Original Article
DOI: https://doi.org/10.70749/ijbr.v3i4.1072

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://induspublishers.com/IJBR
ISSN: 2960-2793/ 2960-2807

Damage Control Resuscitation in Pediatric Trauma Patients

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ARTICLE INFO

Keywords

Massive Transfusion Protocol, Thromboembolic Events, Pediatric.

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Declaration

Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.
Conflict of Interest: No conflict of interest.
Funding: No funding received by the authors.

Article History

Received: 10-01-2025 Revised: 03-04-2025
Accepted: 15-04-2025 Published: 26-04-2025

ABSTRACT

Background: Pediatric Damage control resuscitation and massive blood transfusions are widely practiced globally, yet there is a lack of comprehensive data on pediatric massive transfusion protocols (MTPs) and their outcomes. We present a pediatric DCR and evaluate its effects on morbidity and mortality. **Methods:** Using a Randomized Control Trial, we gathered the data on all pediatric trauma patients who presented from January 2022 to September 2022 in emergency department of pediatric surgery, Mayo hospital, Lahore. Our study encompassed patients who received blood products according to the DCR protocol as well as patients who were transfused crystalloids and whole blood according to conventional protocol. Outcomes between groups were compared. **Results:** A total of 58 patients were included, with 29 patients in the DCR group and 29 patients receiving blood according to conventional protocol (control group). Mortality was significantly different between groups.(6.89 % in DCR group versus 27.58 % in control group, p-value : 0.027) Injury Severity Score for the two groups was not statistically different.(20 ± 11 in DCR group vs 20 ± 12) Incidence of thromboembolic complications was found to be equal in both groups.(3.44% in each group) Coagulopathy, indicated by partial thromboplastin time (PTT) greater than 36, was linked to crystalloids and whole blood use.(3.44% in DCR group versus 20.69% in control group, p-value : 0.044). **Conclusion:** DCR have been widely implemented in hospitals to lessen coagulopathy associated with hemorrhage. Blood transfusion via DCR is associated with decreased mortality and decrease incidence of coagulopathy. These findings endorse the implementation of pediatric DCR and highlight the need for additional research to understand its key factors and effects.

INTRODUCTION

Trauma remains a significant contributor to global mortality accounting for 9% of the deaths worldwide, with approximately 5 million fatalities in 2012.[1] Bleeding is a major culprit, being the second leading cause of death in trauma patients and primary cause of preventable deaths after hospital admission. Infact, hemorrhage accounts for 30-40% trauma related mortality[2], with 7% of these deaths considered preventable.[3,4]

Damage control resuscitation (DCR) is a strategy of managing adult trauma resuscitation in order to avoid the lethal triad of acidosis, hypothermia and coagulopathy.[5,6]

Although it has evolved over the last ten years, this strategy first appeared during World War II when a whole-blood transfusion was advised because it was thought that treating both shock and coagulopathy would improve patient outcomes.[7] Military data from Joint Theater Trauma Registry[12], revealed that a higher ratio of FFP and PRBC benefits the patients in penetrating trauma by preventing coagulopathy and improving survival.[18]

The current standard of care for DCR includes immediate bleeding control, restricted use of crystalloid fluids, warmed blood products use, permissive hypotension, balanced massive transfusion protocols (MTPs) , use of hemostatic medications, and damage control surgery.[31]

Evidence supporting these techniques in children is limited and is largely extrapolated from adult studies.

We will review paediatric trauma evidence for DCR, focusing on fluid management and hemostasis through case studies.

MATERIALS AND METHODS

This protocol was approved by institutional review board of KEMU/Mayo Hospital Lahore (500/RC/KEMU. Dated 23-05-22). From January 2022 to September 2022, patients were prospectively recruited for our study.

Pediatric trauma patients aged 1-12 years requiring transfusion were included in this study.

ISS (injury severity score) was calculated for all patients. Data was collected including age, gender, weight, mechanism of injury, vital signs, amount of crystalloid infusion, amount of blood and blood products infusion, complications in term of thromboembolism and coagulopathy. Level of anemia and coagulopathy were tracked via PT/PTT and Hgb/Hct. Length of hospital stay, morbidity and mortality at 24 hours and first 30 days were the primary outcome variables. All patients were followed through their hospital admission.

Statistical Methods

Data analysis was performed using SPSS, with results presented as percentages, means and standard deviation. A p-value<0.05 was considered statistically significant. Student t-test was used to assess statistical significance, while the chi-square test analyzed the association between variables. The t-test was also employed for comparing thromboembolic data, given the small sample size. All statistical tests were two-tailed with p<0.05 significance threshold. Logistic regression was employed to identify factors associated with DCR initiation.

RESULTS

A total of 58 patients were enrolled in the study, 29 in the DCR group and 29 in the non-DCR group. The DCR group was not statistically significantly different from the non-DCR group regarding sex, race, or age. The demographic breakdown showed a higher prevalence of male patients (86.20%) as compared to female patients (13.79%). All the patients in control group experienced blunt trauma, whereas the DCR group had a mix of injury types, with 4 patients (13.79%) having sustained penetrating trauma.

The DCR group had a significantly higher consumption of blood products, including FFP, PRBC, and platelets with a p-value of 0.005.

Before receiving blood transfusion, both groups received similar amounts of crystalloid resuscitation, with the DCR group receiving an average of 431ml per patient and the control group receiving an average of 445ml per patient. The level of anemia, defined as a hemoglobin level below 11g/dL at presentation, was also similar between two groups. However, coagulopathy, indicated by PTT of more than 36 seconds, was linked with non DCR group.(p value :0.04), as these values were considered abnormal according to the laboratory's standards. The average length of stay was 10.72 days in the DCR group and 6.2 days in the control group but the difference between the two groups was not statistically significant (p-value :0.158)

Mortality rates were higher in the control group (6.89% in DCR group versus 27.58% in control group) and the difference between the two groups was statistically significant (p value: 0.027). Thromboembolic complications were evenly distributed between the two groups, with one complication occurring in each group, constituting the 2 complications (3.448%) in the study.

Table 1

		DCR group		Control group		*p*
		Average ± ss/n-%		Average ± ss/n-%		
Gender	Male	24	82.75%	26	89.65%	0.446χ^2
	Female	5	17.24%	3	10.34%	
Weight		21.41±9.15		21.82±6.58		
Age		7.14±3.08		7.96 ±3.35		
Mechanism of injury	Blunt trauma	25	86.20%	29	100%	0.038χ^2
	Penetrating trauma	4	13.79%			
Injury Severity Score		20±11		20±12		
Crystalloid infusion		431.69±180.25		445.17±141.84		
Amount of blood transfused		866.89±383.52		443.79±135.71		
Injection transamine shot	Yes	29	100%	25	82.75%	<0.001χ^2
	No			4	17.24%	
Length of stay		10.72±8.79		6.20±4.22		
Complications	Yes	2	6.89%	9	31.03%	0.019χ^2
	No	27	93.10%	20	68.96%	
Thromboembolism	Yes	1	3.44%	1	3.44%	1.00χ^2
	No	28	96.55%	28	96.55%	
Surgery	Yes	12	41.37%	8	27.58%	0.269χ^2
	No	17	58.62%	21	72.41%	
Coagulopathy	Yes	1	3.44%	6	20.69%	0.044χ^2
	No	28	96.55%	23	79.31%	
Mortality	Yes	2	6.89%	8	27.58%	0.027χ^2
	No	27	93.10%	21	72.41%	

Statistical significance (p-values) measured by χ^2 (Chi-square test).

Figure 1
Mortality (DCR Group)

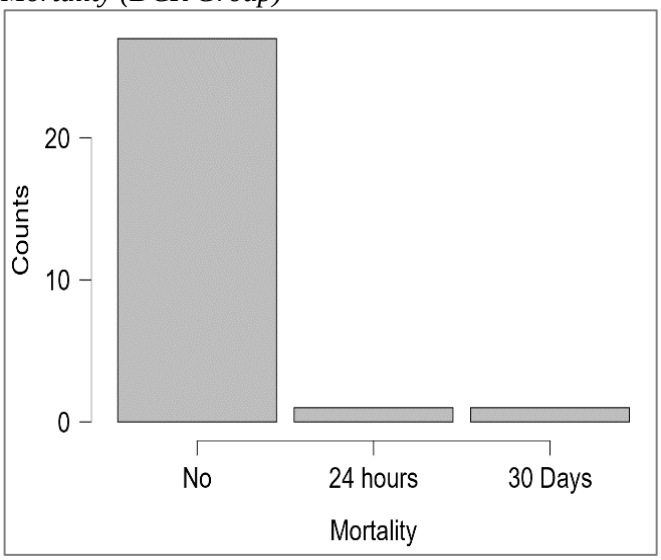


Figure 2
Control Group

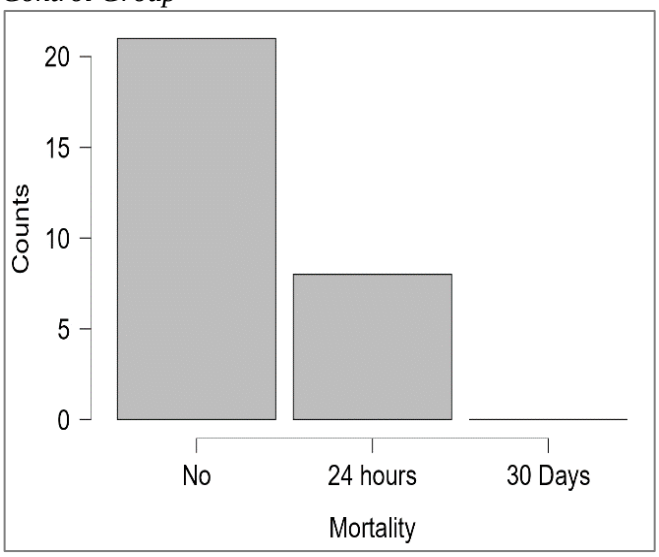


Figure 3
Coagulopathy (DCR Group)

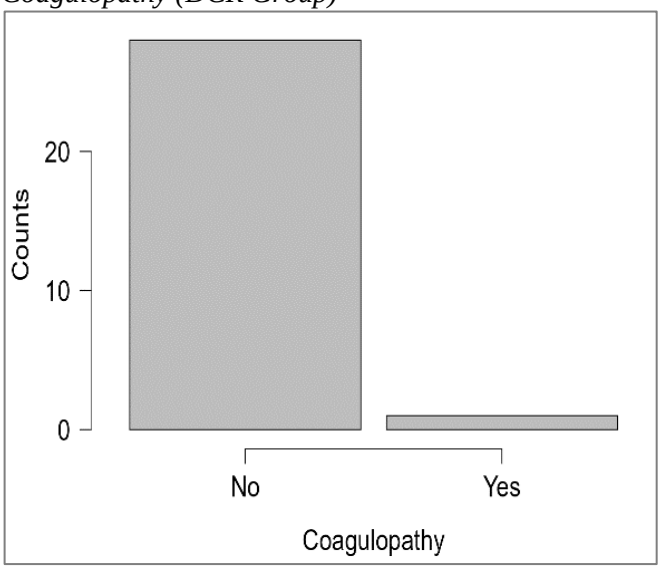
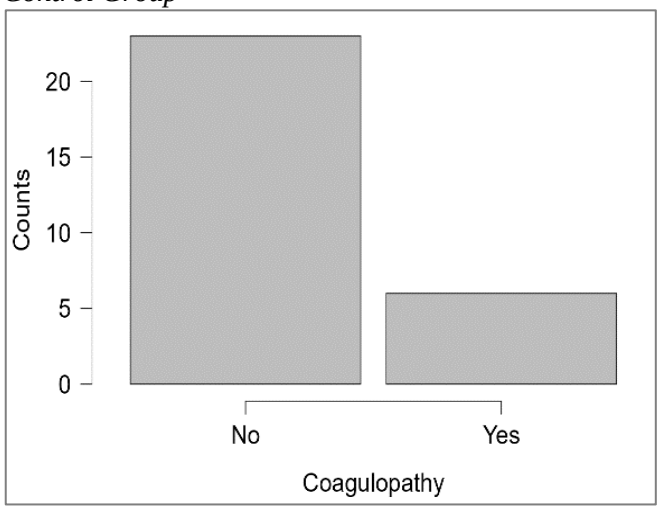


Figure 4
Control Group



DISCUSSION

DCR fundamentally involves controlling hemorrhage through both surgical and non surgical methods. Key interventions include tourniquets, pelvic binder and direct pressure application which are critical in prehospital settings to control bleeding and saving lives. The effectiveness of modern tourniquets is underscored by an estimated 1000 to 2000 lives saved during the conflicts in Iraq and Afghanistan.[8-10]

In paediatric trauma resuscitation, the optimal fluid amount remains unclear. However adult trauma literature suggests using crystalloid fluid judiciously and initiating packed red blood cell transfusions(PRBC) early. This approach is based on evidence indicating excessive fluid resuscitation can cause hemodilution of clotting factors, exacerbating coagulopathy and acidosis as well as leading to tissue damage due to edema.[11]

Advanced Trauma Life Support (ATLS) Student Manual. 9th ed. Chicago, Illionois: American College of Surgeons; guidelines have evolved, recommending 1 liter of crystalloid for adult trauma patients, a change from the previous 2-liter recommendation.[13] In contrast, pediatric trauma guidelines still suggest three 20ml/kg crystalloid boluses before packed red blood cell transfusion. The 2010 Pediatric Advanced Life Support (PALS) guidelines recommend 60ml/kg of crystalloid for hypovolemic shock, while the 2015 update acknowledges the risk of aggressive fluid resuscitation but doesn't specifically address hemorrhagic shock.[14] However, 2015 Advanced Pediatric Advanced Life Support Update (United Kingdom) recommends immediate blood or 10ml/kg crystalloid aliquots before transfusion in pediatric trauma.[15] The upcoming 10th edition of ATLS may provide further clarification on this issue.

Our study's findings on crystalloid use align with those of Edwards at al.(2015), which examined the children under 14 requiring transfusions using the

Department of Defense Trauma Registry. We found that increased crystalloid administration was linked to longer hospital stays and intensive care, as well as more days on ventilators, even after adjusting for age and injury severity score (ISS). Notably, patients receiving over 150ml/kg of crystalloid fluid in the first 24 hours had a significantly higher mortality rate(18% versus 10% , p-value : 0.011) and those receiving less than 50ml/kg also had increased mortality, possibly due to early death or inadequate resuscitation.[16] Similar to this, in our study administration of 40ml/kg crystalloids did significantly reduced mortality.

Similar findings have been reported by Acker et al.who discovered that crystalloid resuscitation exceeding 60ml / kg/24 hours was linked to longer hospital stays and the need for mechanical ventilation, but not with higher rates of other complications. This suggests that injured children seem to be somewhat immune to some of the negative effects of high volume fluid resuscitation.[17]

While the amount of resuscitation fluid in both groups was the same(20ml/kg of crystalloid), the DCR group received a balance 1:1:1 transfusion of PVC:PRP: FFP, which was almost half the patient's blood volume. Since the method can and should vary depending on age and injuries incurred, research defining crystalloid volumes in children is desperately needed. Patients in compensated shock should now receive cautious crystalloid resuscitation(10-40ml/kg) for bleeding and injured children, understanding that an early switch to blood products is required if their status does not improve. Children with decompensated hemorrhagic shock require urgent blood transfusions, either right away or as soon as feasible.

Prior to 2015, when Neff et al. retrospectively reviewed the outcomes of more than 3600 transfusion dependent patients to identify massive transfusion in a pediatric war trauma group, the definition of massive transfusion in pediatrics was not defined. The major transfusion threshold for identifying pediatric patients at risk for both short term and long term mortality, according to specificity and sensitivity analysis, is 40ml/kg(about half of a child's circulatory volume) of any blood product within the first 24 hours.[19]

As a part of hemostatic resuscitation, MTPs aim to manage hemorrhagic shock by replicating whole blood through a balanced transfusion of plasma, platelets and packed red blood cells.

The objective in adult trauma care is to use a 1:1:1 ratio to minimize the dilution of clotting factors and prevent coagulopathy.

Studies have shown that patients who received balanced MTPs early on tend to have better outcomes and we observed a significant decrease in the incidence of coagulopathy and mortality in the DCR group.[19-21,23]

Extensive multicenter prospective studies including PROMMT and PROPPR, have shown that higher plasma-to-PRBC transfusion ratios in adult trauma patients are linked to improved hemostasis and reduced deaths due to hemorrhage.[22,23]

In the PROPPR trial, a randomized control trial focused on transfusion strategies in adult trauma patients, no significant difference in overall mortality at 24 hours or 30 days was observed between those receiving a 1: 1: 2 (plasma: platelets: PRBCs) transfusion and those receiving a 1: 1: 1 transfusion. However the 1:1:1 group demonstrated improved hemostasis and reduced deaths from exsanguination within the first 24 hours.[23] Likewise in our study DCR group demonstrated lower incidence of coagulopathy(3.44% vs 20.69%)and reduced mortality(6.89% vs 27.58%) compared to control group.

Given that reported rates of coagulopathy in children range from 10 to 77%, pediatric patients may be at equal or even greater risk.[24]

Initial tissue injury and shock are believed to be primary drivers of trauma-induced coagulopathy (TIC), which is further exacerbated by hemodilution, hypothermia and acidosis.

Traumatic brain injury is a common condition in children linked to TIC and ongoing research continues to explore this relationship.[24-26] In our observations, the use of balanced transfusion strategies was associated with a decrease incidence of coagulopathy.

Although children's coagulation systems differ from those of adults due to developmental factors, it is reasonable to assume that balanced resuscitation could provide comparable benefits. However, current literature has yet to definitely confirm this in pediatric populations.[27-29]

While some case reports highlight favorable outcomes in children who received balanced massive transfusion protocols without developing coagulopathy, larger studies have not consistently demonstrated the same advantage of 1:1:1 transfusion strategy in pediatric trauma as well as seen in adults.[30]

CONCLUSION

Our study suggests that 1:1:1 ratio of FFP to PRBC and platelets in early transfusion was associated with lower 30-day mortality and decrease incidence of coagulopathy in patients experiencing severe hemorrhage following trauma. However, further research is needed to develop tailored and adaptive transfusion approaches that enable clinicians to make real time adjustments.

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