusion ratio to improve patients' clinical outcomes. Healthcare organizations and blood centers can also maintain financial stability by reducing plasma waste and healthcare costs. There is a plasma donation shortage following the onset of the COVID-19 pandemic (Shokouhifar & Ranjbarimesan, 2022). A study by (Veseli et al., 2022) revealed that during the COVID-19 pandemic, there was a notable decrease in short-term and long-term intentions for blood donation. Active donors initially felt more aware of their ability and eligibility to donate when the pandemic began compared to before it, but as the pandemic progressed, their confidence in their ability to donate decreased significantly.

Similarly, inactive donors' perceived ability to donate decreased during the pandemic phase compared to the pre-pandemic phase. Importantly, both active and inactive donors felt less responsibility and moral obligation to donate during the pandemic, resulting in an overall negative impact on blood donation intentions. These findings are concerning as they indicate that the pandemic had a detrimental effect on blood donations, putting the critical blood supply at risk. Blood product donations decreased due to social restrictions and health concerns (Li Covington et al., 2022).

According to the American Association of Blood Banks (AABB), all plasma-containing components and whole blood for transfusion must be collected from men, women who have not been pregnant, or women who have tested negative for human leucocyte antigen antibodies (HLA). Transfusion-related acute lung injury (TRALI) is still the leading cause of transfusion-related death in the United States (Otrock et al., 2017). Most reported TRALI cases were caused by plasma components from female donors (Eder et al., 2010). Accepting plasma donations from males and females who have been tested since their most recent pregnancy and results interpreted as negative for HLA antibodies makes plasma a rare and life-saving blood product.

The findings help alleviate the severe plasma shortage in the United States by lowering the plasma waste that can be used for other patients. The findings of this study inform policy and practice related to trauma patients who require massive or emergency transfusions to optimize early plasma administration and improve adherence to transfusion ratio guidelines, thereby improving clinical outcomes (Beattie et al., 2020).

Study Assumptions

In analyzing secondary data, the researcher made the following assumptions: 1) All patients' electronic medical records were accurately documented for each outcome variable in the study, 2) All electronic medical records represented actual patients. The accuracy of documented data in the patient's medical records had to be assumed to be correct and accurate. The study assumptions were validated and verified, and the electronic medical records were found to be accurate and represent actual patients. A group of clinical and medical experts confirmed the collected data's appearance validity.

Research Questions

The research question posed for this study was: For patients who require emergency and massive transfusion, what is the impact of using liquid plasma compared to fresh frozen plasma on the blood product wastage and cost, one year before and after using liquid plasma? The null hypothesis for this research stated that liquid plasma during massive transfusion protocols and emergency transfusions does not decrease blood product waste and cost. The alternate hypothesis stated that liquid plasma during massive emergency transfusions reduces blood product waste and increases plasma-saving costs.

Limitations and Delimitations of the Study

The research results cannot be generalized due to using a single site. The findings could provide insight for other organizations as they review their practices and protocols to reduce blood product waste and improve delivery time. Upgrading the hospital information system from the hospital information system HIS (Sunquest) to another HIS (epic) might challenge collecting all data after merging into the new HIS. The data format can be different when collected from two different HIS; thus, it may require reformatting some of the collected data.

Definition of Terms

Blood transfusion

The choice to transfuse should consider the clinical symptoms, rate and amount of continuous blood loss, cardiac function, and the requirement for surgical intervention in addition to transfusion triggers. Transfusions are ultimately intended to increase volume and oxygen-carrying capacity. The type of component to be transfused relies on evaluating the patient's clinical condition (Nunez et al., 2011).

Whole blood

Whole blood has ceased to be used as a resuscitation fluid due to the development of blood component treatment. In addition to high concentrations of potassium, ammonia, and hydrogen ions, whole blood lacks clotting components. There could be volume overload before the necessary components are restored, even though it promotes volume expansion and enhances oxygen-carrying capacity (Sohn et al., 2013).

Packed red blood cells

The prompt introduction of red blood cells is the most crucial part of resuscitation since hemorrhagic shock's primary pathophysiology is a failure of oxygen supply. Crystalloids and packed red blood cells must typically be transfused when there has been a blood loss of more than 25% to 30%. When a patient is quickly exsanguinating, having a ready supply of type "O" blood on hand that can be delivered right to the bedside can save their life (Dehnavieh et al., 2015).

Fresh frozen plasma

Fresh frozen plasma (FFP) is used in trauma resuscitation for its clotting factor content. When severe bleeding or coagulopathy is present, one unit of FFP is supplied for every four or five units of red cells. Serial measurements of clotting times, fibrinogen levels, prothrombin time (PT), and activated partial thromboplastin time should be used to guide the administration of FFP (APTT). FFP is recommended in trauma patients for purposes other than volume expansion (Sehdev et al., 2022). Rapid bleeding, however, benefits from a more aggressive strategy to stop the onset of coagulopathy. Decisions about hemotherapy should minimize a problem's severity before it deteriorates beyond the point of no return (Roquet et al., 2023). Following predetermined platelet or plasma transfusion guidelines could worsen the patient's bleeding (Beyer et al., 2017).

Other techniques, such as the use of thromboelastography analysis of the blood's ability to clot, can help identify a problem. These methods include assessing patient factors such as reduced body temperature and the presence of acidosis, both of which decrease the in vivo activity of the coagulation system (Dirkmann et al., 2008). Another challenging task is accurately predicting the dosage of plasma required to treat coagulopathy (Hunt et al., 2015). The prothrombin time changes exponentially with factor activity and changes more quickly when the patient's procoagulant activity deviates significantly from normal. Another crucial factor in plasma transfusion is time. The correction should be administered right before any hemostatic challenges, including major surgery, for the best results (Salomon et al., 2008).

Platelets

The requirement for surgical intervention, the cause of thrombocytopenia, the presence or absence of active bleeding, and the decision to transfuse platelets should all be considered. Also undetermined is the point at which platelet transfusion will begin. Platelets are typically transfused prophylactically to prevent spontaneous bleeding when the platelet count is below 10,000/l. When the count is between 10,000 and 50,000/l and the patient is bleeding, or an invasive procedure is planned, platelet transfusion should be administered (Estcourt et al., 2017). The count of these patients needs to be kept above 50 000/l. The post-transfusion platelet count should be monitored to guide platelet therapy. Patients with splenomegaly, disseminated intravascular coagulation, heavy bleeding, fever, infections, or any of these conditions may not see the anticipated increase in platelet count after transfusion (Shari et al., 2017).

Transfusion-related acute lung injury (TRALI)

Transfusion-related acute lung injury (TRALI) is a life-threatening syndrome that occurs within six hours of a blood transfusion. TRALI is widely regarded as the leading cause of transfusion-related diseases and death. Many TRALI cases are most likely the result of antibodies to leukocyte antigens (HLA or HNA) in blood components. These antibodies are present in 10% to 20% of female blood donors with a history of pregnancy and 1% to 5% of male blood donors (Chen et al., 2023).

Hemoglobin-based oxygen carriers

An attempt to develop a resuscitative fluid with the ability to carry oxygen like red blood cells without the requirement for cross-matching or the risk of virus transmission is represented by hemoglobin-based oxygen carriers (HBOCs). These solutions, which contain hemoglobin dimers or tetramers, can be either human or bovine in origin. Compared to red blood cells, they have shorter half-lives (hours to days). Studies have produced encouraging findings, suggesting that HBOCs can entirely or partially replace the need for transfusions in surgery. Vasoconstriction-induced systolic blood pressure increase is one possible drawback. Ongoing research into using HBOCs instead of blood transfusion in trauma patients may demonstrate their efficacy (Cavallieri et al., 1994).

Recombinant erythropoietin

Erythrocyte synthesis is suppressed in hemorrhagic shock as a result of cytokines generated as a result of the systemic inflammatory response. Recombinant erythropoietin delivery resulted in high erythropoietin levels, which established a strong erythrocyte response in the badly damaged patient (Holst et al., 2014). Early administration of recombinant erythropoietin to trauma victims may dramatically reduce the need for transfusions. A prospective randomized, double-blind, placebo-controlled multicenter experiment discovered that giving recombinant human erythropoietin to critically ill patients once a week lowers the need for allogeneic red cell transfusions (Yuan et al., 2022). The trial group comprised medical and surgical patients and saw increased hemoglobin and hematocrit readings. Recombinant erythropoietin-related observations were comparable to those reported by other publications. According to the EPO Critical Care Trials Group, erythropoietin-alfa therapy for trauma patients resulted in lower mortality. However, the course of treatment is linked to a marked rise in thrombotic events. Recombinant human erythropoietin can be used in conjunction with other blood conservation strategies to overcome the problem of the trauma surgeon faced with life-threatening blood loss in a Jehovah's Witness who refuses blood transfusions owing to religious prohibitions. (Alimohammadi et al., 2017).

Cryoprecipitate

You can make cryoprecipitate by gradually defrosting FFP. Factor VIII, von Willebrand factor, and fibrinogen are all abundant. Cryoprecipitate might not be necessary if FFP is added to a large transfusion unless the fibrinogen level drops below 100 mg/dl. The benefits of cryoprecipitate in high concentration in the catastrophically bleeding trauma patient have not been established, even though it can quickly enhance the concentration of fibrinogen and von Willebrand factor (Watanabe et al., 2021).

Factor VII

Factor VII is a serine protease initiating the coagulation cascade, specifically the extrinsic pathway (Hoffman & Monroe, 2001). In the context of massive bleeding, FVII is critical for the rapid formation of the initial clot. Tissue factor (TF) is exposed upon vascular injury, triggering the extrinsic pathway. FVII binds to TF, forming the TF-FVIIa complex, which activates Factor X (FX) to its active form, FXa. This initiation step is essential in initiating the coagulation process and controlling massive bleeding (Hoffman & Monroe, 2001).

Factor X

Factor X is a pivotal component in the coagulation cascade, serving as a convergence point for both the extrinsic and intrinsic pathways. In massive bleeding, FX plays a central role in converting prothrombin into thrombin, which further catalyzes the conversion of soluble fibrinogen into insoluble fibrin, ultimately forming the blood (Hoffman & Monroe, 2001).

Factor IX

Factor IX, part of the intrinsic pathway, contributes to the amplification of the coagulation cascade. In cases of massive bleeding, FIX is instrumental in forming the tenase complex, which activates FX into FXa. FIX deficiency can lead to hemophilia B, increasing the risk of uncontrolled bleeding during traumatic events (Hoffman & Monroe, 2001).

Factor VIII

Factor VIII acts as a cofactor for Factor IX in the intrinsic pathway, significantly enhancing its activation. In the context of massive bleeding, FVIII plays a vital role in promoting the formation of FXa from FIXa, contributing to efficient blood clot formation(AlGahtani et al., 2010). FVIII deficiency results in hemophilia A, characterized by an increased susceptibility to bleeding(Hoffman & Monroe, 2001).

Factor VIIa

When all other options have failed, recombinant factor VIIa treats bleeding in both trauma and non-trauma patients. It can halt blood loss, lessen the need for blood, and enhance clotting characteristics. Recombinant factor VIIa has recently been shown to control bleeding in adjunctive therapy for trauma patients, significantly reducing the need for red blood cell transfusions (Hoffman & Monroe, 2001). The authors further assessed the pharmacokinetic characteristics of the factor in trauma patients. They recommended that the dosage be changed in accordance with the amount of bleeding and the clinically determined blood loss. More research must be done before recombinant factor VIIa is suggested for trauma patients (AlGahtani et al., 2010)

Emergency transfusion

The performance of customary testing procedures may be hindered by the urgent need for transfusion in a patient who needs prompt surgical intervention. Before administering any donor blood, adequate pretransfusion samples should be obtained so that later compatibility testing, antibody screening, and, if necessary, identification tests can be carried out as recommended by the AABB. Group-specific blood can be given out in an emergency if cross-matching cannot be done in time. Group "O" Rh-negative packed red cells may be given out in the case of a significant emergency when there is not enough time to collect and test a sample. In this case, the clinician must sign a release allowing and admitting liability for using untested products to save lives (Goodell et al., 2010).

Massive transfusion

Massive transfusion is defined as the transfusion of more than ten units of blood in 24 hours or a transfusion that approaches or exceeds the patient's blood volume (Pham & Shaz, 2013). Massive transfusions also replace more than 50% of the blood in circulation in less than three hours or occur at a rate of more than 150 ml/min (Kogutt & Vaught, 2019). In surgical and trauma patients, the requirement for enormous (or significant volume) transfusions typically results from severe bleeding. Less than 20% of the total blood volume generally is adequately tolerated. In comparison, 20% to 40% of the total blood volume lost will affect the vital signs and show indicators of decreased tissue perfusion (Pham & Shaz, 2013). More than 40% of blood volume loss could result in severe anemia. (Butler et al., 2011).

The quantity and type of fluids utilized during the initial resuscitation significantly impacted the results. Maintenance of intravascular volume and appropriate oxygen-carrying capacity should come first (Spahn et al., 2019). Monitoring should also be done for additional variables such as serum electrolyte levels and coagulation factors. The mainstay of the treatment plan for individuals with hemorrhagic shock is administering blood and blood products. While all blood transfusions include a risk of side effects, the massive transfusion of banked blood has outcomes such as a shift to the left in the oxygen dissociation curve, an acid-base imbalance, hypothermia, hypocalcemia, dilutional coagulopathy, respiratory distress (Strandenes et al., 2014).

The American College of Surgeons and the American Association of Blood Banks advise that laboratory tests like PT, PTT, platelet count, and fibrinogen levels be used to guide the transfusion of blood and blood components. Proper plasma can contain excess coagulation factors because only a minimal amount is needed for normal fibrin and hemostasis development. Patients can typically tolerate replacing one or more blood volumes with red cells and crystalloids without requiring FFP. According to guidelines, a PT 1.5 times the upper limit of normal or the midpoint of the normal range and a PTT 1.5 times the upper limit of normal are the requirements for therapeutic or preventative FFP. (Goodell et al., 2010).

A platelet count of less than 50 000/l and a fibrinogen level of less than 100 mg/dl are more robust indicators of bleeding in consumptive coagulopathy than PT and aPPT. After one volume is lost, FFP supplementation should be considered and begin as soon as blood loss reaches 15% of the entire volume. 4-5 units of FFP should be injected at this point, with four units of FFP added for every six units of red blood cells (Gregory et al., 2015). Effective transfusion regimens should use a 1:1 ratio of plasma to red blood cells for all hypo-coagulable patients after severe injuries. The authors found that early delivery of high ratios of FFP and platelets increases survival and reduces the overall need for red blood cells in massively transfused patients. (Chhibber et al., 2014).

Early and vigorous transfusion intervention and resuscitation with blood components is the innovative treatment for significant trauma that tackles the fatal triad of acidosis, coagulopathy, and hypothermia (Holcomb et al., 2015). These are crucial components of damage control. Current studies support a target ratio of plasma: red blood cell: platelet transfusions of 1:1:1, even though the optimal amounts of plasma, platelet, cryoprecipitate, and other coagulation components in relation to the red blood cell transfusion volume are not yet established (Butler et al., 2011; (Ball et al., 2013; Miller, 2013).

Conclusion

Fluid delivery to arrest the pathophysiology of shock and identify and address the source of bleeding should be the foundation of initial resuscitation for a patient with hemorrhagic shock. Reusability fluids should be administered at a pace that supports tissue perfusion. Early blood component therapy can support maintaining coagulation and oxygen delivery characteristics (Crombie et al., 2022). Extensive blood transfusions increase the risk of transfusion responses, infections, and metabolic issues. Consequently, the widespread or preventative use of blood products is unjustified (Strandenes et al., 2014).

Chapter 2. Literature Review

Thematic Review of Literature

Smith et al. (2020) identified three themes about the benefits of using liquid plasma in massive blood transfusions for patients and clinicians: (a) decreasing blood product waste, (b) improving the patient's survival rate by controlling hemostatic resuscitation balance, and (c) decreasing blood product delivery time:

The first theme is reducing blood product waste as liquid plasma (LQP) is another alternative to traditional plasma, which is in a frozen state and requires time to thaw. The shelf life is limited (five days after thawing), resulting in wasting plasma. Liquid plasma is in a liquid state and has never been frozen (Al Khan et al., 2019). LQP is available immediately to transfuse in case of an emergency and has a shelf life of 26 days. Liquid plasma provides rapid availability in massive bleeding situations and decreases plasma waste if not used. Chehab et al. (2021) performed a retrospective study in a level 1 trauma center and collected the wastage data before and after implementing the liquid plasma usage. The conventional plasma is in a frozen condition and gets thawed before it is transfused to the patient, which can take up to 30 minutes to be thawed, and it expires after five days. Chehab et al. (2021) reviewed two years of plasma use before and after introducing liquid plasma. The author found improved patient outcomes with the use of liquid plasma compared to fresh frozen plasma due to the rapid availability of the liquid plasma to correct the coagulopathy. The plasma wastage dropped from 176 units annually to 60 units after using liquid plasma in massive bleeding, which affects the cost of healthcare services (Beattie et al., 2020). The enactment of a major hemorrhage protocol was associated with a decrease in platelet waste from 14% pre-protocol to 2% post-protocol (McDaniel et al., 2014).

The second theme is optimizing early and balanced plasma resuscitation in a massive transfusion that increases the patient's survival rate. (Beattie et al., 2020) conducted a study on the impact of liquid plasma on plasma resuscitation in massive transfusing. The study showed that liquid optimized early plasma administration and improved devotion to transfusion ratio guidelines, leading to improved clinical outcomes. The liquid plasma showed significant improvement in maintaining the transfusion ratios for patients requiring massive transfusion. A recent four-year analysis of the TQIP database by Nederpelt et al. (2020) revealed that patients who achieved a 1:1 FFF: PRBC ratio had the lowest mortality rate, which can be achieved using liquid plasma during a massive and emergency transfusion. The study included 95 patients, with 39 patients receiving traditional thawed plasma (pre-LQP) and 56 patients receiving liquid plasma (post-LQP). The study found that post-LQP implementation was associated with a shorter time to initial plasma transfusion and improved plasma/red blood cell (RBC) ratios at four and twenty-four hours. Additionally, there was a reduction in RBC units transfused. These findings suggest that using liquid plasma in massive transfusion protocols can lead to more efficient, effective, and timely resuscitation of critically ill patients. The effect of FFP vs. fibrinogen concentrate in severe postpartum hemorrhage was assessed by Jarraya et al. (2022), which showed a 2: 1 FFP: PRBC ratio was associated with reduced Intensive Care Unit (ICU) stay and the need for platelet transfusion. Furthermore, LQP can be implemented for prehospital MTP, as shown by Botteri et al. (2022), to increase the number of patients transfused within one hour of admission to the Emergency Department.

The third theme identified in the literature is decreasing blood product delivery time. Massive bleeding causes more than 47% of preventable deaths in the United States (Danaei et al., 2009). The need for an improved, standardized, and harmonized massive transfusion protocol is crucial and significantly improved patient outcomes (Abdelmonem., et al., 2022). Aside from using liquid plasma for massive transfusion protocol, (Hu et al., 2021) highlighted the use of whole blood to control massive bleeding to increase the patient's survival rate and decrease mortality. The use of whole blood for trauma patients has significantly reduced mortality compared to using other blood components separately (Yazer & Spinella, 2019). American College of Surgeons Trauma Quality Improvement Best Practices (ACS-TQIP) recommended initial massive transfusion (MTP) cooler delivery within 15 minutes of protocol activation, with a goal of 10 minutes(Meyer, D. E. et al., 2017).

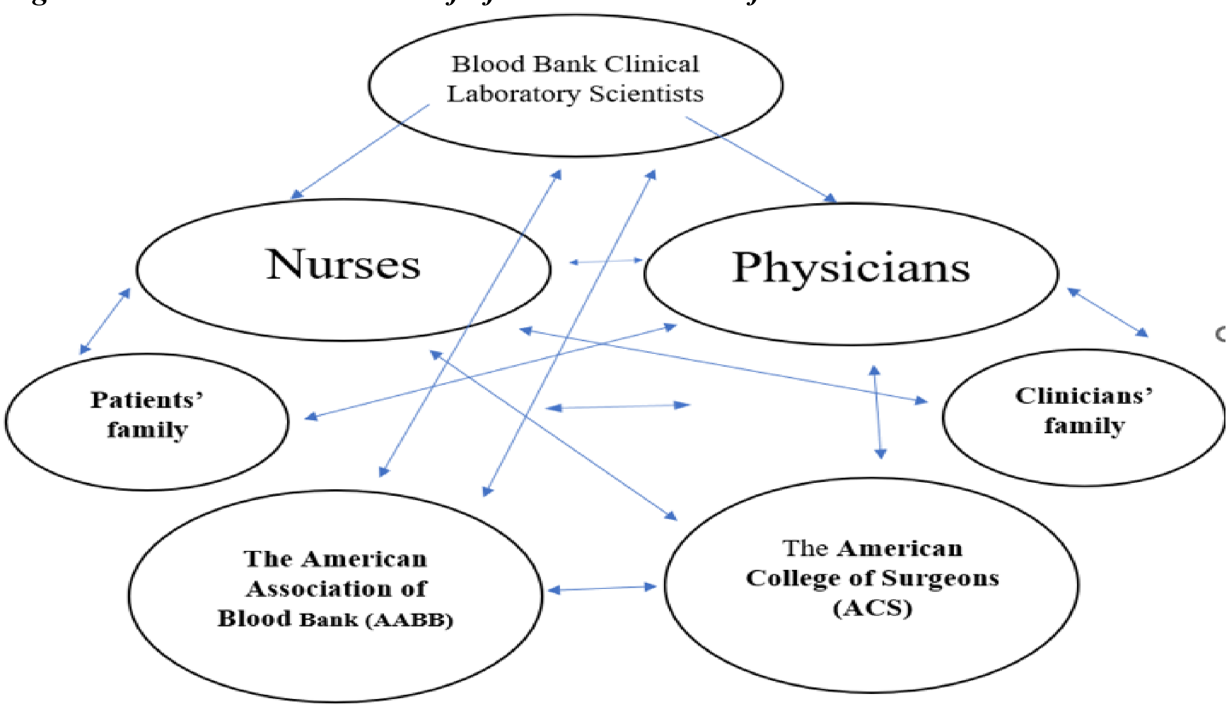
Stakeholders and Audiences

Massive blood transfusion is revealed in many cases, such as massive bleeding after surgeries, trauma settings (level 1, 2, and 3 trauma centers), and labor and delivery. Patients who require a blood transfusion of >10 units of packed red blood cells in 24 hours or a transfusion of ≥4 units of packed red blood cells (PRBCs) in one hour are the massive blood transfusion protocol candidates (Chang & Holcomb, 2017). The stakeholders who may benefit from answering these research findings are trauma patients, physicians, nurses, vendors, insurance agents, government, patients, patient's families, clinician's family members, clinical laboratory scientists in the blood bank, as well as transfusion medicine regulatory agencies such as the American College of Surgeons (ACS) and the American Association of Blood Bank (AABB).

The Practice of Plasma Transfusion

Plasma is an essential component of the human blood as it contains proteins and other crucial substances that are important for people's health. Plasma transfusions can either be used in bleeding or non-bleeding patients, depending on the severity of their condition. Adam and Fischer (2020) argued that this type of transfusion is often used prophylactically in non-bleeding patients before surgeries and therapeutically in bleeding patients. Even though plasma transfusion has proved to be an effective intervention in some clinical situations, it is also associated with various adverse outcomes (Goel et al., 2019). Therefore, clinicians must weigh the expected benefits of plasma transfusion against its related risks before embarking on this critical procedure. Plasma transfusion is given to patients suffering from trauma, shock, burns, clotting deficiencies, and even severe liver disease to help boost their blood volume and improve their blood clotting ability (American Red Cross, 2021).

Figure 1. Stakeholders Who Benefit from Massive Transfusion Protocol



There are various methods of collecting and storing blood plasma where they are aligned with preventing plasma wastage (Cannon et al., 2017). Each of the developed methods of collection and storage affects the plasma proteins differently. Plasma can be stored in its frozen form, liquid, or frozen, then thawed form while awaiting transfusion. According to Ryan and John (2015), there are four main types of plasma. They include freshly frozen plasma (FFP), plasma is frozen within 24 hours, thawed plasma, and liquid plasma. Freshly frozen is often prepared by separating platelets and red blood cells from the whole blood through apheresis or a process called centrifugation. The obtained plasma is then frozen and stored until it is needed for transfusion. Fresh frozen plasma is frozen within eight hours after the blood has been extracted from the donor.

Freshly frozen plasma contains high levels of coagulation factors like labile VIII and V factors. Before transfusion, this type of plasma is thawed in water at a temperature of about 30-37 °C (Ryan & John, 2015). Plasma is frozen within 24 hours (FP24), obtained via apheresis or phlebotomy process, and frozen within 8 to 24 hours after the donor obtains blood. Hence, while aiming to prevent plasma wastage, this type of plasma also has high coagulation factors, protein C because of delayed freezing, and has diminished labile factors VIII and V. When thawed, FP24 must be transfused within 24 hours (Ryan & John, 2015). When FFP and FP24 are transformed into a liquid, they form thawed plasma.

The fourth type is liquid plasma (LQP). This type of plasma is never frozen. It is obtained from the donated blood within five days after the expiry period of 21 days. Liquid plasma is stored at temperatures of 1-6 °C and lasts up to 30 days. LQP effectively manages acute hemorrhaging patients who require a massive blood transfusion. This plasma has been proven more effective than thawed and FFP plasma. According to (Matijevic et al., 2013), LQP had a better capacity to form a clot and generate thrombin compared with TP. It has the highest level of coagulation factors and vitamin K factors II, X, IX, and VII (Ryan & John, 2015). However, this type of plasma storage has low levels of V and VIII labile factors. The high coagulation and vitamin K factors make this type of plasma effective for patients suffering from massive hemorrhages. In contrast, its low labile factors V and VIII make it unsuitable for patients with various deficiencies (Meledeo et al., 2021b).

The amount and component of blood transfused to a patient mainly depends on the condition and needs of the involved victim. According to the American Cancer Society (2017), blood transfusion is administered through tubing connected to either a needle or catheter in a vein. Therefore, before the transfusion process is conducted, the patient is tested for a complete blood count to determine the amount and type of blood component they need to be transfused.

Preparations for Blood Component Transfusion

Blood transfusion is a routine medical procedure that aims to deliver blood into a patient's body via a narrow tube conveniently connected to a vein in either their arm or hand (McDaniel et al., 2014). The process allows blood to flow from the veins to a bag through a rubber tube and into the patient's veins through the needle (Shander et al., 2020). There is a need for close monitoring of the patient's vital signs throughout the procedure (Gajic et al., 2007). Blood transfusions are considered to be potentially life-saving procedures where blood loss is replaced during surgery or after injury. A blood transfusion aims at treating patients with illnesses that have negated their ability to produce sufficient blood cells for their bodies naturally (Carson et al., 2016). Plasma transfusions aim to provide the patient with vital proteins and other substances that are crucial to their overall health. Plasma transfusions are mainly administered to patients with liver failure, severe burns, or serious infections (Adam & Fischer, 2020).

A blood transfusion may take one to four hours, depending on how much blood the patient requires at their bedside (Savage et al., 2013). The procedure starts when an intravenous line is placed into the patient's body. The process is performed by qualified health experts like Registered Nurses (RN) and Licensed Vocational Nurses (LVN) or Licensed Practical Nurses

(LQPN). However, there is a need to focus on plasma transfusion, which contains composites of blood clotting in this instance. Plasma sources and plasma processing have been developed to address and mitigate potential risks associated with transfusion hazards (Spinella et al., 2015). Some are single donor FFP against pooled plasma or quarantine FFP against pathogen-deactivated FFP. Some of them include FFP, frozen within eight hours, and FP24, frozen within 24 hours, which will enable the removal of high-risk transfusion infections (Cardigan & Green, 2015).

While researching the variability of clotting factors and natural decoagulant levels in different plasma preparations, factor V and factor VIII display a diverse decrease during storage with the condition of the formulas (Pusateri et al., 2020). The processing conditions affect the coagulation factor levels, microparticle particulars, clot generation bulk and protein components in blood plasma, and coagulation factor constancy after defrosting (Cao, et al., 2014). The American College of Surgeons (ACS) requires massive transfusion protocols (MTP) to observe the time between shock and blood transfusion, moving the hemoglobin from the blood bank to the medical unit, identifying the plasma unit before transfusion, and providing the defrosted liquid plasma (Paganini et al., 2021). Hence, plasma supply is a logistic challenge for blood bankers since the demand for plasma transfusion is high due to its growing universal use in treating massive bleeding, but we have scarce AB plasma type. Consequently, some policies have been enacted to enable the procedures of plasma availability. For instance, the male policy is distributed to donate hemoglobin from male donors only (Murphy, et al., 2018).

Assessing the Efficacy and Safety of Liquid Plasma

The plasma transfer is extensively defined in different settings, from massive transfusion to Vitamin K Antagonist (VKA) reversal. Plasma is an effective hemostatic agent for patients with blood loss (von Heymann et al., 2023). However, compared to other alternatives in hemostatic therapies, no defined measurements and randomized controlled trials can assess the efficacy and safety of therapeutic plasma to act as a means of intervening in blood loss for patients compared to other alternatives, which are scarce (von Heymann et al., 2023).

Massive bleeding in the clinic occurs mainly due to different reasons. In clinical settings, hemorrhage is manifested through obstetrics, gastroenterology, shock, and operating theatres. Here, there is a need for massive transfusion, which is vital to save the lives of patients suffering from intensive acute loss of blood (Allen, et al., 2015). There have been ongoing criticisms and reviews concerning the plasma volumes that can be transfused and the ratio of red blood cells (RBC) to fresh frozen plasma (FFP) and to platelets (PLT) (Nederpelt et al., 2020). Particularly interested in handling trauma patients, an intensive therapy of coagulopathy is mainly aimed at improving the outcome (Cao, et al., 2014). Even though plasma transfusion has been consistently associated with massive bleeding, there have been no visible benefits for trauma patients who experienced intensive transfusion with FFPs (Pusateri et al., 2020). Studies depict the same results in outcome when comparing the patients who had a 1:1 RBC: FFP ratio to those who did obtain any FFP (Holcomb, et al., 2015). According to Holcomb, et al. (2020), they found no significant differences in mortality at 24 or 30 days. However, more patients from the 1:1:1 group were discovered to achieve hemostasis, and the few who experienced death were victims of exsanguination by 24 hours.

Another study by McQuilten, et al. (2018) revealed the effect of dose, timing, and ratio to RBCs during therapy with blood components for patients suffering severe bleeding in a setting that requires a massive transfusion. Through his meta-analysis, McQuilten, et al. (2018) could not identify any variations in the mortality and morbidity at the ratio of transfusion of 1:1:1

(FFP:PLT: RBC) compared to a ratio of transfusion of 1:1:2 (FFP:PLT: RBC). McQuilten, et al. (2018) were supported by da Luz, et al. (2019), who demonstrated that higher fixed ratios of FFP and PLT to RBC are associated with a higher transfusion of FFP and PLT, lacking demonstration of clinical benefit when the standard care of ratio 1:1:2 is used. The limited evidence for RCTs of ratio 1:1:1 versus ratio 1:1:2 demonstrated that this type of standard care for adult patients with intensive blood loss could not be recommended for use (Abdelmonem, Mohamed, 2018). Even though a high FFP: RBC ratio or early coagulopathy therapy benefits the survival rate of patients, its efficacy is still questionable compared to the available research.

Role of Liquid Plasma

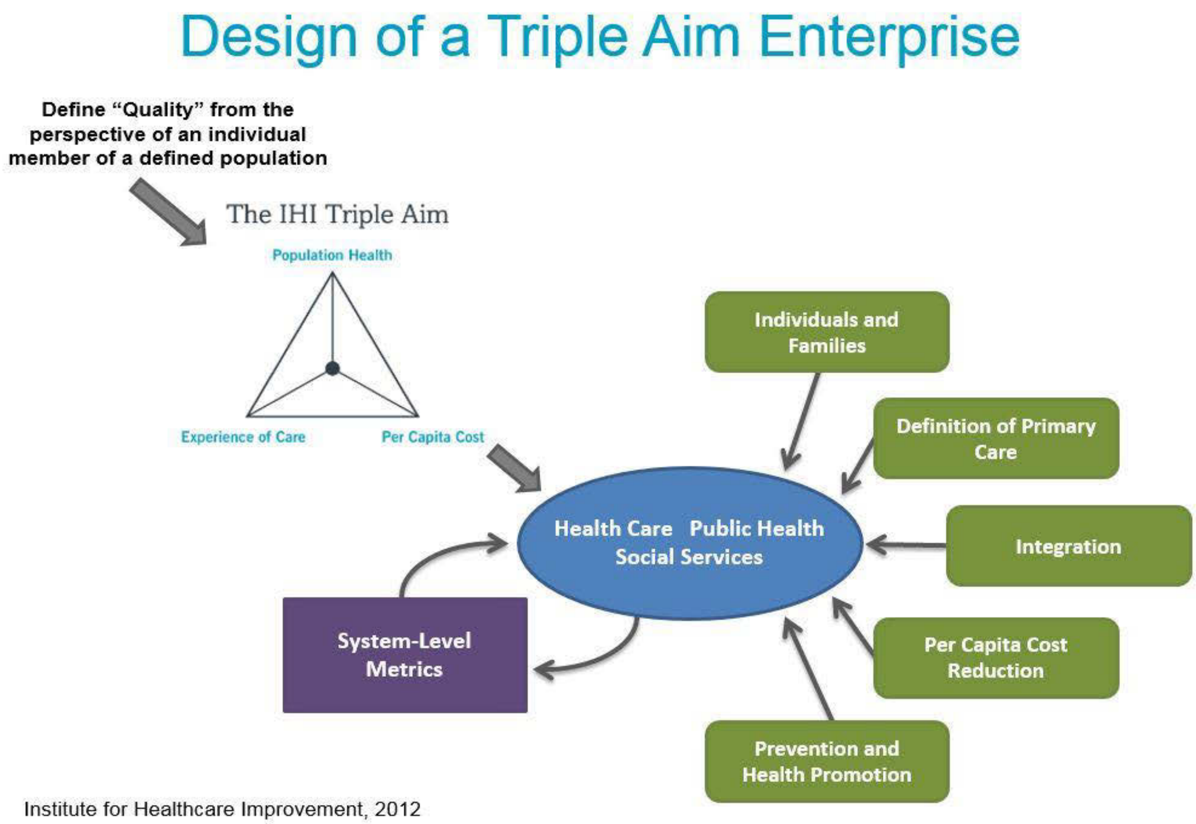
Liquid plasma is currently used in incidences of traumatic blood loss, whereas its role is visible in hospitals, medical centers, and health care systems to enable patient survival. The use of liquid plasma is advantageous in practice due to its rapid accessibility and durable shelf-life, making it a unique option for MTPs (Beiriger et al., 2023). They have also been adopted to include Red Blood Cell (RBC) units in the transport coolers used in the emergency response team(Chehab et al., 2021). Thus, liquid plasma can be applied in a prehospital setting, like a site of injury to blood delivery time to the patient's bedside (Rieske, et al., 2020).

Plasma contains nutrients, water, salt, and enzymes to save lives. Its components include antibodies, coagulant factors, and proteins used in treating trauma victims and applied in other medical emergencies (Machin & Ragni, 2020). The plasma components also treat rare chronic conditions, including hemophilia and autoimmune disorders. People diagnosed with these illnesses can expand their life duration and become productive due to these treatments. Plasma is considered the 'gift of life' due to its aspects to facilitate the survival of patients (D'Hondt et al., 2017).

Conceptual Framework

Healthcare and medical waste are one of the major problems in healthcare as it contributes to the increase in healthcare costs (Hughes & Meadows, 2020). According to Berwick et al. (2008), improving the US healthcare system necessitates simultaneously pursuing three goals: improving care experience, improving population health, and lowering per capita healthcare costs (Triple Aim Theory). The Triple Aim Theory was developed by the Institute of Healthcare Improvement (IHI) in 2007; it focuses on three dimensions: better care for individuals, better health for populations, and reduced per capita cost of healthcare. The study is aligned with three pillars of the Triple Aim Theory, which is the theoretical framework for this action research. The Triple Aim Theory was instrumental in pointing out the need to reduce healthcare costs while improving the quality of patient care, according to (Reppeto et al., 2021), who looked at psychological screening measures, healthcare use, and hospital costs to determine how the behavioral health consultants affected patient costs overall and population health. The findings showed that patient charges had changed: visits to the emergency department had decreased by 8%, and psychological distress had increased significantly (Reppeto et al., 2021). As the American College of Surgeons outlines, using liquid plasma in massive and emergency transfusions may decrease plasma waste while improving patient clinical outcomes by reducing blood product delivery time, achieving early resuscitation, and accomplishing a high FFP: RBC resuscitation transfusion ratio.

Figure 2. Design of a Triple Aim Enterprise



Source: Institute for Healthcare Improvement, 2012. Design of a Triple Aim Enterprise

A conceptual or theoretical framework aligns with the statement of the problems in most research as it categorizes research variables and explains relationships among them (McGaghie, et al., 2001). The independent variable in the study is using liquid plasma in massive blood transfusion emergency transfusion, while the dependent variables are blood product waste and plasma cost saving. Due to the more prolonged expiration of liquid plasma LQP., it may reduce plasma waste. (Beattie et al., 2020)

Conclusion

In conclusion, liquid plasma is used in massive blood transfusion because it has high coagulation and vitamin K content, which makes it the most effective type of plasma for patients suffering from massive bleeding. Furthermore, while focusing on reducing plasma waste, decreasing blood delivery time to the patient's bedside, and improving patient survival, its low levels of labile factors V and VIII make it unsuitable for patients with various deficiencies. There are different types of plasma. They include liquid plasma, freshly frozen plasma, plasma frozen within 24 hours, and thawed plasma. Each type of plasma has various components, thus suitable for patients in other conditions. Apart from these types of plasma, blood plasma can also be dried and used to develop plasma-derived medications that can be used to treat various deficiencies in the human body. While bleeding is the most common indicator that a patient needs a transfusion, other indications indicate that a transfusion is required. Symptomatic anemia, septic shock, cancer, acute coronary syndrome with ischemia, and sickle cells, among many others. Therefore, in non-bleeding situations, freshly frozen plasma, frozen within 24 hours, and thawed plasma can be used during transfusion. However, liquid plasma is effective in bleeding patients because it has high vitamin K levels, facilitating blood clotting.

Chapter 3. Methodology

Description of Research Design

The study used a quantitative retrospective comparative design study analyzing secondary data from medical records of a level 1 trauma center in the Southwest United States. A comparative study evaluates, contrasts, and assesses two or more subjects or ideas, showing how two subjects are similar or different (Bukhari, 2011). Data on liquid plasma usage in massive and emergency blood transfusion outcomes were collected from the hospital medical records for pre-and-post-liquid plasma usage implementation. The study investigated the impact of the independent variable (liquid plasma usage in massive transfusion protocol) on the dependent variables (blood product wastage and cost).

Research Design

The chosen research methodology for this study was a quantitative retrospective comparative design, which evaluated the relationship strength between the independent and dependent variables and facilitated the generalization of study results (Creswell & Creswell, 2017). The comparative study explored the impact of using liquid plasma in massive and emergency transfusions of trauma patients on plasma waste and plasma cost savings before and after liquid plasma implementation. Using secondary data from medical records obtained from a level one trauma center in the Southwest United States provided a robust foundation for analyzing the research questions.

The research presented here collected data using structured procedures and instruments. According to (Queirós et al., 2017), the quantitative methodology enabled the collection of data in a systematic fashion as well as the statistical analysis of those data through the use of software such as SAS, SPSS, and R. A quantitative methodology was utilized in this study because it focused on the collection, analysis, and interpretation of numerical and statistical data to respond to the research questions and hypotheses. According to Creswell and Creswell (2017) and Wilson (2019), quantitative research collects numerical data, objectively measures data, and examines and quantifies mathematical relationships and variables. According to Bloomfield and Fisher (2019), the quantitative study was necessary for collecting quantifiable data regarding the study variables to draw inferences about the research population.

This research design was appropriate for several reasons. The quantitative approach enabled the collection of numerical data, making it suitable for systematically analyzing variables related to plasma waste and cost-saving. By utilizing a retrospective design, the study leveraged existing data, allowing for a comprehensive assessment of outcomes before and after the implementation of liquid plasma in the massive blood transfusion protocol. This retrospective analysis helped establish a temporal relationship between the intervention (use of liquid plasma) and the outcomes of interest, improving the study's internal validity.

The comparative design enabled the examination of differences between two or more groups (i.e., before and after the implementation of liquid plasma). This allowed the researchers to identify potential changes and trends associated with using liquid plasma in emergency transfusions and its impact on blood product waste and plasma cost-saving. The design also offered a control group (i.e., pre-implementation data) against which the post-implementation data can be compared, providing insights into the effectiveness of the intervention.

The focus on various variables, including the primary independent variable of using liquid plasma during massive blood transfusions in emergencies and the two dependent variables of blood product waste and plasma cost-saving, ensured a comprehensive assessment of the implications of adopting liquid plasma. By analyzing these variables separately, the study aimed to understand the benefits of using liquid plasma compared to conventional methods.

The study's investigation of the impact of liquid plasma on reducing wastage and overall healthcare costs is crucial in providing evidence-based insights for healthcare decision-makers and policymakers (Huyler & McGill, 2019). This research design allowed for generating meaningful data that can inform transfusion practices and contribute to the cost-effectiveness of healthcare services.

In conclusion, the quantitative retrospective comparative research design was well-suited for this study. It provided the means to assess the relationship between the independent and dependent variables, explored the impact of using liquid plasma, and evaluated the effectiveness of this intervention in reducing plasma waste and cost-saving. The utilization of secondary data from medical records and the focus on relevant variables contributed to the study's robustness and the potential generalizability of its findings to similar trauma centers and emergency transfusion settings.

Variables

The primary independent variable is using liquid plasma during massive blood transfusions in emergencies. The study considered two dependent variables: blood product waste and plasma cost saving. These variables play significant roles in determining the impact and cost-effectiveness of employing liquid plasma in emergency transfusions. By analyzing these variables separately, the study aimed to understand the potential benefits of adopting liquid plasma compared to conventional methods. Moreover, it assessed the implications of using liquid plasma in terms of reducing wastage and overall healthcare costs.

Research Hypothesis

The null hypothesis (H0) proposed that utilizing liquid plasma during massive transfusion protocols and emergency transfusions does not decrease blood product waste and does not increase cost savings. According to this hypothesis, using liquid plasma would not significantly impact the management of blood products and would not offer any distinct advantages over conventional methods in terms of waste reduction or cost-effectiveness.

The alternate hypothesis (H1) postulates that incorporating liquid plasma during massive and emergency transfusions reduces blood product waste and increases cost savings in plasma management. This hypothesis suggests that liquid plasma's properties, such as longer shelf life and improved reusability, contribute to a more efficient blood product utilization process, ultimately reducing wastage and associated costs.

Through rigorous data analysis and statistical testing, the researcher tested the hypothesis to determine the effectiveness of liquid plasma in optimizing blood management during critical transfusion scenarios. By scrutinizing the outcomes, the researcher gained valuable insights into the potential benefits of adopting liquid plasma and its implications for healthcare institutions' transfusion practices.

Description of Research Participants and Population of Interest

The population of interest consisted of all trauma patients treated at a level one trauma center located in the Southwest United States. This specific medical center was chosen due to its significance as a high-volume trauma care facility, which enabled a substantial representation of trauma cases for analysis. The research participants were selected from this population based on specific inclusion criteria, focusing on trauma patients who experienced massive bleeding or emergency blood transfusion and necessitated plasma transfusion one year before and one year after liquid plasma implementation. All the participants' data were deidentified and were assigned unique identifiers to ensure confidentiality.

The data for this study was obtained from the medical records of the identified trauma patients. These records served as a valuable and comprehensive source of information, containing crucial details about patient demographics, medical history, transfusion practices, and relevant clinical outcomes. By leveraging this data, the study investigated the impact of using liquid plasma during massive and emergency transfusions or emergency blood transfusion on two key variables: blood product waste and plasma cost-saving.

The target population for this research included trauma patients who underwent MTP or emergency blood transfusion during two specific time frames: one year before the implementation of liquid plasma in the massive blood transfusion protocol or emergency blood transfusion and one year after its implementation. By examining data from both periods, the study effectively evaluated any changes or improvements brought about by the introduction of liquid plasma. This longitudinal approach allowed for a robust analysis of the impact of this intervention on blood product utilization and cost-effectiveness.

Focusing on trauma patients with massive bleeding, the study addressed a critical aspect of transfusion practices in emergency scenarios. Trauma-induced hemorrhage often necessitates large quantities of blood products, making efficient management of these resources crucial for patient outcomes and healthcare costs. Using liquid plasma presents a potential solution to optimize blood product usage, minimize wastage, and enhance cost-effectiveness in massive transfusion protocols.

In summary, this study's research participants consisted of trauma patients at a level one trauma center, while the data was drawn from their medical records. The primary focus was on trauma patients who underwent MTP or emergency blood transfusion, specifically those who received liquid plasma during massive and emergency transfusions. The research aimed to explore how this intervention impacts blood product waste and plasma cost-saving, contributing to the body of knowledge on efficient transfusion practices in emergency care settings.

Sample Size Determination

The sample for the study was the number of liquid and thawed plasma orders for trauma patients who received a massive transfusion protocol one year before and one year after the implementation of liquid plasma. The inclusion criteria for the study were any patient who received an emergency and massive blood transfusion and received a plasma transfusion. The sample size, which was one year before and one year after the implementation of liquid plasma 1077 plasma units .

Operationalization of Variables

The operationalization of the study variables refers to defining and measuring different variables in the study (Andrade, 2021). It is imperative to establish an operationalization definition of using liquid plasma in massive blood transfusion protocol (independent variable) and the dependent variables in this study (blood product waste, blood product cost). Massive transfusion protocols (MTP) allow for efficiently delivering large quantities of blood components to the rapidly exsanguinating patient (Malone, Debra L 2006). MTPs are required in complex medical scenarios, and the considerations for MTP activation are often constrained by limited time and information (Meyer, David E 2017). Blood products can be wasted for multiple reasons, such as improper blood product storage (improperly stored plasma was excluded from the waste). Plasma and red blood cells must be stored in the blood bank at 1-6 C (Hyatt et al., 2019a). Once the plasma and the red blood cells are distributed for transfusion, they must be maintained at 1-10 C if they are not transfused (Meledeo et al., 2021c). Another reason to waste the blood product is returning the blood product out of the temperature range to the blood bank. Another communal reason to waste the blood product is expiration, especially for the thawed plasma five days after being thawed from the frozen state. Heitmiller et al. (2010) discovered that 87% of RBC and plasma units that were wasted were either single units that were left outside of the blood bank for longer than 30 minutes (dispensed but not administered) or units packed in transport containers with temperature indicators attached to each unit.

The American College of Surgeons- Trauma Quality Improvement Process ACS-TQIP) best practices propose initial massive transfusion (MTP) cooler delivery within 15 minutes of protocol activation, with a goal of 10 minutes (Meyer, David E 2017). The plasma wastage was measured as the number of plasma units that get discarded due to expiration without being transfused.

Data Collection Instrument

The study analyzed secondary retrospective data collected from patients' medical records. Medical professional personnel record the data in the hospital information system as part of the patient's medical records. The data was then cleaned to remove the irrelevant data (patient’s blood type, plasma unit number, patient’s medical number), duplicate data, fix formatting errors, and checked for any missing data.

Each admission received a unique study number to protect patients' identity. Patient identifiers were kept in a dataset separately from the primary database. The data was entered into a secure electronic database during the review. The reviewer had a personal password for the electronic database. The web-based database complied with the safety and privacy requirements. Patients' names were not included in the database, and medical record identifiers were destroyed after the data collection and analysis. The identities of patients were not revealed in research reports. The records were never left unattended and were stored in a locked room during the data collection. The cleaned data were entered into statistical software for analysis. The data were collected from medical records to measure the massive blood transfusion of the two dependent variables (blood product wastage and delivery to the patient's bedside after massive transfusion activation).

Reliability and Validity

Data was collected using a well-established and reliable hospital trauma registry that the hospital and manufacturer validated for accuracy. Massive Transfusion Protocol MTP data were collected prospectively, including the number of blood products distributed and transfused to the patients and the blood product wastage pre- and post-use of liquid plasma in MTP. Standardized chart reviews are widely used and have high face validity. Standardized medical record review, for example, has been used to identify and classify areas of potential harm as well as detect adverse events and negligence (Siems et al., 2020). A team of clinical and medical experts verified the face validity of the collected data, along with the laboratory medical directors, blood bank scientists, and laboratory quality specialists. To ensure data validation, the secondary data was presented to the quality coordinator and the medical director, who are responsible for ensuring the quality of transfusion services.

Data Collection and Procedures

The data was collected from a level one trauma center in Southwest United States medical center. Liquid plasma usage in massive blood transfusion outcomes was collected from the hospital medical records for pre- and post-liquid plasma usage implementation. The data that was collected includes the number of patients who received emergency and massive transfusions as the proxy source of the date of liquid plasma, the patient's demographic data such as age, gender, and ethnicity, and the liquid plasma wastage. This data was de-identified to remove all patient identifiers, such as the patient's name, address, and medical record number. The data was then cleaned to remove any irrelevant data from the study and checked for any missing data. Lastly, the dataset was presented to the transfusion service manager, medical director, and the quality coordinator, who agreed to review it for data validation and clarity. The researcher obtained IRB approval from the research site and Franklin University before collecting the data from the medical records.

Data Analysis and Procedures

After approval of the research proposal and obtaining the IRB approvals, the researcher met with the transfusion service manager, the transfusion service medical director, and the quality coordinator and discussed the various processes of acquiring access to the data, informed consent, and confidentiality. The collected data are the numbers of patients who served as the proxy source to identify the date liquid plasma was ordered and administered and who received emergency and massive blood transfusion and blood product waste (the unit of analysis) one year before and after the implementation of liquid plasma in the massive blood transfusion protocol. The researcher reported the data on the patient's demographic characteristics so that he could investigate whether or not there was any connection between those characteristics and the independent or dependent variables. Statistical analysis was performed using Microsoft Excel 2003 (Microsoft, Inc., Redmond, WA, USA) and Statistical Package for the Social Sciences (SPSS) program version 23, 2016 (SPSS Inc., USA). The chi-square-test with Fischer's exact value was used to compare the statical significance of the plasma waste and cost before and after using liquid plasma and test the study's hypothesis and the statical significance for nominal variables (blood product waste and cost) and correlation lambda test analysis for the hospital departments' plasma waste.

The Chi-square test examines independence across two or more categorical variables (Franke et al., 2012). The chi-square test of independence was appropriate to examine if significant associations existed between the variables of gender, group, and age rank. The research was conducted with a confidence level of 95% and a margin of error of 5% (Andrade, 2019). Therefore, the significance of the statistical tests was determined using the.05 alpha level. The null hypothesis for this research stated that using liquid plasma during massive transfusion protocols and emergency transfusions does not decrease blood product waste or increase the cost. The alternate hypothesis stated that using liquid plasma during massive and emergency transfusions reduces blood product waste and increases plasma-saving costs.

Statistical Assumptions

The chi-square test for independence was used in this study to determine whether there were any significant associations between plasma waste and cost between the first and second years. The presence of more than five frequencies in each cell indicated that the sample size was adequate (Schober & Vetter, 2019). Each group's observations were distinct, and the expected frequencies appeared only once (Verma & Abdel-Salam, 2019). As a result, all of the chi-square test assumptions were met.

Ethical Considerations

Incorporating ethics is essential in all research studies, as highlighted by (Varkey, 2021). The investigator employed diverse methodologies and approaches to guarantee adherence to ethical principles in the present investigation. Prior to the commencement of the study, the Institutional Review Board (IRB) at Franklin University conducted a thorough review and granted approval, thereby ensuring the protection of all human subjects involved. The researcher also obtained IRB approval from the level 1 trauma center study site. To ensure the safeguarding of human participants, it is necessary for an Institutional Review Board (IRB) comprising a range of professionals to engage in a comprehensive evaluation to determine the viability of proceeding with the study (Creswell & Creswell, 2017; Logan, 2020). According to Creswell and Creswell (2017), researchers must evaluate ethical considerations, regardless of whether or not the study involves the direct participation of human subjects. The ethical considerations, including but not limited to data security, confidentiality, privacy, and interpretation of results, were thoroughly deliberated with the Dissertation Committee to seek guidance, and ensure adherence to ethical standards. As stated earlier, the present study employed secondary data and did not involve any human subjects, thereby mitigating potential participant risks (White, 2020). The data underwent a cleansing process, ensuring that only relevant fields from the datasets were utilized in the computer programs (Bloomfield & Fisher, 2019). In addition, it should be noted that the data sets were securely stored in password-protected files to ensure confidentiality, as mentioned by (Logan, 2020).

Conclusion

In conclusion, this methodology chapter included the research design, description of study participants, sampling design, and data collection. The chapter also provided information about measurement and instruments, variables' operationalization, reliability, validity, and ethical considerations. In the next chapter, data collection and analysis will be discussed. The procedures for analyzing the data and the subsequent results will be presented in Chapter 4. A brief overview of the study and the hypotheses that will be investigated come first in this chapter.

In addition to reviewing the tests' results, the descriptive statistics and assumptions were also examined.

Chapter 4: Finding and Results

The current study examined the effect of using liquid plasma in massive and emergency blood transfusions at a level one trauma center in the Southwest United States. In this chapter, the researcher reports findings from the data analysis after providing a brief background for the research question that guided this study. Following a brief review of the research methodology, results are reported from descriptive statistics, assumption testing, and hypothesis testing.

Background

The study focused on the effects of using liquid plasma in massive and emergency blood transfusions. The Triple Aim Theory was used as the theoretical framework for the study. The focus was on improving the care experience, improving population health, and lowering per capita healthcare costs (Reppeto et al., 2021b). The research design was quantitative retrospective comparative. The research design allowed for an evaluation of the relationship strength between the independent and dependent variables and the generalization of study results.

The sample consisted of 1077 plasma units that were ordered for 258 trauma patients who received a massive transfusion protocol (315 plasma units were ordered for 92 patients in year one before the implementation of liquid plasma and 762 plasma units were ordered for 166 patients in year two after the implementation of liquid plasma). The researcher used SPSS to calculate descriptive and inferential statistics of the data. The descriptive analysis tests were conducted to determine the independent and dependent variables' means, frequencies, and standard deviations. The researcher used SPSS to assess assumptions about the data for linear logistic regression, including generating graphs, running tests, and creating tables. SPSS was then used to perform a hierarchical regression to evaluate the relationship strength between the independent and dependent variables.

Primary Research Question & Hypothesis

For patients who require emergency and massive transfusion, what is the impact of using liquid plasma compared to fresh frozen plasma on the blood product wastage and cost one year before and after using liquid plasma? The null hypothesis stated that using liquid plasma during massive transfusion protocols and emergency transfusions does not decrease blood product waste and cost. The alternate hypothesis stated that using liquid plasma during massive emergency transfusions reduces blood product waste and increases plasma-saving costs.

Hypothesis Testing

The researcher took the following steps to ensure that the data collected was appropriate for answering the research question and associated hypotheses. The first step was to compute descriptive statistics for the independent variable (liquid plasma utilization in massive transfusion protocol) and each dependent variable (blood product wastage and cost). Following the descriptive data analysis, a logistic regression analysis was performed to explain the relationship between the dependent binary variable and the independent variables. The chi-squared test was used to test and compare the difference in plasma waste between year one and year two. The chi-squared test was used to determine if there is a difference in the dependent variable between two independent groups since it compares whether the distribution of the dependent variable is the same for both groups and, hence, from the same population (Karadimitriou et al., 2018). The researcher used SPSS software to analyze the data and tested the hypotheses.

Descriptive Results

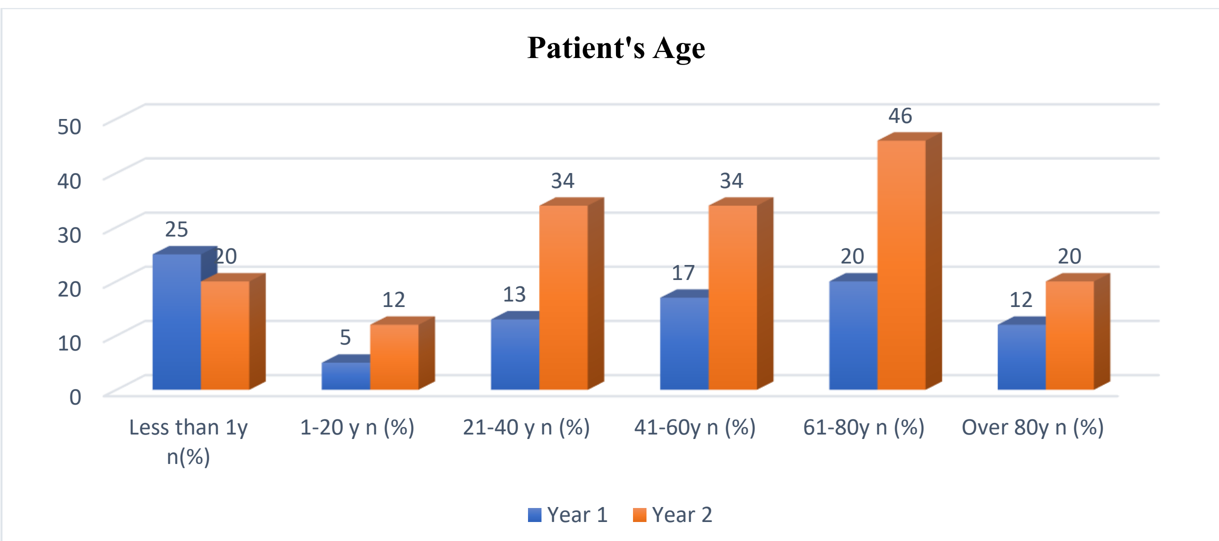
The data was collected from a level one trauma center in the Southwest United States. The study participants were divided into Group One (year one before implementing liquid plasma LQP) and Group Two (year two after implementing LQP). There were 92 participants in Group One (35.7%) and 166 in Group Two (64.3%). The patients' demographic data are summarized in Table 1. The researcher reported the patient's demographic data for context and informative purposes. The study had a total of 258 participants, of which 109 were female (42.2%) and 149 were male (57.8%). In year one, there were 45 female and 47 male participants, with percentages of 48.9% and 51.1%, respectively. In year two, the number of patients increased from 92 to 166 as the hospital services and departments expanded; 62 female and 104 male participants were 37.3% and 62.7%, respectively.

Table 1. Patients' Demographic Data

	Variable	Year one n=92	Year two n=166	P-value	Test
Age	mean±SD	41.06±31.9	47.18±27.3	0.124	f=6.182
	Less than 1y n (%)	25 (27.2%)	20 (12%)	0.066	X^2=10.357
	1-20 y n (%)	5 (5.4%)	12 (7.2%)		
	21-40 y n (%)	13 (14.1%)	34 (20.5%)		
	41-60y n (%)	17 (18.5%)	34 (20.5%)		
	61-80y n (%)	20 (21.7%)	46 (27.7%)		
	Over 80y n (%)	12 (13%)	20 (12%)		
Sex	Male n (%)	47 (48.9%)	62 (37.3%)	0.036	X^2=4.578
	Female n (%)	45 (51.1%)	104 (62.7%)		

The Chi-square test examines independence across two or more categorical variables (Franke et al., 2012). The chi-square test of independence was appropriate to investigate if significant associations existed between the variables of gender, group, and age rank. The research was conducted with a confidence level of 95% and a margin of error of 5% (Andrade, 2019). Therefore, the significance of the statistical tests was determined using the.05 alpha level. The results of the Chi-squared tests showed a significant relationship between gender and group (p = .036); females were more likely to be members of year one, while males were more likely to be members of year two. However, there was no significant relationship between age rank and group (p = .066). A chi-square goodness-of-fit test on the dependent variable, age rank, was used to examine selection bias. The results showed no difference in the proportions of the age ranks, with a p-value of 0.066 for X2 (1, N = 258). This indicates that there might not be any selection bias, which means that the results apply to other populations.

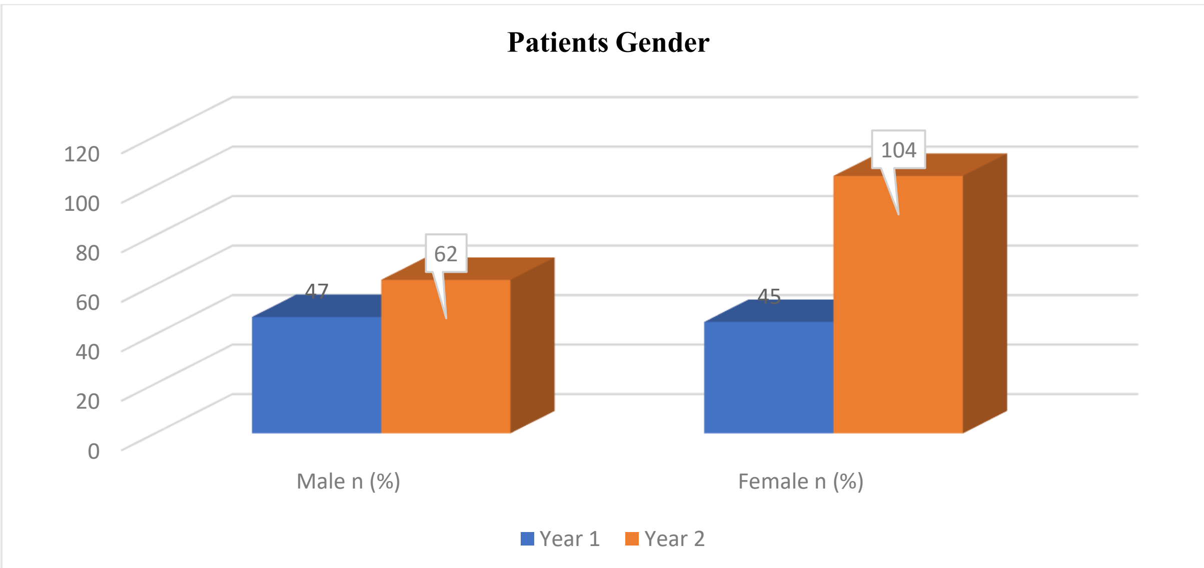
Figure 3. Demographic Data (Age) of Study Groups



Note. This figure demonstrates the patient's demographic information (age), categorized into six age groups in years one and two.

The study participants were divided into age groups based on age: less than one year, 1-20 years, 21-40 years, 41-60 years, 61-80 years, and older than 80 years. Dividing the research participants into age groups is a common and valuable practice in research that enables researchers to explore age-related differences, control for potential confounding variables, and offer more tailored insights and recommendations based on participants' life stages. There were 25 participants in the less than one year age group (9.7%), 5 participants in the 1-20 years age group (1.9%), 13 participants in the 21-40 years age group (5.0%), 17 participants in the 41-60 years age group (6.6%), and 20 participants in the 61-80 years age group (7.8%).

Figure 4. Demographic Data (Gender) of Study Groups



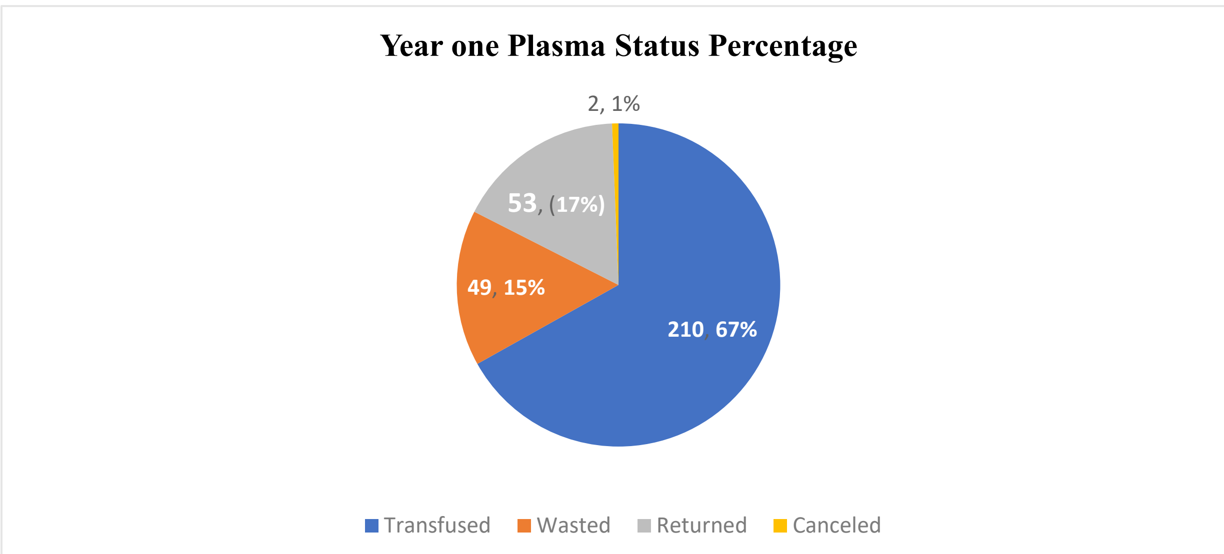
Note. This figure demonstrates the patient's demographic information (gender) in years one and two.

Plasma Type and Status

During the study period, a total of 1,077 plasma units were ordered, with 315 in year one and 762 plasma units in Year two. A total of 258 patients received plasma transfusions during the study. Of the 1077 units, 487 units (11.9%) were wasted, and most plasma (729 or 67.7%) was transfused. A total of 128 plasma units (11.9%) were returned, while 209 (19.4%) were returned but not transfused due to various reasons such as patient refusal or change in clinical condition. Only a small number of plasma orders (11 or 1%) were canceled.

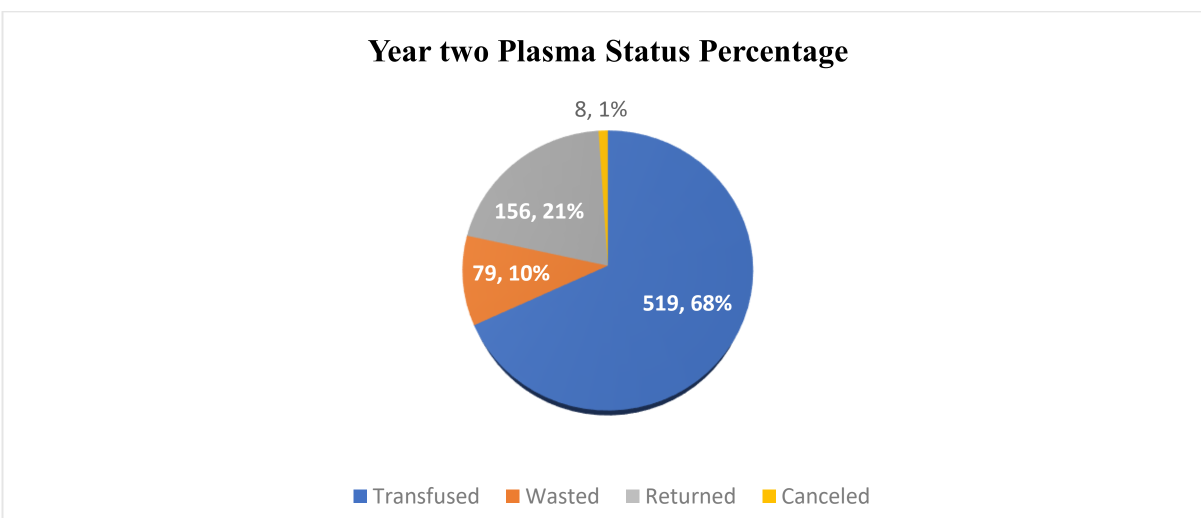
In year one, 315 plasma units were ordered for trauma patients. Of these, 210 (66.7%) units were transfused, 49 units (15.6%) were wasted, 53 (16.8%) were returned to the blood bank, and three orders (1%) were canceled. In year two, 762 plasma units were ordered for trauma patients. Of these, 519 (68.1%) units were transfused, 79 (10.4%) were wasted, 156 (20.5%) were returned to the blood bank, and eight (1%) orders were canceled. As shown in Table 2, the liquid plasma was unavailable in year one, and all the plasma ordered was thawed. In year two, 641 plasma units (84.1%) were thawed, and 121 (15.9%) were liquid.

Figure 5. Year One Plasma Status Percentage



Note. This figure demonstrates plasma status reported in numbers and percentages in year one.

Figure 6. Year Two Plasma Status Percentage



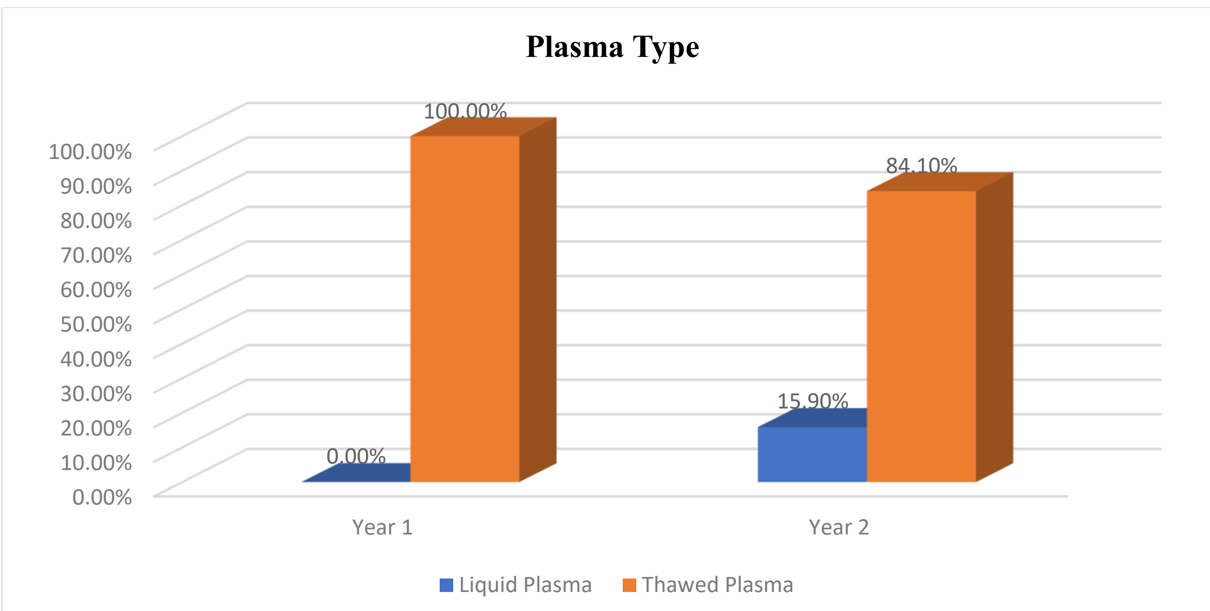
Note. This figure demonstrates plasma status reported in numbers and percentages in year two.

Table 2. Plasma Type and Status

	Variable	Year one n=315	Year two n=762	P-value	X^2 Test
Plasma Status	Transfused n (%)	210 (66.7%)	519	0.083	X^2=6.664
	Wasted n (%)	49 (15.6%)	79		
	Returned n (%)	53 (16.8%)	156		
	Cancel n (%)	3 (1%)	8		
Plasma Type	Liquid Plasma n (%)	0 (0%)	121(15.9%)	0.001	X^2=56.351
	Thawed Plasma n (%)	315 (100%)	641 (84.1%)		

Note. Values are considered to be significant at $p \leq 0.05$. **n:** number of samples.

Figure 7. Plasma Type in Year One and Year Two



Note. This figure demonstrates the plasma type reported in numbers and percentages in year one and year two.

Chi-squared tests were conducted to determine if there were any significant relationships between the variables of plasma status (transfused, wasted, returned, and canceled) and plasma type (liquid plasma and thawed plasma). The results of the Chi-squared tests showed that there was no significant relationship between plasma status and years (p = 0.083). However, there was a significant relationship between plasma type and year (p = 0.001).

Binary Regression Between Year One and Year Two with Product Status

Binary logistic regression was conducted to explore the relationship between year and plasma status. The analysis results showed a significant relationship between years and wasted plasma status (p = .0013), as shown in Table 3. Specifically, there was a decrease in the percentage of wasted plasma from year one to year two. There was no significant difference in the percentage of transferred or canceled plasma between years one and two.

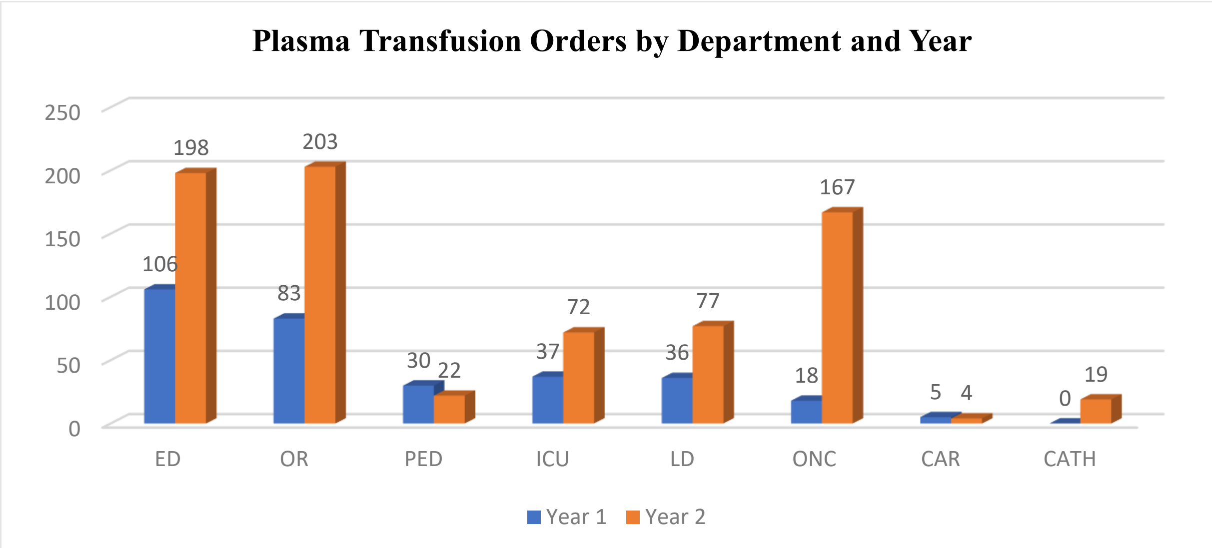
Table 3. Binary Regression Between Year One and Year Two with Product Status

Variable	B	SE.	Wald	df	Sig.	Exp(B)
PRODUCT STATUS (wasted)	-0.602	0.242	6.210	1	**0.013**	0.548
PRODUCT STATUS (transferred)	-0.175	0.179	.955	1	0.328	0.840
PRODUCT STATUS (canceled)	-0.099	0.695	.020	1	0.887	0.906
Constant	1.080	0.159	46.105	1	0.000	2.943

Plasma Transfusions and Ordering Departments

The study results on the hospital departments ordering plasma in years one and two showed significant differences in the percentage of orders placed by various departments, p-value <0.001. There were 315 plasma orders in year one and 762 orders in year two, with a p-value of 0.01. The emergency department (ED) had the highest percentage of plasma transfusion orders in both years, with 33.7% in year one and 26% in year two, respectively. The odds ratio (OR) for ED was similar in year two, with 26.3% and 26.6% for ED and OR, respectively. The pediatric department (PED) significantly decreased plasma transfusion orders from year one to year two, with only 2.9% of orders placed in year two compared to 9.5% in year one. The oncology department (ONC) significantly increased plasma transfusion orders from year one to year two, with only 5.7% of orders placed in year one compared to 21.9% in year two.

Figure 8. Plasma Transfusion Orders by Department and Years



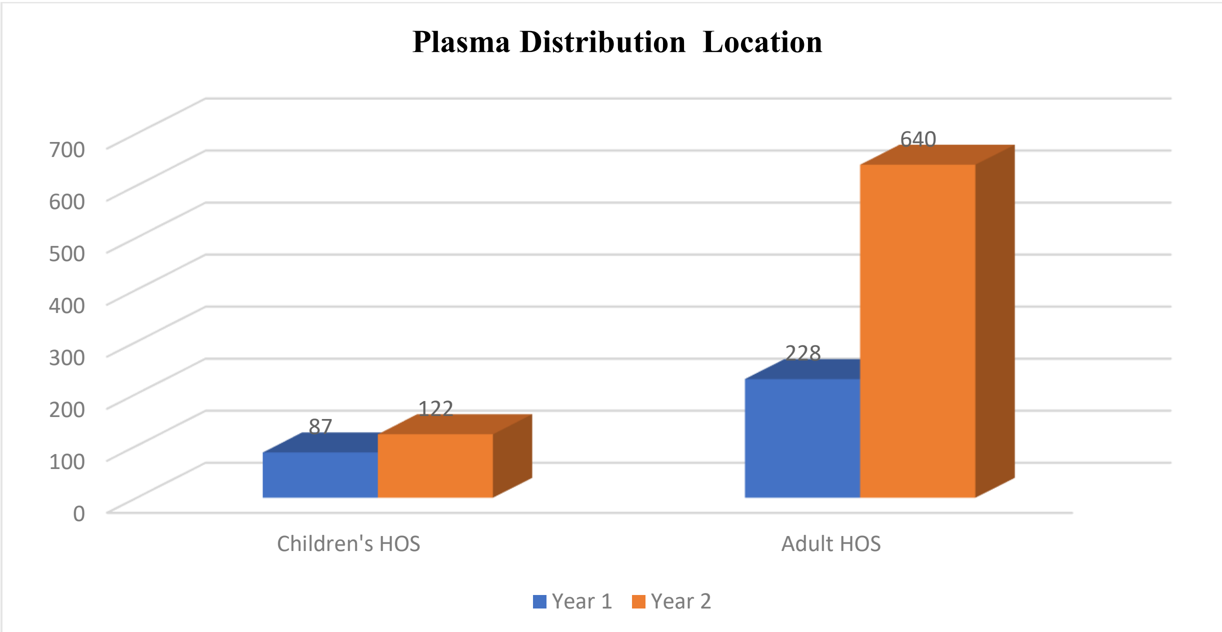
Note. This figure demonstrates plasma transfusion orders by departments in year one and year two.

Table 4. Hospital Departments Ordering Plasma Transfusions in Year One and Year Two

Variable		Year one n=315	Year two n=762	P-value	X^2 Test
Department	ED n (%)	106 (33.7%)	198 (26%)	0.001	X^2=71.435
	OR n (%)	83 (26.3%)	203 (26.6%)		
	PED n (%)	30 (9.5%)	22 (2.9%)		
	ICU n (%)	37 (11.7%)	72 (9.4%)		
	LD n (%)	36 (11.4%)	77 (10.1%)		
	ONC n (%)	18 (5.7%)	167 (21.9%)		
	CAR n (%)	5 (1.6%)	4 (0.5%)		
	CATH n (%)	0 (0%)	19 (2.5%)		
Distribution Location	Children's HOS n (%)	87 (27.6%)	122 (16%)	0.001	X^2=19.203
	Adult HOS n (%)	228 (72.4%)	640 (84%)		

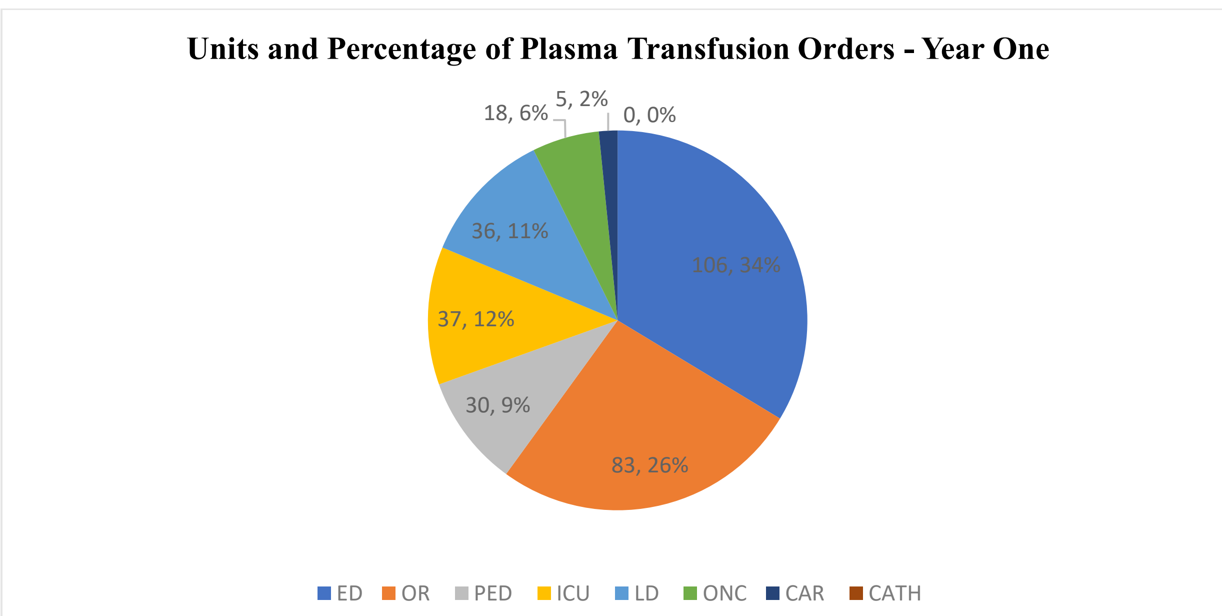
Note. Data are reported in percentages. Values are considered to be significant at $p \leq 0.05$. **n:** number of samples, **ED:** emergency department, **OR:** operating room, **Child:** pediatrics, **ICU:** Intensive care unit, **LD:** labor and delivery, **ONC**: oncology, **CAR:** Cardiac, **CATH:** Cath lab, **LQPCH:** Children Hospital, **SHC:** adult hospital.

Figure 9. Plasma Order Location



Note. This figure demonstrates plasma order locations (reported in units and percentages) in year one and year two.

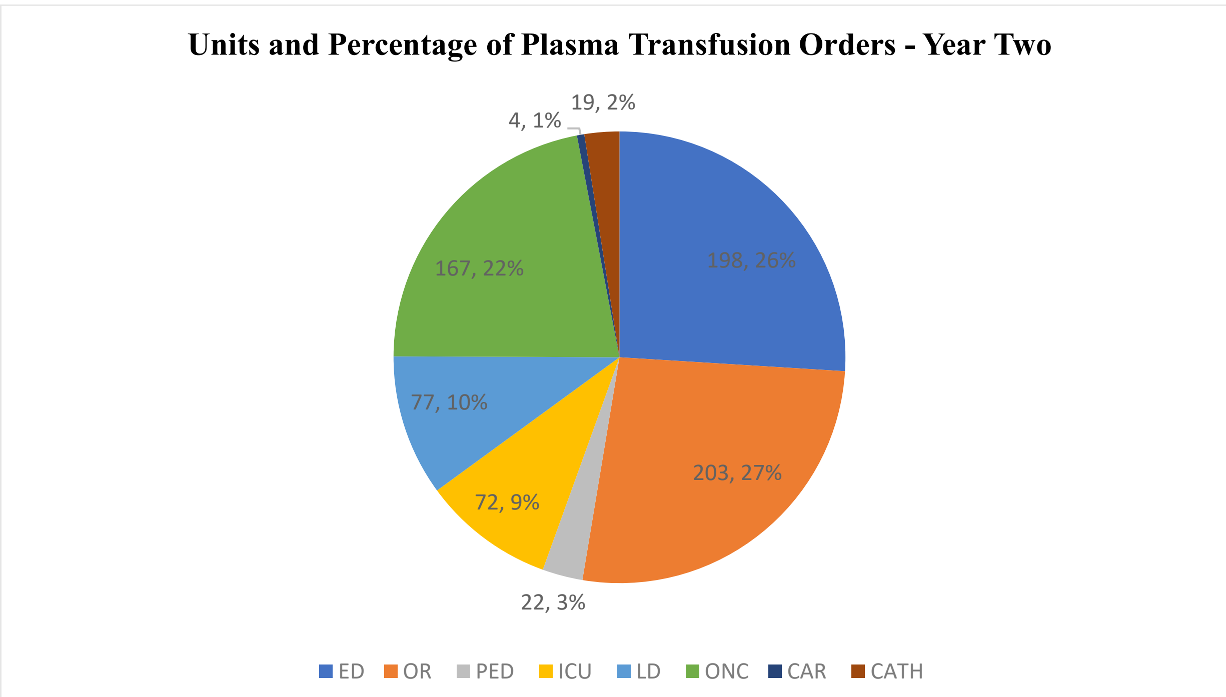
Figure 10. Units and Percentage of Plasma Transfusion Orders - Year One



Note. This figure demonstrates department plasma transfusion orders (reported in units and percentages) in year one.

The plasma order locations also showed significant differences between children's and adult hospitals. In year one, children's hospitals had a higher percentage of plasma transfusion orders at 27.6%, compared to adult hospitals at 72.4%. However, this difference decreased significantly in year two, with only 16% of orders placed at children's hospitals compared to 84% at adult hospitals. The results suggest significant differences between hospital departments and order locations when ordering plasma transfusions (p = .001).

Figure 11. Units and Percentage of Plasma Transfusion Orders - Year Two

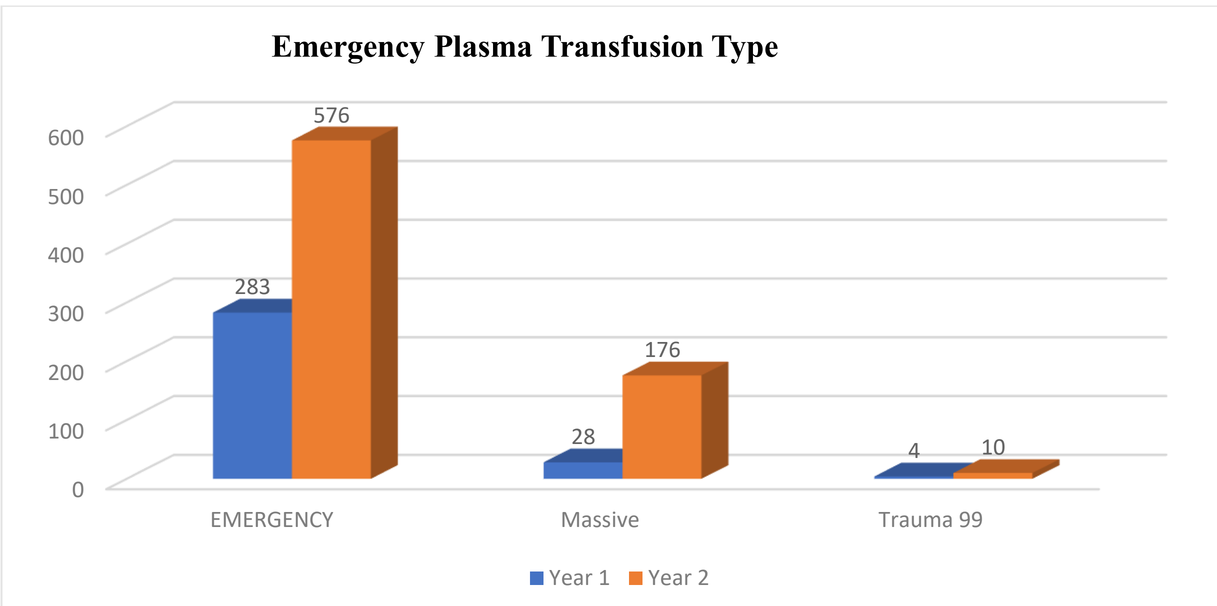


Note. This figure demonstrates department plasma transfusion orders (reported in units and percentages) in year two.

Emergency Transfusion Type

The results of the crosstab analysis showed significant differences in the emergency transfusion types between year one and year two. Out of the 315 plasma units ordered in year one, there were 283 units (90%) of emergency release, 28 units (9%) ordered as massive transfusion protocol, and four units (1%) ordered as trauma 99. Out of 762 plasma units ordered in year two, there were 576 units (75.6%) emergency release, 176 units (23.1%) ordered as massive transfusion protocol, and ten units (1.3%) ordered as trauma 99. The Chi-squared test results showed a significant relationship between emergency transfusion type in year one and year two (p = 0.001). Specifically, there was a decrease in the percentage of plasma transfusions ordered for emergency release and an increase in the rate of plasma transfusions ordered for massive transfusion and trauma 99, as shown in Table 4.

Figure 12. Emergency Plasma Transfusion Type



Note. This figure demonstrates the plasma transfusion type in year one and year two.

Table 5. Emergency Plasma Transfusion Type

	Variable	Year one n=315	Year two n=762	P-value	X^2 Test
Department	EMERGENCY n(%)	283 (90%)	576 (75.6%)	0.001	X^2=31.606
	Massive n(%)	28 (9%)	176 (23.1%)		
	Trauma 99 n(%)	4 (1%)	10 (1.3%)		

Note. Data are reported in percentages. Values are considered to be significant at $p \leq 0.05$. **n:** number of samples, **ED:** emergency release **MTG:** Massive Blood Transfusion Protocol.

The Difference in Plasma Waste between Year One and Year Two

There was a significant decrease in the number and percentage of plasma waste products between the two years. In year one, 15.6% of plasma was wasted. This percentage decreased significantly to 10.4% in year two, as shown in Table 5. When only thawed plasma (TP) was offered in year one, a total of 315 plasma units were ordered; 49 units (15.5 %) of those orders were wasted. When both liquid plasma (LQP) and thawed plasma (TP) were available in Year two, 762 units (both types of plasma) were ordered, with 79 units (10.3 %) wasted. The Chi-squared test results revealed a significant association between plasma waste in years one and two (p = 0.008). The results showed a significant difference in the amount of plasma wasted between year one and year two.

Table 6. The Difference in Plasma Waste between Year One and Year Two

	Variable	Year-1 n=315	Year-2 n=762	P-value	X^2 Test
Wast	n(%)	49 (15.6%)	79 (10.4%)	0.008	X^2=7.031
	% from total wasted	38.3%	61.7%		

Note. Data are presented as percentages. Values are considered to be significant at $p \leq 0.05$. **n:** number of samples.

Table 7. The Mann-Whitney Test Result

Variable	Product Description	Product Status	Distribution Location	Hospital Department	Emergency Type
Z Test	-7.503	-0.013	-4.380	-4.550	-5.199
P-value	0.001	0.989	0.001	0.001	0.001

The Mann-Whitney test was used to compare the difference in plasma type, plasma status, plasma order location, hospital departments, and emergency type between year one and year two. The test results showed a significant difference between the two groups, with a p-value of 0.001, as shown in Table 7. This suggests that the decrease in plasma waste from year one to year two was not due to chance.

Results for Using Thawed and Liquid Plasma

In year one, there were no liquid plasma units available. However, there was a significant decrease in the percentage of thawed plasma units (n=315) from year one to year two (n=641), as shown in Table 7. In year two, there was a significant statistical difference in the percentage of the product's status in thawed plasma units compared to liquid plasma units, as shown in Table 8.

Table 8. The Difference in the Plasma Status Between Both Plasma in Year One

Variable		Liquid n=0	Thawed n=315	P-value	X^2 Test
Product Status	Transfused n (%)	0 (0%)	210 (66.7%)	0.001	311.273
	Wasted n (%)	0 (0%)	49 (15.6%)		
	Returned n (%)	0 (0%)	53 (16.9%)		
	Cancel n (%)	0 (0%)	3 (1%)		

Table 9. The Difference in the Plasma Status Between Both Plasma in Year Two

Variable		Liquid n=121	Thawed n=641	P-value	X^2 Test
Product Status	Transfused n (%)	73 (60.3%)	446 (69.6%)	**0.001**	X^2=18.340
	Wasted n (%)	7 (5.8%)	72 (11.2%)		
	Returned n (%)	37 (30.6%)	119 (18.6%)		
	Cancel n (%)	4 (3.3%)	4 (0.6%)		

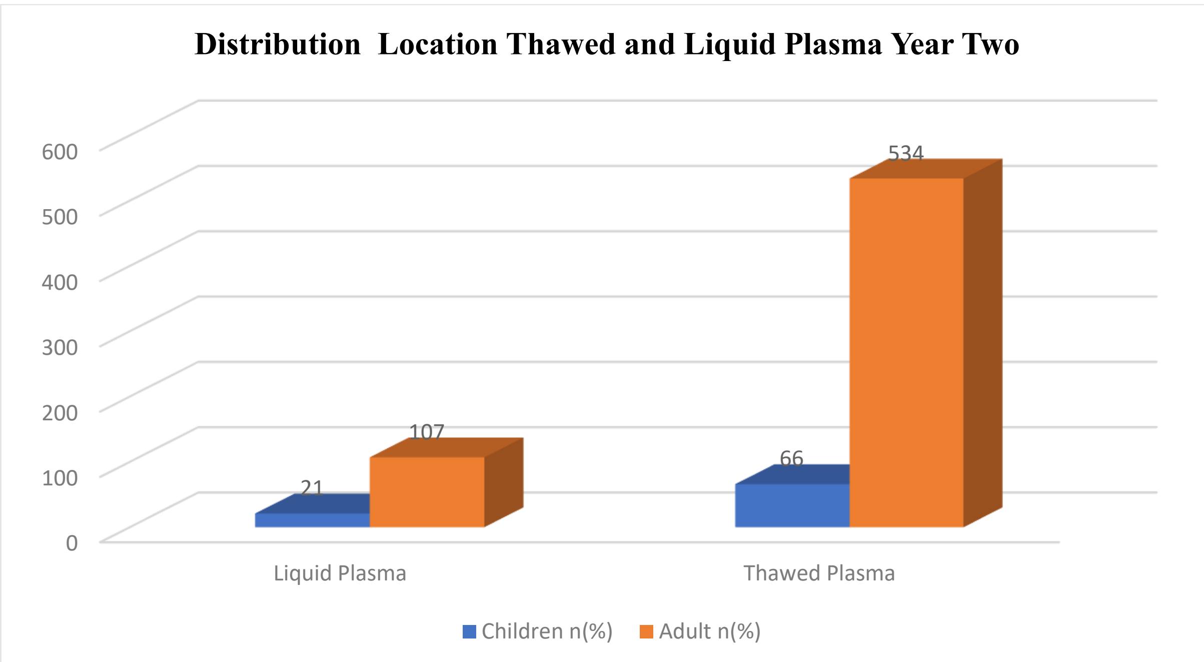
Note. Data are presented as percentages. Values are considered to be significant at $p \leq 0.05$. **n:** number of samples.

The results of the crosstab analysis showed significant differences in the plasma status between thawed and liquid plasma in year one and year two. Specifically, a higher percentage of thawed plasma was transfused in year two than in year one. There was also a lower percentage of thawed plasma wasted in year two than in year one.

The Difference in Plasma Distribution Location Between Thawed and Liquid Plasma

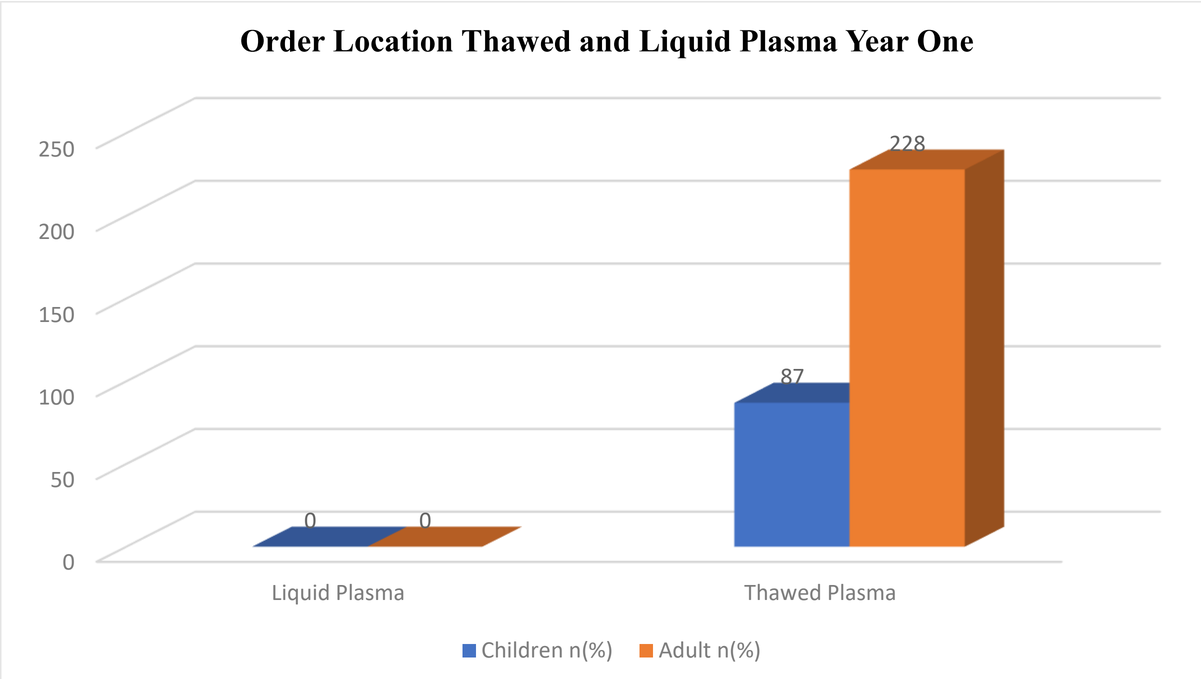
In year one, no liquid plasma was distributed to either adult or children's hospitals. In year two, 121 units of liquid plasma were distributed. The data showed no significant difference in the distribution location between thawed and liquid plasma for the Children's Hospital (p-value = 0.147, X2 test value = 1.397). However, for the Adult Hospital, there was a higher percentage of thawed plasma distributed (83.3%) than liquid plasma (16.7%), as shown in Tables 10 and 11. The data showed a higher percentage of thawed plasma distributed to adult hospitals (72.4%) than children's hospitals (27.6%), with a p-value of 0.001 and an X2 test value of 63.114.

Figure 13. Distribution Location Thawed and Liquid Plasma Year Two



Note. This figure demonstrates the thawed and liquid plasma order location in year two.

Figure 14. Distribution Location Thawed and Liquid Plasma Year One



Note. This figure demonstrates the thawed and liquid plasma order location in year one.

Table 10. The Difference in Plasma Distribution Location Between Both Plasma Year One

Variable		Liquid n=0	Thawed n=315	P-value	X^2 Test
Distribution Location	Children n(%)	0 (0%)	87 (27.6%)	0.001	63.114
	Adult n(%)	0 (0%)	228 (72.4%)		

Table 11. The Difference in Plasma Distribution Location Between Both Plasma Year Two

Variable		Liquid n=121	Thawed n=641	P-value	X^2 Test
Distribution Location	LQPCH n(%)	21 (18.8%)	66 (32.5%)	0.147	X^2=1.397
	SHC n(%)	107 (16.7%)	534 (83.3%)		

Note. This figure demonstrates the thawed and liquid plasma order location in year two.

The Difference in Order in Department Between Thawed and Liquid Plasma

Table 12. The Difference in Ordering Department Between Both Plasma Year One

Variable		Liquid n=0	Thawed n=315	P-value	X^2 Test
Department	ED n (%)	0 (0%)	106 (33.7%)	0.001	174.7 56
	OR n (%)	0 (0%)	83 (26.3%)		
	CHILD n (%)	0 (0%)	30 (9.5%)		
	ICU n (%)	0 (0%)	37 (11.7%)		
	LD n (%)	0 (0%)	36 (11.4%)		
	ONC n (%)	0 (0%)	18 (5.7%)		
	CAR n (%)	0 (0%)	5 (1.6%)		
	CATH n (%)	0 (0%)	0 (0%)		

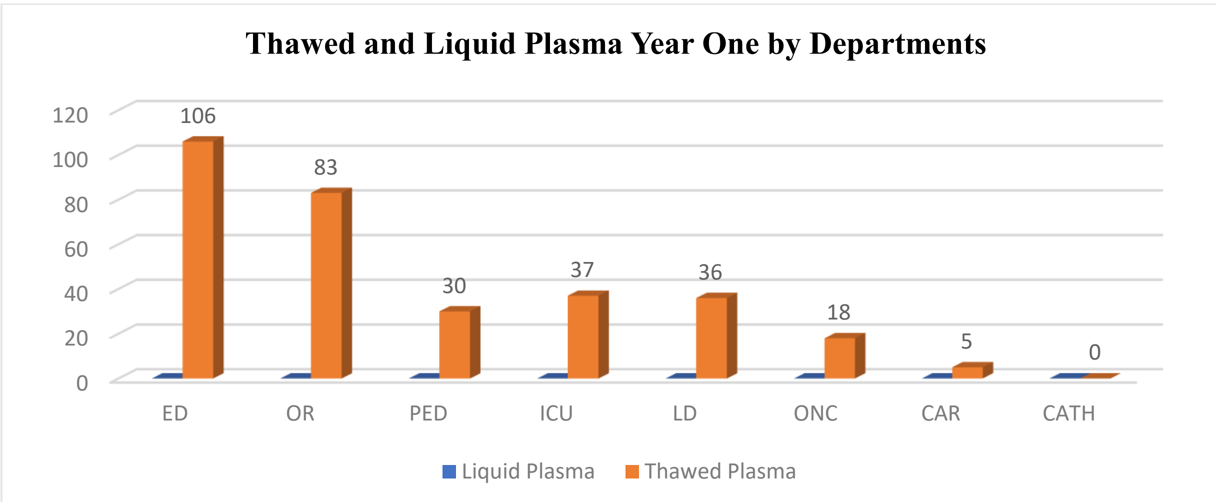
Table 13. The Difference in Ordering Department Between Both Plasma Year Two

Variable		Liquid n=121	Thawed n=641	P-value	X^2 Test
Department	ED n (%)	48 (39.7%)	150 (23.4%)	**0.005**	**X^2=20.225**
	OR n (%)	33 (27.3%)	170 (26.5%)		
	CHILD n (%)	1 (0.8%)	21 (3.3%)		
	ICU n (%)	6 (5%)	66 (10.3%)		
	LD n (%)	7 (5.8%)	70 (10.9%)		
	ONC n (%)	21 (17.4%)	146 (22.8%)		
	CAR n (%)	1 (0.8%)	3 (0.5%)		
	CATH n (%)	4 (3.3%)	15 (2.3%)		

Note. Data are reported in percentages. Values are considered to be significant at $p \leq 0.05$. **n:** number of samples, **ED:** emergency department, OR**:** operating room, Child**:** pediatrics, **ICU:** Intensive care unit, **LD:** labor and delivery, **ONC**: oncology, **CAR:** Cardiac, **CATH:** Cath lab.

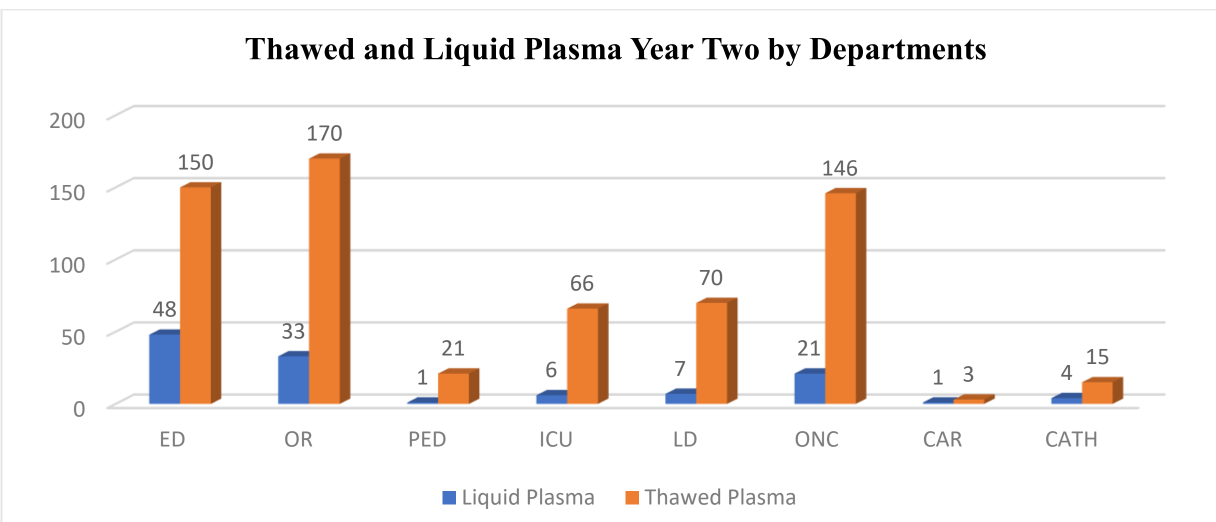
There were no liquid plasma units ordered by any department in year one. There was a decrease in the percentage of thawed plasma units ordered by the pediatrics and cardiac departments in year two, from 9.5% and 1.6%, respectively, to 3.3% and 0.5%, respectively. The percentage of thawed plasma ordered by the emergency department, operating room, intensive care unit, labor and delivery department, oncology department, and Cath lab decreased in year two.

Figure 15. Thawed and Liquid Plasma Year One by Departments



Note. This figure demonstrates thawed and liquid plasma orders by departments in year one.

Figure 16. Thawed and Liquid Plasma Year Two by Departments



Note. This figure demonstrates thawed and liquid plasma orders by departments in year two.

In year two, there was a statistically significant difference in the percentage of thawed units (n=641) and liquid units (n=121) plasma units ordered by the emergency department, operating room, pediatrics department, intensive care unit, labor and delivery department, oncology department, cardiology department, and Cath lab (p-value = 0.005).

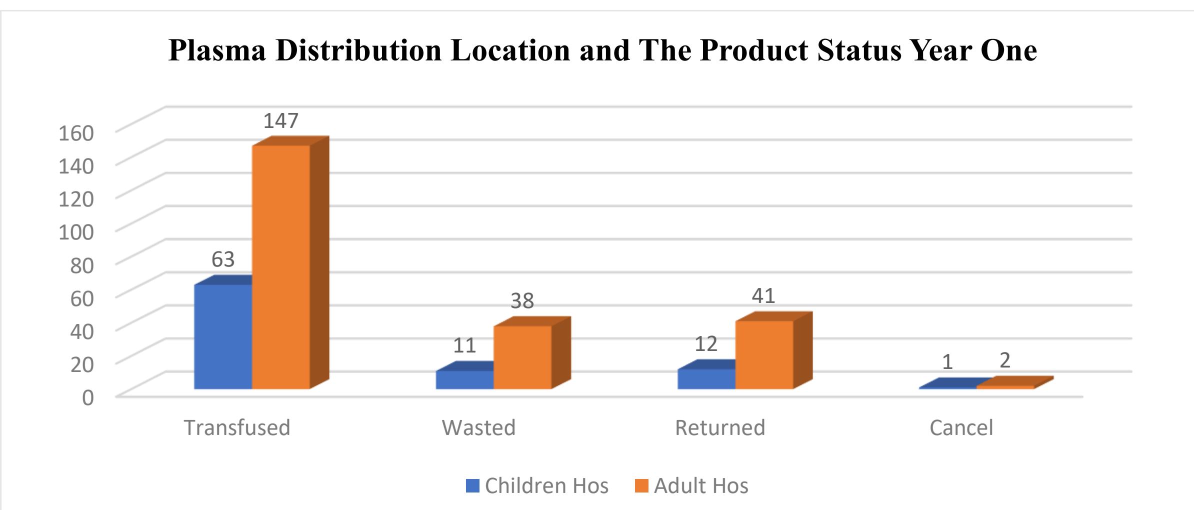
The Difference in the Plasma Order Location and The Product Status

The results of the crosstab analysis showed no significant differences in the distribution location and status of the product in year one (p = 0.581). On the other hand, there were also non-significant differences in the distribution location and status of the product in year two (p = 0.152). A higher percentage of transfused plasma was distributed to the Adult Hospital in Year two than to the Children's Hospital. A lower percentage of wasted plasma was distributed to the Children's Hospital in year two than to the Adult Hospital, as shown in Table 14 and Table 15.

Table 14. The Difference in Plasma Distribution Between the Product Status Year One

Variable		Transfused n=210	Wasted n=49	Returned n=53	Cancel n=3	P-value	X^2 Test
distribution Location	LPCH n (%)	63 (30%)	11 (22.4%)	12 (22.6%)	1 (33.3%)	0.581	X^2=1.957
	SHC n (%)	147 (70%)	38 (77.6%)	41 (77.4%)	2 (66.7%)		

Figure 17. The Difference in Plasma Distribution Between the Product Status Year One

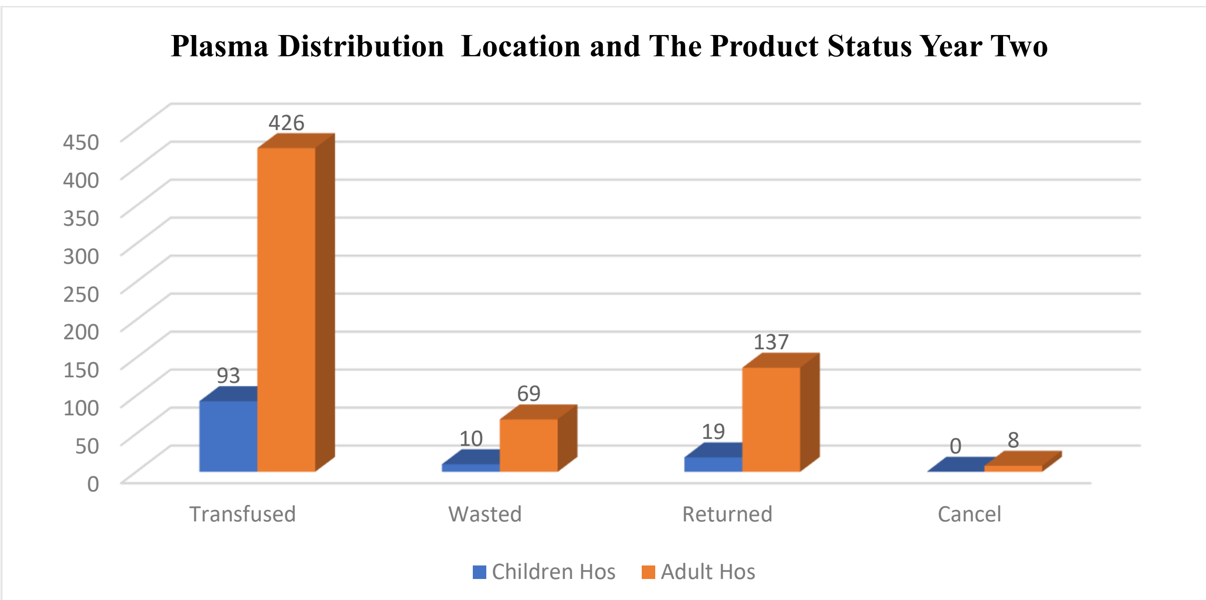


Note. This figure demonstrates thawed and liquid plasma orders by departments in year one.

Table 15. The Difference in Plasma Distribution Between the Product Status Year Two

Variable		Transfused n=519	Wasted n=79	Returned n=156	Cancel n=8	P-value	X^2 Test
Distribution Location	LPCH n(%)	93 (17.9%)	10 (12.7%)	19 (12.2%)	0 (0%)	0.152	X^2=5.294
	SHC n(%)	426 (82.1%)	69 (87.3%)	137 (87.8%)	8 (100%)		

Figure 18. The Difference in Plasma Distribution Between the Product Status Year Two



Note. This figure demonstrates thawed and liquid plasma orders by departments in year two.

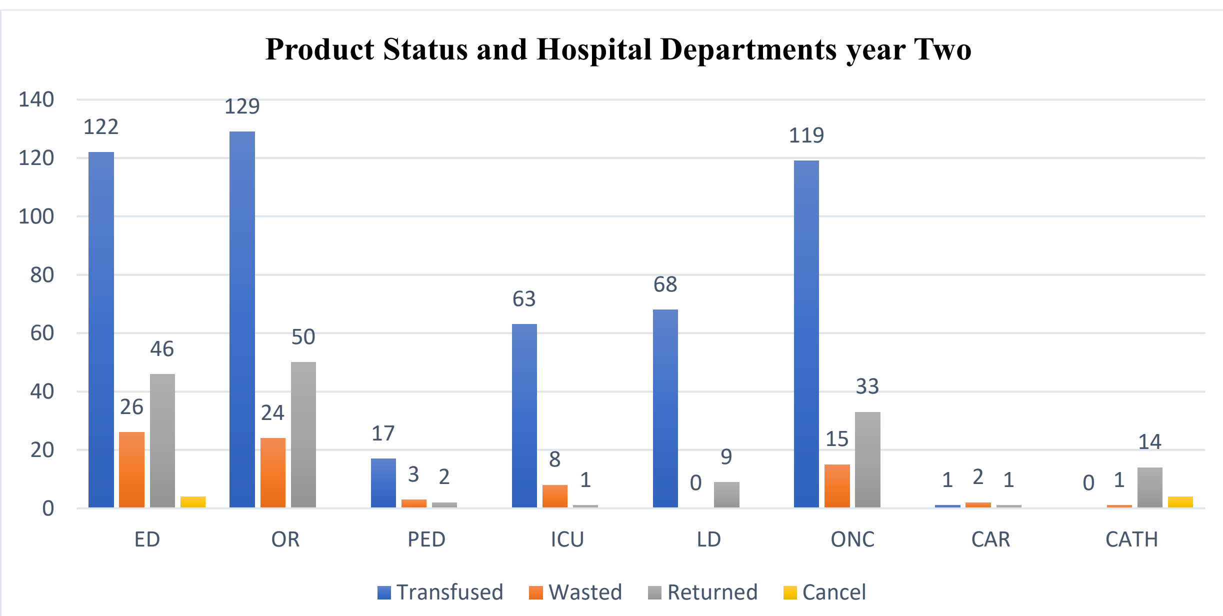
Product Status and Hospital Departments Year One

The results showed significant differences in the hospital department and the product status in both year one and year two (p = 0.001). Specifically, a higher percentage of transfused plasma was distributed to the Emergency Department in years one and two. There was also a lower percentage of wasted plasma from the Emergency Department in years one and two, as shown in Table 16 and Table 17.

Table 16. Product Status and Hospital Departments Year One

Variable		Transfused n=210	Wasted n=49	Returned n=53	Cancel n=3	P-value	X^2 Test
Department	ED n(%)	75 (35.7%)	20 (40.8%)	9 (17%)	2 (66.7%)	0.001	X^2=49.243
	OR n(%)	43 (20.5%)	14 (28.6%)	26 (49.1%)	0 (0%)		
	CHILD n(%)	30 (14.3%)	1 (2%)	2 (3.8%)	1 (33.3%)		
	ICU n(%)	30 (14.3%)	5 (10.2%)	2 (3.8%	0 (0%)		
	LD n(%)	25 (11.9%)	5 (10.2%)	6 (11.3%)	0 (0%)		
	ONC n(%)	10 (4.8%)	4 (8.2%)	4 (7.5%)	0 (0%)		
	CAR n(%)	1 (0.5%)	0 (0%)	4 (7.5%)	0 (0%)		
	CATH n(%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)		

Figure 19. Product Status and Hospital Departments Year Two

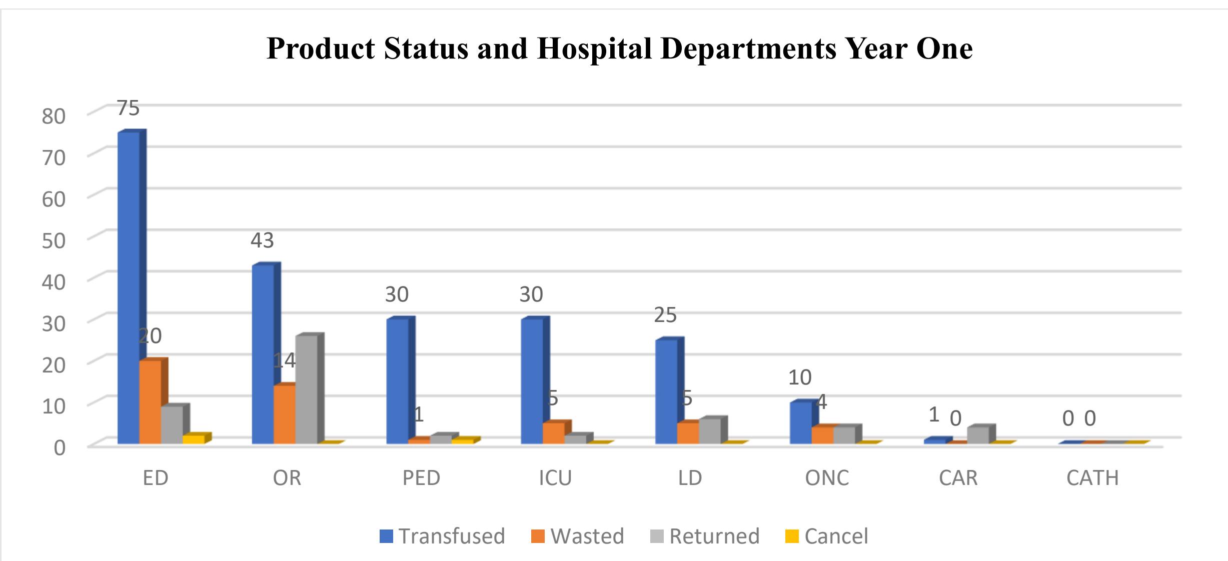


Note. This figure demonstrates Product Status and Hospital Departments in year two.

Table 17. Product Status and Hospital Departments Year Two

Variable		Transfused n=519	Wasted n=79	Returned n=156	Cancel n=8	P-value	X^2 Test
Department	ED n(%)	122 (23.5%)	26 (32.9%)	46 (29.5%)	4 (50%)	**0.001**	**X^2=167.77**
	OR n(%)	129 (24.9%)	24 (30.4%)	50 (32.1%)	0 (0%)		
	CHILD n(%)	17 (3.3%)	3 (3.8%)	2 (1.3%)	0 (0%)		
	ICU n(%)	63 (12.1%)	8 (10.1%)	1 (0.6%)	0 (0%)		
	LD n(%)	68 (13.1%)	0 (0%)	9 (5.8%)	0 (0%)		
	ONC n(%)	119 (22.9%)	15 (19%)	33 (21.2%)	0 (0%)		
	CAR n(%)	1 (0.2%)	2 (2.5%)	1 (0.6%)	0 (0%)		
	CATH n(%)	0 (0%)	1 (1.3%)	14 (9%)	4 (50%)		

Figure 20. Product Status and Hospital Departments Year One



Note. This figure demonstrates Product Status and Hospital Departments in year one.

Statistical Analysis and Hypothesis Testing

The research question was: "for patients who require a massive or emergency blood transfusion, what is the impact of using liquid plasma compared to fresh frozen plasma on the blood product wastage and cost one year before and after liquid plasma?" The following null hypothesis was tested: "Using liquid plasma during massive and emergency transfusions does not decrease blood product waste and cost." The chi-squared test for independence accomplished this by showing the statistical significance of the association between using liquid plasma and plasma waste and cost. There was a significant association between using liquid plasma during massive and emergency blood transfusion and plasma waste, $p = 0.008$. The null hypothesis was rejected; therefore, there was a significant association between using liquid plasma during massive and emergency blood transfusion and plasma waste. In the process of hypothesis testing, the level of marginal significance is indicated by the P-value, which is the probability value. A lower p-value (less than 0.05) indicates that the alternative hypothesis is accepted over the null hypothesis and that the null hypothesis should be rejected. The significance level of the confidence level, known as alpha, was set at 0.05, and it was used in the study to decide whether or not to accept or reject the null hypotheses.

Statistical Assumptions

In this study, the chi-square test for independence was used to determine if there were significant associations between plasma waste and cost between the first and second years. Each cell contained more than five frequencies, indicating an adequate sample size (Schober & Vetter, 2019). The observations in each group were distinct, and the expected frequencies only appeared once (Verma & Abdel-Salam, 2019). Accordingly, all assumptions for the chi-square test were satisfied.

Conclusion

Chapter 4 presented the data analysis procedures and subsequent results. The chapter began with a background of the study and the hypotheses to be tested. The descriptive statistics and assumptions were reviewed, along with the testing results. During the study period, 1,036 trauma patients who received blood product transfusions (511 in year one and 525 in year two) were presented to the institution. Among the 1,036 trauma patients, 258 trauma patients received plasma transfusions (92 in year one and 166 in year two). The demographics of the study population were similar, with slight differences in gender and age.

A total of 1,077 plasma units were ordered (315 units in year one and 762 units in year two), with 487 total units (11.9%) of plasma wasted during both years. 258 patients received plasma transfusions during the study period.

When only thawed plasma (TP) was available in year one, 315 plasma units were ordered, and 49 units (15.5%) were wasted. During year two, when both thawed plasma (TP) and liquid plasma (LQP) were available, 762 units (both liquid and thawed plasma) were ordered, with 79 units (10.3%) wasted, which was significantly lower than in year one ($p = 0.001$). In year two, there were 641 units of TP ordered, with 72 units (11.2%) wasted ($p = 0.10$), and there were 121 units of LQP ordered, with seven units (5.8%) wasted ($p < 0.0001$).

In year two of the study, the researcher took additional steps to address the potential impact of sample size on the statistical testing. Specifically, the researcher randomly selected equal numbers of thawed and liquid plasma units to ensure that differences in sample size did not confound the analysis. These matching numbers allowed for a more accurate assessment of the impact of liquid plasma compared to thawed plasma on plasma wastage.

The results of this matching showed that the waste rate for liquid plasma was 5.8%, while the waste rate for thawed plasma was 19.9%. This significant difference in wastage rates between the two plasma types indicated that the sample size difference between liquid and thawed plasma did not affect the statistical testing. The reduction in wastage for liquid plasma compared to thawed plasma in this matched sample further supported the advantages of using liquid plasma in the context of massive and emergency blood transfusion. This suggests that the benefits of reduced wastage associated with liquid plasma were not simply due to differences in sample size but could be attributed to the inherent characteristics of liquid plasma as compared to thawed plasma.

Liquid plasma was more likely to be returned to the blood bank and be able to be redistributed for other patients more times than TP. During year one, a unit of TP was wasted every 7.4 days, while in year two, a unit of TP was wasted every 5.07 days, and a unit of LQP was wasted every 52.1 days. During the study period, if TP were wasted at the same rate as LQP, there would have been 42 fewer units of plasma wasted, which would have equated to US \$5,376 of healthcare expenses saved (units of TP and LQP both have charged rates of US \$128/unit). Chapter 5 reviews the data analysis findings and recommends future research areas based on the current study and prior literature results.

Chapter 5: Discussion, Implications, and Recommendations

Introduction

In this chapter, the researcher has analyzed and contemplated the findings presented in chapter 4 of the study on the impact of using liquid plasma compared to fresh frozen plasma on blood product wastage and cost during massive or emergency blood transfusions. The researcher compared the findings with previous literature on the cost of liquid plasma (LQP) and reduced waste, as well as plasma cost and delivery time. Furthermore, the researcher acknowledged the study's limitations, provided recommendations for further research and implications for practice, and concluded with a summary.

Summary of the Results

The present study aimed to evaluate the impact of using liquid plasma (LQP) compared to thawed plasma (TP) in emergency and massive blood transfusion. The study period included 1,036 trauma patients who received blood product transfusion, of which 258 received plasma transfusion. The participants were divided into two groups: Group One, which consisted of patients from year one before implementing LQP, and Group Two, which consisted of patients from year two after implementing LQP. Group One had 92 participants (35.7%), while Group Two had 166 participants (64.3%). Demographic data of the patients were collected to explore any potential relationship between the demographic variables and the independent and dependent variables. The total sample size consisted of 1077 plasma units that were ordered for 258 trauma patients who received a massive transfusion protocol (315 plasma units were ordered for 92 patients in year one before the implementation of liquid plasma and 762 plasma units were ordered for 166 patients in year two after the implementation of liquid plasma), with 109 females (42.2%) and 149 males (57.8%). In year one, 45 female and 47 male participants accounted for

48.9% and 51.1%, respectively. In year two, as the hospital services and departments expanded, patients increased from 92 to 166. In year two, there were a total of 62 female participants and 104 male participants, representing percentages of 37.3% and 62.7%, respectively.

The study included 1,036 trauma patients who received blood product transfusions during the study period, with 258 of them receiving plasma transfusions. The demographics of the study population were similar, with slight differences in gender and age. A total of 1,077 plasma units were ordered, with 487 units (11.9%) wasted during both years.

In year one, when only TP was available, 315 plasma units were ordered, and 49 units (15.5%) were wasted. When TP and LQP were available in year two, 762 units were ordered, with 79 units (10.3%) wasted. The comparison between years one and two showed a significant decrease in plasma wastage when LQP was introduced ($p = 0.001$). Specifically, in year two, 641 units of TP were ordered, with 72 units (11.2%) wasted, and 121 units of LQP were ordered, with seven units (5.8%) wasted ($p < 0.0001$). Liquid plasma was more likely to be returned to the blood bank and redistributed for other patients than TP. The wastage rate for LQP was significantly lower than TP, with a unit of LQP wasted every 52.1 days, compared to a unit of TP wasted every 5.07 days in year two. If TP were wasted at the same rate as LQP during the study period, there would have been 42 fewer units of plasma wasted, resulting in US $5,376 of healthcare expenses saved.

The results suggested that the use of liquid plasma (LQP) compared to thawed plasma (TP) can significantly reduce plasma wastage during an emergency and massive blood transfusion ($p = 0.008$). In the study period, a total of 1,077 plasma units were ordered, with 487 units (11.9%) wasted during both years. However, when TP and LQP were available in year two, 762 units were ordered, with 79 units (10.3%) wasted, significantly lower than in year one, when only TP was available. The findings reveal that the cumulative wastage rate for LQP was significantly lower than TP.

Discussion of the Results:

The present study investigated the impact of using liquid plasma compared to fresh frozen plasma (FFP) in massive and emergency blood transfusions. The study utilized a retrospective comparative research design and collected data from a level one trauma center in the Southwest United States. The analysis included two groups: Group One (year one before implementing liquid plasma) and Group Two (year two after implementing liquid plasma). The findings revealed significant differences in various variables, including plasma waste, distribution location, ordering departments, and emergency transfusion types between the two years.

The demographic characteristics of the participants were analyzed to explore any potential relationships between these characteristics and the independent and dependent variables. Gender and group were found to be significantly associated, with a higher percentage of females in year one and a higher percentage of males in year two. Age, however, did not show a significant association with the group. This suggests that the demographic characteristics did not introduce significant confounding variables that might affect the study's outcomes.

The study examined the plasma type (liquid vs. thawed plasma) and its status (transfused, wasted, returned, or canceled) over two years. The results showed a significant decrease in plasma waste from year one to year two. In year two, the introduction of liquid plasma decreased the percentage of wasted plasma. Moreover, the study found a significant difference in the percentage of plasma types between the two years, with a higher percentage of liquid plasma in year two.

The study investigated the differences in plasma transfusion orders across various hospital departments. There were significant differences in the percentage of orders placed by different departments between the two years. The emergency department (ED) consistently had the highest percentage of plasma transfusion orders. Furthermore, the pediatric department significantly decreased its plasma transfusion orders, while the oncology department significantly increased its orders in year two. These findings suggested a shift in the distribution of plasma orders among departments after the implementation of liquid plasma.

The analysis revealed significant differences in the types of emergency transfusions between year one and year two. The percentage of plasma units ordered for emergency release decreased, while the percentage of units ordered for massive transfusion protocol increased in year two. This shift indicates a potential change in the clinical decision-making process for plasma orders, with a preference for specific types of emergency transfusions.

One of the study's primary objectives was to assess the impact of using liquid plasma on plasma waste. The results clearly demonstrated a significant reduction in the percentage of wasted plasma units in year two compared to year one. This reduction was observed across different types of plasma wastage (transfused, wasted, returned, or canceled). The Mann-Whitney test further confirmed that the decrease in plasma waste between the two years was not due to chance. This finding supports the hypothesis that introducing liquid plasma contributed to reduced plasma wastage.

The study also examined the impact of liquid plasma on plasma distribution location and the ordering departments within the hospital. In year one, there were no liquid plasma units available for distribution. However, liquid plasma was distributed to children's and adult hospitals in year two. The percentage of liquid plasma units ordered was significantly higher in the adult hospital compared to the children's hospital. This suggests that liquid plasma might have been more suitable for specific patient populations or clinical scenarios.

The analysis revealed significant associations between the product status (transfused, wasted, returned, or canceled) and hospital departments. The emergency department consistently had the highest percentage of transfused plasma units in both years. This finding suggests that liquid plasma might have been particularly beneficial for emergency cases, leading to a higher rate of successful transfusions in the emergency department.

The study employed the chi-square test for independence to evaluate the associations between various variables. The hypothesis testing results showed a significant association between using liquid plasma and plasma waste. The null hypothesis, which stated that using liquid plasma would not decrease blood product waste and cost, was rejected. This suggests that the introduction of liquid plasma positively impacted reducing plasma wastage.

The findings demonstrated a significant association between using liquid plasma during massive and emergency blood transfusion and plasma waste ($p = 0.008$). The rejection of the null hypothesis indicates that liquid plasma can significantly reduce plasma waste. The statistical analysis and hypothesis testing validate the statistical significance of this association. The results supported the potential benefits of using liquid plasma over fresh frozen plasma regarding reduced waste during transfusion procedures.

In year two of the study, a rigorous approach was adopted to ensure the validity of the findings and to account for potential sample size effects on the statistical testing. To this end, the researcher deliberately randomly selected equal amounts of thawed plasma (TP) and liquid plasma (LQP) units, effectively eliminating the influence of sample size disparities on the statistical analysis. This meticulous matching procedure allowed for a direct and unbiased comparison of the waste rates between liquid and thawed plasma. The results of this comparison revealed a waste rate of 5.8% for liquid plasma and a significantly higher waste rate of 19.9% for thawed plasma. These findings confirm that the observed reduction in plasma waste associated with using liquid plasma in year two was not confounded by differences in sample size, further strengthening the credibility of the results.

Along with reducing wastage, LQP may also have other advantages over TP. For example, LQP is more straightforward to store and transport than TP, and LQP can be stored for up to 26 days compared to TP's shelf life of five days, allowing for more efficient redistribution. Moreover, LQP can be used in emergencies and disasters when there is a shortage of blood products. Therefore, the present study suggested that hospitals and blood banks should consider switching to LQP to save costs and reduce healthcare waste. The study showed that if TP were wasted at the same rate as LQP, there would have been 42 fewer units of plasma wasted, equating to $5,376 of healthcare expenses saved. The results of this study are consistent with prior literature suggesting that using LQP can significantly reduce plasma wastage during emergency and massive blood transfusions. Liquid plasma is more stable and has a longer shelf life than TP, making it easier to manage and redistribute.

Additionally, the cumulative wastage rate for LQP was significantly lower than TP's. This suggests that LQP may be a cost-effective alternative to TP that can improve the management of plasma inventory and reduce wastage. The current study also highlighted the potential cost savings associated with reducing plasma wastage. If TP were wasted at the same rate as LQP, there would have been 42 fewer units of plasma wasted during the study period, resulting in a cost savings of $5,376. This suggests that the use of LQP can not only improve plasma management but also result in significant cost savings for healthcare organizations.

Conceptual Implications

The conceptual implications stemming from the results of this study, which focused on the utilization of liquid plasma (LQP) compared to thawed plasma (TP) in emergency and massive blood transfusions, are far-reaching and provide valuable insights into healthcare waste management, cost reduction, and the enhancement of patient care. These implications are discussed below:

Cost Reduction through Waste Minimization: One of the primary conceptual implications of this research is the potential for substantial cost reduction within the healthcare system. The findings demonstrate that introducing LQP resulted in a significant decrease in plasma wastage compared to using TP. This waste reduction directly translates into cost savings, saving thousands of dollars in healthcare expenses. This aligns with the Triple Aim Theory's goal of lowering per capita healthcare costs while maintaining or improving care quality.

Resource Optimization and Sustainability: The research outcomes underscore the importance of resource optimization in healthcare settings. By reducing plasma wastage, healthcare facilities can better utilize their resources and minimize the environmental impact associated with waste disposal. This aligns with broader sustainability goals and the recognition that healthcare organizations have a role in environmental stewardship.

Enhanced Patient Care Experience: Reducing plasma wastage has practical implications for patient care. With a more efficient allocation of resources, healthcare providers can ensure the availability of vital blood products like plasma when needed, especially in critical situations such as emergencies and massive transfusions. This directly contributes to improved patient care experiences and aligns with the Triple Aim Theory's goal of enhancing individual care.

Data-Driven Decision-Making in Healthcare: The study's emphasis on data analysis to assess the impact of different plasma types reinforces the importance of data-driven decision-making in healthcare. It highlights the need for healthcare providers to continually evaluate and adapt their practices based on empirical evidence to achieve better outcomes. This aligns with the broader healthcare transformation goals outlined in the Triple Aim Theory.

Transfusion Medicine Advancements: The research results provide valuable insights into transfusion medicine practices. The preference for LQP over TP due to its lower wastage rate signifies a potential shift in transfusion protocols. This conceptual implication suggests that healthcare organizations should consider updating their guidelines and procedures to maximize the use of LQP, leading to more efficient blood product management.

Policy and Practice Implications: The study's findings affect healthcare policy and practice. Policymakers may consider incentivizing the adoption of LQP or similar innovations to reduce healthcare costs. Healthcare facilities can reevaluate their blood product management protocols to align with the best practices identified in this research.

In conclusion, the conceptual implications of this study extend beyond the immediate scope of plasma transfusion management. They emphasize the importance of cost reduction, resource optimization, and data-driven decision-making in healthcare. Furthermore, the findings align with the Triple Aim Theory's overarching goals of enhancing patient care, improving population health, and lowering healthcare costs, highlighting the potential for innovation and improvement in healthcare waste management practices. These implications are significant for healthcare practitioners, administrators, and policymakers seeking to create a more efficient and sustainable healthcare system.

Comparison of the Findings with Previous Literature on LQP Cost

The findings on LQP cost saving are consistent with previous literature suggesting that using LQP increases the cost saving of healthcare expenses compared to using TP only. A recent study conducted by Smith et al. (2020) reported that if TP had been wasted at the same rate as LP, there would have been a reduction of 368 units of plasma wastage, amounting to a total of US $39,376 in wasted healthcare expenses, based on the cost of US $107 per unit.

The current study's findings are also consistent with previous research assessing the cost-effectiveness of liquid plasma compared to thawed plasma. A study by Salinas et al. (2020) reported that using LQP for emergency transfusions led to significant cost reductions due to reduced waste and the ability to reuse units. The current study also found that LQP was more likely to be returned to the blood bank and be able to be reissued for other patients more times than TP. Therefore, the present study's results and previous literature suggest that LQP is a cost-effective alternative to TP and should be considered by healthcare providers and policymakers. The findings align with previous literature that supports the cost-effectiveness of using liquid plasma compared to other plasma products. The decreased wastage and longer shelf-life of liquid plasma contribute to significant cost savings for healthcare facilities.

Comparison of the Findings with Previous Literature on Reduced Waste

The present study's investigation into the impact of using liquid plasma (LQP) on wastage and cost during blood transfusions aligns with previous literature, which consistently supports the notion that LQP reduces wastage compared to traditional plasma (TP). Van Waesberghe et al. (2018) conducted a study that demonstrated significantly lower cumulative wastage rates for LQP than TP, supporting the findings and suggesting that adopting LQP can lead to substantial reductions in waste and enhanced efficiency in blood management systems.

Additionally, the study is consistent with the findings of Spinella et al. (2019), who reported that LQP is associated with a significantly lower wastage rate than TP. In the current study, we observed that the wastage rate for LQP was markedly lower than TP, with a unit of LQP being wasted every 52.1 days compared to a unit of TP being wasted every 5.07 days in year two. These consistent results reinforce the existing body of research, highlighting the positive impact of implementing liquid plasma in reducing plasma wastage during blood transfusions. Such findings are crucial in optimizing blood product utilization and contributing to more sustainable healthcare practices.

Furthermore, the study supports previous literature demonstrating the cost-effectiveness of using liquid plasma compared to other plasma products. As reported in various studies, the decreased wastage and longer shelf-life of liquid plasma contribute to significant cost savings for healthcare facilities (Spinella et al., 2019; Van Waesberghe et al., 2018). By minimizing wasteful practices and adopting more efficient plasma management strategies, healthcare institutions can reduce costs and ensure a more effective allocation of resources for improved patient care.

Comparison of the Findings with Previous Literature on Plasma Delivery Time

This study's primary focus was to investigate the impact of using liquid plasma (LQP) on wastage and cost compared to traditional plasma (TP) during blood transfusions. While plasma delivery time was not a primary outcome of interest, it is essential to acknowledge its potential implications. Limited literature directly compares the specific findings of this study regarding plasma delivery time. The reduced wastage of liquid plasma can indirectly contribute to shorter delivery times, as there is a greater availability of plasma units that can be promptly distributed to patients in need. The current study's findings align with previous literature that reports LQP has a faster delivery time than TP. For instance, Venema et al. (2017) found that the median time for LQP was two minutes, compared to 165 minutes for TP, suggesting that LQP can significantly reduce plasma delivery time, potentially leading to improved patient outcomes. Cotton et al. (2019) also demonstrated that LQP could be prepared and delivered faster than TP, increasing plasma availability during emergencies. Additionally, literature on the cost of LQP supports the study's findings, with studies conducted by Allen et al. (2015) and Chehab et al. (2021) demonstrating substantial cost savings associated with utilizing LQP in massive transfusion protocols compared to conventional plasma transfusion approaches. Removing frozen plasma storage and associated expenditures contributes to the decreased cost of LQP.

Another study (Hyatt et al., 2019b) proposed a multimodal approach to minimize time to plasma administration and reduce fresh frozen plasma (FFP) waste in a trauma center. Their approach aligns with the core objective of the current study, which is to enhance the efficiency of plasma administration in critical scenarios. Both studies recognized the importance of timely plasma infusion to improve patient outcomes. Using liquid plasma could potentially address the challenges identified by Hyatt et al. in terms of rapid availability and waste reduction. Hyatt et al. (2019) highlighted the significance of reducing time to plasma administration. The study's findings suggest that liquid plasma can contribute to achieving this goal by eliminating thawing time. By leveraging the rapid availability of liquid plasma, healthcare facilities can align with Hyatt et al.'s objective of minimizing delays in critical plasma transfusions. This integration could potentially revolutionize plasma administration practices in massive transfusion scenarios.

Studies by Bates et al. (2021) emphasized the cost-efficiency achieved through parachute delivery of LQP in blood and plasma transfusion scenarios, further reducing overall expenses. The current study also aimed to compare the findings of reduced waste with previous literature.

Al Khan et al. (2019) showed that implementing the AB plasma appropriateness index resulted in notable reductions in wastage, supporting the findings.

Beiriger et al. (2023) emphasized the effectiveness of liquid plasma for early and balanced resuscitation during massive transfusion, further reducing plasma wastage. By optimizing transfusion practices and employing low-tech approaches such as whiteboards, whole blood, and liquid plasma, as highlighted in Beckermann et al.'s (2022) study, healthcare facilities have the potential to reduce waste and support sustainability initiatives. While the current study did not directly address plasma delivery time, future research should consider exploring this aspect further to elucidate the specific benefits and potential limitations of using LQP in terms of delivery time, ultimately contributing to improved transfusion practices and patient outcomes. (Jarraya et al., 2022) explored the impact of fresh frozen plasma versus fibrinogen concentrates on maternal outcomes in severe postpartum hemorrhage. While the current study does not directly pertain to maternal cases, the comparison highlights the diverse applications of plasma products. The findings indicate that liquid plasma can provide rapid and balanced resuscitation in emergencies, improving patient outcomes. While maternal cases have unique considerations, the studies' parallel emphasis on balanced plasma transfusion remains common.

The study by Beattie et al. (2020) presented liquid plasma as a means to achieve early and balanced plasma resuscitation in massive transfusion scenarios. The present study broadly aligns with their findings. Both studies emphasized the importance of rapid plasma availability and balanced resuscitation to improve patient outcomes. The utilization of liquid plasma can potentially overcome logistical challenges associated with thawing and processing frozen plasma units. The alignment between the current study and Beattie et al.'s underscores the significance of adopting innovative strategies for effective plasma administration in emergencies.

Comparison of the Findings with Previous Literature on Plasma Wastage by Hospital Departments

The current study presented compelling evidence of a significant correlation between the hospital department and product status in years one and two ($p = 0.001$). Notably, there is a marked increase in the proportion of transfused plasma channeled to the Emergency Department (ED) during these periods. Additionally, there is a noteworthy reduction in the percentage of wasted plasma originating from the ED in both years. This outcome accentuates the positive impact of incorporating liquid plasma into emergency and massive transfusion protocols, resulting in enhanced plasma utilization and a concomitant reduction in wastage.

The present study's results demonstrated significant disparities in hospital department and product status between year one and year two ($p = 0.001$). Notably, both years exhibit an elevated proportion of transfused plasma being directed toward the Emergency Department (ED). Additionally, there is a notable decrease in the percentage of wasted plasma originating from the ED in both years. This highlights the positive impact of integrating liquid plasma into emergency and massive transfusion protocols, leading to enhanced plasma utilization and diminished wastage.

Comparing these findings with the research of (Meyer, M. J. et al., 2018), a parallel theme emerges. Meyer et al.'s evidence-based quality improvement initiative within the operating room also reduced plasma waste. This similarity underscored the broader significance of evidence-driven interventions in blood component management, which translates to improved patient care and resource optimization.

Furthermore, (Shamshirian et al., 2020) review of blood usage and wastage in a tertiary heart center echoes the importance of efficient resource allocation. While their focus differs, the core message remains consistent: minimizing wastage through strategic interventions improves overall resource utilization and ultimately benefits patient care.

Analyzing the distribution of plasma waste across different departments, it is evident that the ED consistently received a notable proportion of transfused plasma, aligning with its role in managing critical and emergency cases. Importantly, the rise in plasma utilization in the ED correlates with reduced wastage percentages, further affirming the effectiveness of introducing liquid plasma into emergency and massive transfusion strategies. The ED emerges as a pivotal recipient of transfused plasma, in alignment with its role in emergency cases. Of significant note is the finding that the rise in plasma utilization in the ED is accompanied by a reduction in wastage percentages, indicating the efficacy of liquid plasma in optimizing plasma usage during emergency scenarios.

Comparing these findings with previous research, a consistent theme emerges. Hyatt et al.'s (2019) study mirrors the current research's objective of minimizing plasma waste through a multi-modal strategy, albeit with a different focus. These studies collectively emphasize the importance of optimizing resource allocation, reflected in plasma waste reduction and enhanced patient care.

Limitations and Implications for Practice:

One limitation of this study is its single-institution focus, which may limit the generalizability of the findings to other healthcare settings with different patient populations and clinical practices. Additionally, the relatively short study period of two years might not capture long-term trends and variations in plasma wastage and cost outcomes. Factors outside the scope of this study, such as individual patient characteristics, could have influenced the results. Future research should include multiple institutions and extended study periods to enhance generalizability and comprehensiveness.

Despite these limitations, the study's findings have significant implications for clinical practice. Hospitals and blood banks can benefit from the substantial reduction in plasma wastage achieved by switching to LQP. The cost-effectiveness of LQP and its longer shelf life present an opportunity for healthcare institutions to reduce overall healthcare costs and optimize blood management systems. However, implementing LQP requires careful consideration of logistical and infrastructural changes, including staff training, appropriate storage facilities, and regulatory compliance. Healthcare providers and policymakers should carefully evaluate these factors before transitioning to LQP.

Recommendations for Further Research:

The findings of this study provided valuable insights into the impact of using liquid plasma (LQP) compared to thawed plasma (TP) in emergency and massive blood transfusions. However, there are several areas where future research can build upon this foundation and expand the understanding of the subject. The following recommendations outline potential avenues for future research in this domain:

Multi-Institutional Studies: Conducting multi-institutional studies can enhance the generalizability of the findings. Collaborating with diverse healthcare settings with varying patient populations and clinical practices can provide a broader perspective on the impact of using liquid plasma (LQP) compared to thawed plasma (TP). This approach will help determine if the observed reduction in plasma wastage and cost is consistent across different contexts.

Long-Term Analysis: Extend the study duration to assess the long-term trends and variations in plasma wastage and cost outcomes. A more extended observation period can provide insights into the sustainability of the benefits associated with using LQP. Tracking changes over several years can help identify any potential fluctuations or seasonal patterns in plasma usage and wastage.

Patient-Centric Factors: Investigate the influence of patient-specific factors on plasma wastage and cost. Factors such as patient acuity, diagnosis, comorbidities, and blood type may impact the type and volume of plasma transfusions required. Analyzing these variables can help tailor plasma ordering practices to optimize resource utilization.

Logistics: Explore the logistical challenges and opportunities associated with transitioning to LQP. Investigate the feasibility of implementing LQP in different healthcare settings, considering aspects like staff training, storage facilities, and regulatory compliance. Understanding the barriers and facilitators of adoption can guide healthcare institutions in making informed decisions about LQP implementation.

Comparative Analysis of Other Blood Products: Extend the research to include other blood products, such as red blood cells and platelets, to assess the broader impact of LQP on overall blood product management. Investigate whether the benefits observed in plasma management translate to other blood components and explore potential synergies in reducing wastage and cost across the blood supply chain.

Cost-Benefit Analysis: Conduct a comprehensive cost-benefit analysis considering the direct cost savings associated with reduced plasma wastage and the indirect costs and benefits. Evaluate the impact of LQP implementation on resource allocation, staff efficiency, patient outcomes, and overall healthcare expenditure. This holistic approach can provide a more accurate assessment of the economic implications of using LQP.

Patient Outcomes: Explore the impact of LQP on patient outcomes, such as mortality rates, transfusion-related complications, and length of hospital stay. Investigate whether the reduction in plasma wastage correlates with improved patient care and clinical outcomes. Analyze data on patient survival and morbidity in relation to the use of LQP in massive and emergency transfusions.

Patient Blood Management: Investigate the integration of LQP into comprehensive patient blood management (PBM) programs. Assess how LQP aligns with PBM principles and strategies to optimize transfusion practices, minimize blood product use, and improve patient outcomes. Examine whether LQP can serve as a valuable component of PBM initiatives.

Supply Chain Efficiency: Evaluate the impact of using LQP on the efficiency of the blood supply chain, from donor collection to patient transfusion. Assess how LQP implementation affects inventory management, blood product availability, and distribution logistics. Explore the potential for reducing supply chain disruptions and improving response to emergencies or disasters.

Regulatory and Quality Assurance: Investigate the regulatory requirements and quality assurance measures associated with LQP production and utilization, such as AABB and FDA. Assess the compliance of LQP with industry standards and regulations. Explore strategies to ensure the safety and quality of LQP throughout its lifecycle.

Patient and Stakeholder Perspectives: Include qualitative research methods, such as interviews and surveys, to gather insights from patients, healthcare providers, and stakeholders regarding their perceptions and experiences with LQP. Understand their attitudes, preferences, and challenges related to LQP implementation and utilization.

Global Context: Extend the research to examine the global applicability of LQP, considering variations in healthcare systems, resource availability, and healthcare infrastructure. Investigate the potential benefits and challenges of implementing LQP in diverse international settings.

Quality Improvement Initiatives: Building on the concept of evidence-driven quality improvement, future research can explore developing and implementing protocols and guidelines that promote the efficient utilization of LQP. These initiatives could involve collaboration between healthcare institutions, blood banks, and regulatory bodies to standardize best practices for plasma management.

In conclusion, future research should build upon this study's findings by addressing its limitations and exploring a broader range of factors related to the use of liquid plasma in blood transfusion. By conducting comprehensive, multi-dimensional research, we can further validate the advantages of LQP, inform evidence-based transfusion practices, and contribute to more efficient and cost-effective healthcare systems.

Conclusion

In summary, the present study provided compelling evidence supporting the implementation of liquid plasma (LQP) over traditional thawed plasma (TP) during emergency and massive transfusion protocols. The use of LQP demonstrated a significant reduction in plasma wastage, resulting in potential cost savings and improved blood product utilization. These findings are consistent with prior research highlighting the cost-effectiveness and reduced waste associated with LQP. Healthcare institutions and blood banks should consider adopting LQP to optimize plasma management and enhance the efficiency of blood transfusion practices.

The study also emphasizes the need for further research to explore the long-term cost-effectiveness and safety of LQP compared to TP and its impact on patient outcomes and other blood products. Additionally, investigating the logistics of implementing LQP in different healthcare settings and assessing patient-centered outcomes would provide valuable insights for its successful integration into clinical practice.

In conclusion, the present study adds valuable insights to the growing body of literature on the benefits of using liquid plasma. The findings provide a strong rationale for considering LQP as a cost-effective and waste-reducing alternative to traditional plasma products. As healthcare facilities strive for more sustainable and efficient blood management practices, implementing LQP may be a valuable solution. Further research, encompassing diverse patient populations and clinical settings, is essential to fully comprehend the potential benefits and limitations of LQP, paving the way for evidence-based decision-making in transfusion medicine.

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