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Systematic review article

Damage-Control Surgery Versus Early Definitive Management in Pediatric and Adolescent Trauma: A Systematic Review of Outcomes and Strategies

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Abstract

Study aim: we aimed to explore whether damage control strategies, damage control laparotomy, surgery (DCL, DCS) and damage control orthopedics (DCO), improve outcomes compared with early definitive surgery and early total care (EDS, ETC) in injured children and adolescents. **Methods:** We performed a systematic review of eight original studies (national databases, registries, single-center cohorts, an audit, a technique series, and a case report) including pediatric and adolescent trauma patients who required operative care. Reported outcomes included mortality, complications, length of stay (LOS), open-abdomen closure, and health-care use. Owing to heterogeneity, we used narrative synthesis and qualitatively appraised risk of bias. **Results:** Among children needing urgent laparotomy, DCL was used in 12–15% and was chosen for patients with worse physiology and higher injury severity. Compared with definitive laparotomy, DCL showed higher crude mortality (9% vs 2%) and longer LOS (17 vs 8 days), reflecting confounding by indication. In a national cohort of traumatic brain injury with femur fracture, DCO (15%) was associated with higher adjusted odds of inpatient death and resource use than ETC. Modern pediatric open-abdomen series reported high survival (93%) with primary fascial closure achievable in many cases, though prolonged open abdomen increased infection risk. **Conclusions:** In pediatric trauma, DCL, DCS, DCO are applied to the sickest patients and track with worse crude outcomes versus EDS, ETC, largely due to illness severity. Pediatric-specific indications and standardized outcome reporting are needed.

Keywords: pediatric trauma; damage control surgery; damage control orthopedics; early definitive surgery; open abdomen; outcomes.

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Introduction

Damage control (DC) concepts, rapid control of hemorrhage and contamination with delayed reconstruction, are integral to modern trauma care but remain variably applied and studied in children [1-5]. Inconsistency in reporting has hampered pooled inferences; a modified Delphi process recently defined a core outcome set for DCL (mortality, 30-day mortality, fascial closure and time to closure, abdominal complications, reoperation re-exploration, GI anastomotic leak, secondary intra-abdominal sepsis, enterocutaneous fistula, and 12-month function), enabling more comparable future research [1]. Concurrently, pediatric blunt solid-organ injury (SOI) management has evolved toward non-operative strategies under APSA-aligned guidance; when operative intervention is required, emphasis is placed on judicious imaging, transfusion thresholds, and minimizing resource use in stable children [2].

Physiologic differences in children heighten susceptibility to the "lethal triad" and rapid heat loss; DC surgery in pediatrics therefore borrows adult principles but adapts technical details (exposure, packing, temporary closure) to pediatric anatomy and thermoregulation [3,4]. DC resuscitation emphasizes early hemostatic transfusion, limitation of crystalloids, and avoiding hypocalcemia, hypothermia; pediatric shock recognition relies on indices beyond hypotension, given late blood-pressure changes in children [5]. Together, these frameworks argue that DC should be reserved for physiologically exhausted children while maintaining a low threshold to abort prolonged operations in deteriorating patients.

Pediatric evidence is dominated by observational cohorts, registry analyses, and institutional experiences. Reported DCL rates in children undergoing urgent laparotomy are modest, and outcomes appear strongly confounded by indication, i.e., DCL is performed in the sickest children. Similarly, for long-bone stabilization in polytrauma, the tension between DCO (temporary external fixation) and early total care (ETC) persists, with pediatric-specific data limited. This review synthesizes original pediatric studies to compare outcomes of DC approaches versus early definitive strategies and to describe open-abdomen results in children. We interpret findings in light of contemporary pediatric trauma guidance and DC resuscitation principles [1-5].

Methods

Protocol and eligibility: Following PRISMA guidance, we predefined the question: in pediatric trauma patients, what are the outcomes of damage control approaches (DCL, DCS, DCO) versus early definitive strategies (definitive laparotomy, ETC)? Inclusion criteria: original studies (any design) with pediatric, adolescent participants (typically ≤18-21 years as defined in each study); trauma requiring operative care (abdominal, thoracic, laparotomy and, or long-bone, fracture stabilization); report of DC strategy (DCL, DCS, DCO) and at least one clinical outcome (mortality, LOS, complications, closure metrics, utilization). Exclusion: non-trauma, adult- only cohorts, editorials without data.

Data items and extraction. We extracted: design, setting, population, age, mechanism, DC, definitive strategy definitions, primary, secondary outcomes (mortality, LOS, complications; for open abdomen, primary fascial closure, days to closure; for fracture management, death, complications, LOS, charges). Where adjusted analyses were available, adjusted estimates were captured.

A meta-analysis was not attempted due to design heterogeneity (definitions of DCL, populations, outcomes). We conducted a structured narrative synthesis, highlighting comparative findings (DCL, DCS, DCO vs definitive) where available, and describing open-abdomen outcomes. Summary tables present study characteristics and key outcomes.

Results

Study overview and characteristics

Eight studies spanning 2002-2025 met criteria: two national database cohorts of urgent pediatric laparotomy and of pediatric TBI with femur fracture[13,7]; one multinational, registry analysis including pediatric orthopedics [6]; one single-center pediatric DCL cohort [12]; one regional audit of pediatric trauma laparotomies from South Africa [9]; one open-abdomen outcomes series [10]; one pediatric DCL wound-vac technique series [8]; and a pediatric case report of DC for grade IV hepatic injury [11]. Across urgent laparotomy datasets, DCL prevalence was approximately 12-15% among children requiring emergent abdominal operation [12,13], with DCL patients consistently exhibiting worse presenting physiology (higher ISS, tachycardia, lower SBP and temperature) and greater transfusion needs [13]. For long-bone fractures in pediatric TBI, DCO (temporary external fixation) was employed in =15% [7]. Table 1 summarizes designs, settings, strategies, and populations.

Comparative outcomes: DCL, DCS vs definitive laparotomy (abdominal trauma)

Two large datasets compared DCL with definitive laparotomy among children requiring urgent abdominal operation. In the NTDB analysis (2010-2014), DCL (defined as a second laparotomy within 5-48 hours) occurred in 12%. DCL patients had higher ISS (median 25 vs 18), higher heart rate, lower SBP and temperature, and were more likely transfused pre-operatively [13]. Outcomes favored definitive laparotomy on crude comparison: longer LOS for DCL (17 vs 8 days) and higher mortality (9% vs 2%), consistent with sicker case-mix and confounding by indication [13]. Similarly, a single-center cohort (1996-2013) found 15% underwent DCL; overall survival in DCL was =55%, with median LOS 26 days, and DCL-associated complications including surgical site infection =18%, dehiscence 2%, and enterocutaneous fistula 2%. Multivariable analysis identified only higher ISS and lower arrival SBP as independent mortality predictors, not DCL per se [12]. A regional audit from South Africa reported a DCS rate =11% among pediatric trauma laparotomies with high mortality in the DCS subset (=37%), reflecting severe injury burden and penetrating mechanisms; overall mortality in the cohort was =5% [9].

Taken together, these studies indicate that DCL, DCS is reserved for physiologically deranged children and is not demonstrated to improve crude outcomes versus definitive laparotomy in unselected pediatric cohorts; rather, worse outcomes track with baseline severity [12,13]. Importantly, adjusted models (where available) suggest physiology and injury burden, not the label of DCL, drive mortality [12].

Open abdomen outcomes and closure

Pediatric open-abdomen (OA) experience is limited but growing. In a modern series (2015-2022), overall survival was =93%; primary tissue closure was achieved in =58%, with the remainder requiring mesh; wound vac was the most common temporary closure, and secondary infections were frequent, especially among those with prolonged OA [10]. Historic pediatric technique reports describe vacuum-packing and innovative bedside “corset-like” fascial approximation, enabling primary closure within days in two children and survival in 5, 6 cases [8]. These experiences underscore that temporary abdominal closure is feasible and often reversible in children when guided by resuscitative goals.

Orthopedic damage control vs early total care

In the TR-DGU registry spanning 2009-2014, among severe multiple-trauma patients with major extremity injury, children most often underwent ETC (=49% with AISExtremity≥3), whereas DCO increased with age and injury severity, including polyregional extremity injury; conservative care was used least. Notably, the study reported no clear outcome differences between children and adults, and identified injury severity and age as independent drivers of DCO use in children [6]. In a national pediatric cohort with TBI plus femur fracture, DCO was applied in =14.9%; DCO patients had greater illness severity and complications and, after multivariable adjustment, higher odds of inpatient death (OR =2.8), prolonged LOS (OR =1.26), and higher total charges (OR =1.79) compared with ETC [7]. While these association signals persisted after adjustment, residual confounding and coding constraints (timing, indications) remain plausible.

Indications and technical application of pediatric DCL.A detailed pediatric case illustrated multimodal DC in an 8-year-old with grade IV hepatic injury and lethal triad emergence:

perihepatic packing + temporary negative-pressure closure, immediate hepatic artery embolization, and planned delayed hepatectomy achieved recovery and timely discharge, showcasing cross-disciplinary DC pathways tailored to pediatric physiology [11]. These technical principles mirror adult DC while accounting for smaller cavities, heat loss, and tissue fragility [8,11].

Discussion

This review of eight pediatric, adolescent studies indicates that DC strategies (DCL, DCS, DCO) are applied to the sickest children, consistent with DC principles, and that crude outcomes appear worse than early definitive strategies due to case-mix rather than a demonstrable causal harm from DC itself. National and single-center datasets show higher ISS, deranged physiology, and greater transfusion among DCL recipients, with mortality and LOS correspondingly higher than definitive laparotomy; where modeled, ISS and hypotension, not the DCL label, predicted mortality [12,13]. For fractures, a national pediatric TBI cohort suggested DCO carried higher adjusted odds of death and resource use than ETC, but selection for DCO likely reflected unmeasured severity and neurologic trajectories [7]. Hence, pediatric DC should remain selective and physiology-guided, aligning with pediatric damage control fundamentals and hemostatic resuscitation practices [4,5].

The open-abdomen literature supports safety and feasibility in children, with high survival and primary closure in many cases when negative-pressure systems and staged approximation are used [8,10]. These findings dovetail with broader WSES guidance emphasizing early fascial closure, mitigation of infection, fistula risk, and cautious OA indications [14]. Standardized outcome reporting is needed; the core outcome set for DCL proposes a pragmatic minimum (mortality at defined intervals, fascial closure and timing, abdominal, major complications, fistula, and functional outcomes) to reduce reporting bias and facilitate meta-analysis [1].

Within pediatric trauma systems, variation in DCL usage mirrors adult practice heterogeneity and underscores the need for center-level performance feedback and prospective pediatric registries capturing DC indications and time-stamped physiology [15]. Pediatric SOI guidelines emphasize non-operative care for stable children; when operative damage control is necessary, integration with TEG-guided transfusion, limited crystalloids, and temperature maintenance is essential to avoid the lethal triad [2,5]. Classic pediatric DC surgical adaptations, transverse exposure in small children, gentle packing, rapid contamination control, and temporary closure, remain relevant [3,4].

Implications: (1) Pediatric DC should be reserved for physiologically compromised patients with clear triggers (persistent acidosis, coagulopathy, hypothermia, escalating transfusion), (2) when DC is undertaken, plan for early re-look and closure, (3) studies should adopt the core outcome set and report

Table 1. Characteristics of included studies

Study (year)	Design, setting	Population	DC strategy vs comparator	Key outcomes reported
Horst et al. 2019 [6]	Registry (TR-DGU), Germany	Severe trauma with extremity fractures; children vs adults	DCO vs ETC (orthopedics)	Strategy use by age, severity; LOS, complications, mortality; factors for DCO
Feingold et al. 2025 [7]	National inpatient sample, USA	Pediatric TBI with femur fracture (≤21y)	DCO vs ETC	Inpatient death, prolonged LOS, high charges (adjusted ORs)
Markley et al. 2002 [8]	Technique series, two centers (USA)	6 pediatric open-abdomen cases (sepsis, ACS)	Vacuum-packing temporary closure; corset approximation	Days with VAC, survival, primary closure feasibility
Reid et al. 2022 [9]	Single-center audit, South Africa	136 pediatric trauma laparotomies	DCS subset (n=16) vs overall	ICU use, complications, mortality overall and in DCS group
Spencer et al. 2024 [10]	Single-center cohort, USA	41-42 pediatric open-abdomen cases (2015-2022)	Open abdomen; "prolonged OA" subgroup	Survival, primary closure rate, infections, mesh use
Kobayashi et al. 2016 [11]	Case series, Japan	8-year-old, grade IV blunt liver injury	DCL with packing, temporary closure, TAE, delayed hepatectomy	Survival; rationale based on lethal triad, ACS
Villalobos et al. 2017 [12]	Single-center cohort, USA	371 pediatric trauma laparotomies	DCL (n=56) vs definitive laparotomy	Mortality, LOS, complications; predictors of death
Polites et al. 2017 [13]	NTDB (2010-2014), USA	2,989 pediatric urgent laparotomies	DCL (surrogate) vs definitive	DCL rate, physiology, transfusion, LOS, mortality

Table 2. Key outcomes comparing DC strategies vs definitive approaches

Domain	Abdominal trauma (DCL, DCS vs definitive)	Long-bone stabilization (DCO vs ETC)	Open abdomen
Utilization	DCL =12-15% in urgent pediatric laparotomy cohorts [12,13]	DCO =15% in pediatric TBI+femur [7]; DCO increases with age, severity in registry [6]	Contemporary pediatric OA cohorts (n=41-42) reported
Severity at baseline	DCL, DCS cohorts had higher ISS, tachycardia, lower SBP, temp; more transfusion [13]	DCO cohort: more extreme illness severity [7]	Indications: second-look, discontinuity, resuscitation, ACS
Mortality	Higher crude mortality with DCL (9% vs 2%) and in DCS subset of audit (=37%) [9,13]; ISS & SBP predicted death, not DCL per se [12]	DCO associated with higher adjusted odds of death (OR =2.8) vs ETC [7]	Survival =93% overall; closure achieved in majority [10]
LOS, resource use	Longer LOS with DCL (17 vs 8 days) [13]	Prolonged LOS and higher charges with DCO (adjusted) [7]	Days to closure varied; mesh required in =42% [10]
Complications	SSI =18%, ECF =2% in DCL cohort [12]	Higher early complications with DCO [7]	Secondary infections higher with prolonged OA [10]
Determinants	Physiology, injury burden drive DCL use and outcomes [12,13]	Severity and TBI likely drive DCO selection and outcomes [7]	Technique (VAC), timely closure influence results [8,10]

adjusted analyses controlling for pre-operative physiology, and (4) in orthopedic polytrauma, consider ETC when safely feasible in children, with DCO for unstable physiology or competing priorities (severe TBI), while acknowledging residual confounding in current data [6,7].

Limitations of the evidence include retrospective designs, surrogate DCL definitions, coding constraints, center variation, and limited pediatric RCTs. Nonetheless, convergent findings across datasets support selective, physiology-first pediatric DC application aligned with contemporary pediatric trauma and resuscitation guidance [1-5,14,15].

Conclusion

In pediatric and adolescent trauma, damage control strategies (DCL, DCS, DCO) are appropriately concentrated among children with severe physiologic derangement and higher injury burden. Compared with early definitive surgery, DC cohorts show higher crude mortality, complications, and LOS, reflecting confounding by indication more than intrinsic harm. Open-abdomen approaches achieve high survival with primary closure feasible in many children. Future pediatric research should apply standardized DC outcomes, control rigorously for pre-operative physiology, and clarify pediatric-specific indications and thresholds to optimize selection between damage control and early definitive strategies.

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