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# Estimating the Need for Prehospital Blood Transfusion in Trauma: Insights from the German Trauma Registry and HEMS Data

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# Abstract

**Background:** Hemorrhagic shock remains a leading cause of preventable death after major trauma. Prehospital blood transfusion (PHBT) has been introduced in several trauma systems but is rarely used in Germany. The target population for PHBT is not well defined. Patients requiring early blood transfusion likely represent the most relevant group for this intervention. This study estimated the number of trauma patients within German Helicopter Emergency Medical Services (HEMS) likely to require early relevant transfusion. A simple prehospital risk score based on routinely collected mission data was developed to identify these patients.

**Methods:** We conducted a retrospective cohort study using anonymized data from ADAC Luftrettung (2018–2022). Early relevant transfusion (ERT) was defined as the administration of ≥5 units of packed red blood cells (PRBC) prior to ICU admission, based on TraumaRegister DGU® documentation. As no existing score met the operational requirements for prehospital use, we developed a new logistic regression model using 46,807 trauma cases. The resulting Luftrettung (LRG) Score was based exclusively on prehospital variables and applied to 28,990 ADAC trauma patients to estimate transfusion probability.

**Results:** The LRG Score demonstrated good discriminatory ability (Area under the curve AUC_0.86; 95% CI: 0.85–0.87) for predicting early relevant transfusion. In the ADAC cohort, 954 patients (3.3%) were estimated to require ≥5 units of PRBC. Transfusion risk exceeded 10% from a score of 7 and peaked at 56% for scores ≥13.

**Conclusion:** This study provides a nationwide, registry-based estimate of prehospital blood transfusion eligibility in Germany. The LRG Score enables identification of trauma patients at risk for early relevant transfusion (≥5 PRBC prior to ICU admission) using only prehospital data, ensuring methodological consistency and operational feasibility. These findings support future observational research, inform strategic planning, and lay the groundwork for pilot implementation of PHBT in civilian trauma systems.


# Background

Hemorrhagic shock is a leading cause of preventable death in major trauma patients [1]. Prompt hemorrhage control and early blood product transfusion are crucial to prevent secondary organ damage or death due to exsanguination. Over the past decade, prehospital blood product transfusion (PHBT) has been introduced in clinical practice in several trauma systems [2], primarily influenced by recent armed conflict experiences [3] and the rationale for initiating transfusion as early as possible in patients with severe bleeding injuries [4]. However, due to a perceived lack of evidence, PHBT remains underutilized in Germany.

The randomized Prehospital Air Medical Plasma (PAMPer) trial demonstrated improved survival with prehospital plasma administration [5]. The Control of Major Bleeding after Trauma (COMBAT) trial, which investigated prehospital plasma transfusion in an urban setting, did not confirm these findings.

Nonetheless, a meta-analysis of both trials suggests a survival advantage for plasma recipients if transport times exceed 20 minutes [6]. A post-hoc analysis of the PAMPer trial data revealed that the combination of packed red blood cells and plasma offered the greatest survival benefit, followed by plasma alone, and then packed red blood cells alone – each superior to crystalloid resuscitation [7]. These findings have accelerated the expansion of prehospital blood transfusion programs, which are now standard practice in several physician staffed EMS systems [8, 9].

However, the recent randomized Resuscitation with Pre-Hospital Blood Products (RePHILL) trial [10] questions this practice, as it failed to demonstrate a beneficial effect of PHBT compared to normal saline. Unfortunately, RePHILL suffered from an indistinct composite outcome and an overestimated effect size [11], as well as not meeting the enrolment timeline, leading to early termination. As a result, despite significant effort invested in RePHILL, it remains unclear which patient groups might benefit from PHBT.

Considering the potentially small effect size of PHBT in civilian trauma and the recruitment challenges faced by RePHILL, we propose that prospective cohort studies may better address the remaining questions rather than randomized controlled trials. In preparation for such trials, we have reviewed the operational data of Europe's largest Helicopter Emergency Service (HEMS) operator, 'ADAC Luftrettung gGmbH (ADAC LRG),'which conducts approximately 50,000 missions per year.

The primary objective of this study was to estimate the number of severely injured patients within the ADAC HEMS cohort likely to require early relevant transfusion (ERT), defined as the administration of ≥ 5 units of packed red blood cells (PRBC) prior to ICU admission. We assumed that these patients represent the subgroup most relevant for PHBT. Hemorrhagic shock is time-critical, and early resuscitation with blood products has been associated with improved survival [12]. This subset could serve as a target population for future prospective studies evaluating the clinical impact of prehospital transfusion in the civilian setting.

To identify this patient subgroup using routine mission data, we initially planned to apply an established transfusion prediction score. However, it became evident during the study that no existing model met the practical requirements for prehospital use within our dataset. Most scores relied on in-hospital diagnostics or were developed in trauma systems not directly comparable to the German civilian context [13]. Consequently, a secondary objective emerged: the development of a simple, operationally feasible risk score based solely on prehospital variables – the Luftrettung (LRG) Score. This score was derived from the German National Trauma Registry (TraumaRegister DGU®) and designed to support risk stratification, inform future research, and guide pilot implementation of PHBT in Germany.

# Methods

***Study Design and Data Sources***

We conducted a retrospective cohort study using anonymized electronic mission records from ADAC LRG covering the period from 1 January 2018 to 31 December 2022. The TR-DGU served as the reference dataset for model development. Ethical approval was obtained from the University of Münster (ref #2022-367-f-S). Scientific analyses of the TR-DGU data were approved according to a peer review process governed by the TR-DGU publication guidelines (Project ID 2024-010).

All data handling complied with the EU General Data Protection Regulation (GDPR). Patient consent was not required, as all data were fully anonymized. This manuscript adheres to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

A completed STROBE checklist is provided as supplementary material.

***The TraumaRegister DGU®***

The TR-DGU of the German Trauma Society (Deutsche Gesellschaft für Unfallchirurgie, DGU) was founded in 1993 to provide a multicenter database for pseudonymized and standardized documentation of severely injured patients. Participating hospitals are primarily located in Germany, but also include sites in Austria, Switzerland, and other countries. Data are collected prospectively from the site of injury until hospital discharge, based on a standardized dataset that includes four consecutive phases: prehospital, emergency room and initial surgery, intensive care unit (ICU), and discharge. The inclusion criterion is admission to hospital via emergency room with subsequent ICU/ICM care or reach the hospital with vital signs and die before admission to ICU. The documentation is performed by local staff trained in trauma documentation and quality assurance. The dataset includes demographics, injury patterns, comorbidities, management, course in ICU, laboratory findings including transfusion data, and outcomes such as organ failure and mortality.

The infrastructure for documentation, data management, and data analysis is provided by AUC – Academy for Trauma Surgery (AUC - Akademie der Unfallchirurgie GmbH), a company affiliated to the German Trauma Society. The scientific oversight is provided by the Committee on Emergency Medicine, Intensive Care and Trauma Management (Sektion NIS) of the DGU. Participating hospitals submit their data into a central database via a web-based application. Currently, approximately 700 hospitals contribute data to the registry.

***Definition of Early Relevant Transfusion vs. Massive Transfusion***

Massive transfusion has traditionally been defined as ≥10 units of packed red blood cells (PRBC) within 24 hours; however, no universally accepted definition exists, and early transfusion–based endpoints have been proposed to reduce survivor bias. In this study, early relevant transfusion (ERT) was defined as the administration of ≥5 PRBC prior to ICU admission. This pragmatic threshold reflects clinically meaningful, time-critical hemorrhage and aligns with the structure of the TraumaRegister DGU® documentation. It is also consistent with contemporary principles of damage control resuscitation and captures patients with substantial early transfusion requirements (14).

### *Limitations of Prehospital Data and Rationale for Score Development*

Due to German data protection laws, it is not permitted to link individual datasets across healthcare sectors without explicit patient consent. As a result, direct access to hospital transfusion for patients treated by ADAC HEMS was not possible. To address this limitation, we evaluated existing scoring systems for their ability to estimate transfusion requirements using prehospital data. Many established models include variables – such as laboratory results or ultrasound findings – not routinely recorded in prehospital documentation [13]. Moreover, these scores were often developed and validated in trauma systems that differ significantly from the German civilian context, limiting their applicability [15].

To identify a suitable transfusion prediction score, we defined the following selection criteria:

1. Use of variables routinely available in the prehospital setting;
2. Documentation compatibility with both the ADAC LRG and TR-DGU datasets;
3. Transfusion endpoint reflecting early critical hemorrhage

(≥5 PRBC prior to ICU admission);

4. Applicability to the German trauma care system.

Only one score – the modified Trauma-Induced Coagulopathy Clinical Score (mTICCS) [16] – met our inclusion criteria. It had been validated against the transfusion of ≥5 units of PRBCs prior to ICU admission and could be reconstructed using variables available in the ADAC dataset. However, when applied to recent data from the TR-DGU, mTICCS demonstrated poor discrimination and sensitivity, making it unsuitable for our study population.

In response to the limitations of the existing models, we developed a new prediction model specifically tailored to the available prehospital data – the LRG Score.

### *Development of the LRG Score*

The LRG Score was developed using logistic regression modelling on a cohort of 46,807 adult trauma cases from the TR-DGU (2018–2022). Inclusion criteria included age ≥18 years, Injury Severity Score (ISS) ≥9, primary admission to a trauma center in Germany, complete prehospital documentation, and use of the standard documentation form.

Candidate variables were selected based on their availability in both datasets and relevance to hemorrhagic shock. These included systolic blood pressure, heart rate, suspected injury pattern (e.g. abdomen, pelvis, extremities), mechanism of injury, administration of catecholamines, and prehospital cardiac arrest.

All variables were converted into categorical predictors. Logistic regression coefficients were transformed into rounded integer point weights, with 1 point corresponding approximately to an odds

ratio of 1.5. The resulting LRG Score ranged from 0 to 17 points.

Model performance was assessed using Nagelkerke's $R^2$ and the area under the receiver operating characteristic (ROC) curve with 95% confidence intervals.

***Application to the ADAC Cohort***

The final LRG Score was retrospectively applied to all adult major trauma patients treated by ADAC HEMS between 2018 and 2022. For each score value, the probability of ERT (as derived from the TR-DGU model) was multiplied by the number of ADAC patients in that category. This provided an estimated number of PHBT-eligible cases across the cohort.

# Results

***Performance of the LRG Score***

Logistic regression was performed on 46,807 patients from the TR-DGU, documented across 231 hospitals, using the need for ERT as the dependent variable. The mean age was 56 years (SD 20), and 71% were male. The average Injury Severity Score (ISS) was 20.9 (SD 11.4), with 64% of patients scoring ≥16. Penetrating trauma accounted for 4.1% of cases. Overall, 10.0% received a blood transfusion prior to ICU admission, and 3.5% required ≥5 units of PRBC (Table 2).

Easily available variables available in both datasets served as independent predictors. Suspected injuries were those classified as moderate or severe in nine body regions by the emergency physician. Predictors, or categories of predictors, with limited power (odds ratio (OR) < 1.50) were removed from the model. The remaining model is presented in Table 1. Nagelkerke's $R^2$ was 0.296 indicating moderate overall fit.

The coefficients of the model were then transformed into simple integer values ranging from 1-4, where 1 point was given if the OR was < 2.00. The sum of point values ranges from 0 – 17 where scores ≥ 12 points were observed in less than 2% of cases. Of the included patients, 1,647 (3.5%) received ≥5 units of PRBC. The predicted probability of receiving ERT is presented in Figure 1. The score demonstrated good discriminatory power, with a steep increase in transfusion probability from score values ≥5. Patients with a score ≥7 had a predicted transfusion probability >10%, those with ≥9 points exceeded 20%, and scores ≥13 exceeded 50%. The area under the ROC curve was 0.86 (95% CI 0.85 – 0.87).

This allowed for meaningful stratification of patients with respect to their likelihood of requiring ERT, supporting its subsequent application to the ADAC LRG cohort for estimation purposes.

**Table 1. Results of logistic regression analysis, and derived score points for the LRG Score**

| Predictor | coefficient | OR | 95% CI of OR | Score points |
|---|---|---|---|---|
| Systolic blood pressure (mmHg) | | | | |
| < 90 mmHg | 2.08 | 8.00 | 6.86 – 9.34 | 4 |
| 90–99 mmHg | 1.37 | 3.94 | 3.25 – 4.79 | 3 |
| 100–109 mmHg | 1.11 | 3.04 | 2.50 – 3.69 | 2 |
| 110–119 mmHg | 0.43 | 1.53 | 1.22 – 1.93 | 1 |
| ≥ 120 mmHg (reference) | | | | 0 |
| Heart rate (beats/min) | | | | |
| ≥ 130 | 1.30 | 3.68 | 3.17 – 4.26 | 3 |
| 100–129 | 0.67 | 1.95 | 1.72 – 2.22 | 1 |
| < 100 (reference) | | | | 0 |
| Suspected injuries | | | | |
| Lower extremities | 0.79 | 2.20 | 1.47 – 2.62 | 2 |
| Abdomen | 0.51 | 1.67 | 1.47 – 1.90 | 1 |
| Pelvis | 0.43 | 1.53 | 1.35 – 1.74 | 1 |
| Penetrating trauma | 1.15 | 3.17 | 2.59 – 3.87 | 2 |
| Catecholamine administration | 0.75 | 2.11 | 1.85 – 2.41 | 2 |
| Prehospital CPR | 0.42 | 1.52 | 1.27 – 1.82 | 1 |
| High fall (>3 m) | 0.66 | 1.93 | 1.61 – 2.32 | 1 |
| Traffic accident | 0.58 | 1.79 | 1.53 – 2.10 | 1 |

***Legend Table 1***. *Multivariable logistic regression coefficients, odds ratios (OR; 95% CI), and corresponding point allocation used to construct the LRG Score for prediction of probability of early relevant transfusion (ERT; ≥5 PRBC prior to ICU admission) in the TR-DGU cohort. Reference categories are indicated; points are summed across predictors to calculate the total score. Abbreviations: SBP, systolic blood pressure; OR, odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation.*

***The ADAC LRG Patient cohort***

Of 29,591 adult major trauma patients treated by ADAC HEMS between 2018 and 2022, 601 were excluded due to missing data. The final analysis included 28,990 patients. The mean age was 50 years (SD 20), and 71% of the cohort were male. Injury severity was assessed using the National Advisory

Committee for Aeronautics (NACA) Score, with a median of 4(IQR 3–5), indicating predominantly moderate to severe injuries. Penetrating trauma accounted for 4.2% of all cases (table 2).

***Application of the LRG score to the ADAC dataset***

The LRG Score was applied to this cohort to estimate the probability of ERT based on prehospital parameters.

Of these patients, 954 (3.3%) were estimated to have required ERT. Score-specific transfusion probabilities increased with rising LRG Score categories (Table 3).

The distribution of trauma patients and the estimated number requiring early relevant transfusion across LRG Score categories are shown in Figures 1 and 2, respectively.

While transfusion likelihood remained below 2% for scores ≤3, it increased steadily from score 5 onward and exceeded 50% in patients with a score ≥13.

**Table 3. Estimated Probability of Early Relevant Transfusion by LRG Score**

| LRG Score | Total number of ADAC trauma patients | Probability of ERT | 95% confidence interval | Projected number of ADAC patients requiring ERT |
|---|---|---|---|---|
| 0 | 6,037 | 0.4% | 0.3–0.6 | 24.1 |
| 1 | 6,200 | 0.6% | 0.5–0.7 | 37.2 |
| 2 | 5,374 | 1.0% | 0.8–1.2 | 53.7 |
| 3 | 4,004 | 1.5% | 1.2–1.8 | 60.1 |
| 4 | 2,588 | 2.3% | 1.8–2.7 | 59.5 |
| 5 | 1,587 | 6.8% | 5.9–7.7 | 107.9 |
| 6 | 1,004 | 8.8% | 7.6–10.1 | 88.4 |
| 7 | 737 | 12.8% | 11.1–14.4 | 94.3 |
| 8 | 480 | 17.6% | 15.5–19.8 | 84.5 |
| 9 | 371 | 28.3% | 25.0–31.7 | 105.0 |
| 10 | 246 | 31.4% | 26.8–35.9 | 77.2 |
| 11 | 185 | 40.3% | 34.1–46.6 | 74.6 |
| 12 | 103 | 45.2% | 36.4–53.9 | 46.6 |
| ≥13 | 74 | 56.0% | 42.2–69.8 | 41.4 |
| Total | 28,990 | 3.3% | 3.1–3.5 | 954.5 |

***Legend Table 3.*** *Distribution of ADAC Luftrettung trauma patients (2018–2022) by LRG Score with predicted probability and projected number of patients requiring early relevant transfusion (ERT). The column Total number of patients includes all trauma patients treated by ADAC Luftrettung (HEMS) during the study period and eligible for analysis. Probability of ERT and corresponding 95% confidence intervals represent predicted probabilities of early relevant transfusion (≥5 units of packed red blood cells [PRBC] prior to ICU admission), derived from TraumaRegister DGU® data.*

*The Projected number of patients requiring ERT was calculated by applying these predicted probabilities to the ADAC cohort size within each score category and may therefore result in non-integer values. These projections represent estimated case numbers and do not imply treatment indication or clinical decision thresholds. PRBC = packed red blood cells*

**Table 2. Comparison of TR-DGU development cohort and ADAC HEMS application cohort (2018–2022)**

| Characteristic | TR-DGU Development Cohort (n = 46,807) | ADAC HEMS Cohort (n = 28,990) |
|---|---|---|
| Age, mean (SD), years | 56 (20) | 50 (20) |
| Male sex, n (%) | 33,233 (71%) | 20,583 (71%) |
| Injury severity measure | ISS | NACA |
| ISS, mean (SD) | 20.9 (11.4) | – |
| ISS ≥16, n (%) | 29,956 (64%) | – |
| NACA score, median (IQR) | – | 4 (3–5) |
| Penetrating trauma, n (%) | 1,919 (4.1%) | 1,218 (4.2%) |
| Any transfusion prior to ICU admission, n (%) | 4,681 (10.0%) | Not available |
| Early relevant transfusion (ERT)*, n (%) | 1,647 (3.5%) | 954.5 (3.3%)† |

***Legend Table 2:*** ** ERT defined as ≥5 units of packed red blood cells (PRBC) prior to ICU admission.*

*† Projected number derived from TR-DGU–based predicted probabilities applied to the ADAC cohort; may result in non-integer values. Observed transfusion outcomes are not available for the ADAC dataset.*

# Discussion

Using the LRG Score applied to nearly 29,000 ADAC HEMS trauma patients, we estimated that 3.3% would require early relevant transfusion (ERT; ≥5 PRBC prior to ICU admission). Because the score relies solely on routinely collected prehospital data, it enables risk stratification without the need for in-hospital data linkage. These results provide an estimate of expected transfusion demand relevant to PHBT programs within ADAC Luftrettung. Patients with LRG Scores ≥ 7 (predicted probability > 10% for ERT) represent a subgroup with substantially higher transfusion risk and may be an appropriate focus for future PHBT research.

Our goal was not to prompt immediate clinical implementation of PHBT but to provide a foundation for future research. Recent randomized controlled trials, such as RePHILL [10], have faced major challenges including complex logistics, limited recruitment, and early termination [11]. Despite considerable effort, these studies have not clearly identified trauma subgroups that benefit most from prehospital transfusion. This highlights the need for alternative study designs to better define appropriate target populations before broader implementation of PHBT programs. In this context, registry-based observational cohort studies provide a valuable approach to generate evidence from routine clinical practice and guide future research [17].

Several factors continue to limit wider adoption of PHBT. Although observational studies have suggested potential survival benefits, randomized trials have produced inconsistent results [11]. In addition, the optimal composition of prehospital transfusion strategies—whether packed red blood cells, plasma, whole blood, or balanced transfusion protocols—remains uncertain [18]. In Germany, implementation is further complicated by the decentralized structure of the prehospital emergency medical system and associated logistical challenges [17].

Many recent investigations have focused primarily on mortality as an outcome measure for evaluating prehospital transfusion strategies. However, further research is needed to assess additional patient-centered outcomes such as long-term survival, neurological recovery, and quality of life [19].

The rationale for PHBT is grounded in the principles of damage control resuscitation. Observational analyses, including studies from PAMPer and the US Joint Trauma System, have suggested improved outcomes when blood products are administered early, particularly in patients with prolonged prehospital transport times [4, 20, 21].

Across Europe, PHBT has been implemented in several physician-staffed EMS systems. In contrast, Germany remains comparatively restrictive: an international survey reported that fewer than 10% of German HEMS bases routinely carry blood products [17].

Previous analyses of TR-DGU data suggest that between 300 and 1,800 trauma patients annually in Germany might require early transfusion support [22]. Using alternative criteria such as massive transfusion (≥ 10 PRBC within 24 hours) combined with physiological shock indicators, other studies estimate that approximately 13 patients per HEMS base per year could qualify for PHBT [15].

The LRG Score was derived exclusively from prehospital parameters that are consistently documented in both the TraumaRegister DGU® and ADAC mission records. Development and application were restricted to the same time period (2018–2022) to minimize potential bias. Because transfusion outcomes are not available within the ADAC mission dataset, the cohort was used as an application cohort to project expected case numbers rather than to perform external validation.

Beyond research applications, the LRG Score may also have operational utility. EMS systems or regional trauma networks could use the score to estimate expected transfusion demand based on mission profiles when considering PHBT implementation. The score may also help identify regions or bases suitable for pilot programs, particularly in rural settings with long transport times or limited access to trauma centers.

At present, the score should be regarded as a retrospective estimation tool. Future integration into electronic mission documentation systems could enable automated real-time calculation and early identification of high-risk patients. Such functionality might also allow earlier hospital notification in cases with a high predicted probability of major hemorrhage, facilitating preparation for potential massive transfusion.

However, such applications require external validation and prospective evaluation before clinical adoption. Until then, the score should primarily be considered a tool for research planning and service development.

This study has several limitations. Most importantly, the analysis relies on projected rather than observed transfusion events within the ADAC cohort. Nevertheless, the prediction model was developed using high-quality registry outcome data and matched closely to the available prehospital variables. Prospective validation in operational EMS settings will be necessary to further assess its performance.

Another limitation relates to the definition of critical hemorrhage used in this study. We defined ERT as transfusion of ≥ 5 PRBC prior to ICU admission. Although this threshold better reflects early life-threatening bleeding than the traditional massive transfusion definition (≥ 10 units within 24 hours) [14], it remains a pragmatic surrogate. Patients who die before hospital arrival or before reaching this transfusion threshold are not captured. Additionally, differences in hospital transfusion protocols and treatment pathways may influence comparability between centers.

In conclusion, this study provides a nationwide estimate of early transfusion demand within the German HEMS system using registry-derived data. By developing and applying a pragmatic prediction score based exclusively on prehospital variables, we identified a subgroup of trauma patients with a substantially increased probability of requiring early transfusion. These findings provide a foundation for future observational studies, support strategic planning, and may help guide targeted pilot implementation of PHBT within civilian trauma systems in Germany

# Declarations

# Author Contribution

J.S. responsibility for the main manuscript text, review; L.S.S. performed statistical analysis, R.L.calculated data and statistical analysis in the name of DGU; K.C.T. reviewed, prepared figures; all authors reviewed the manuscript

# Data Availability

datasets were used from the electronically stored medical records from the HMS operator; additionally data were used from the trauma register of German association of traumatology; all data were anonymized

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# Figures

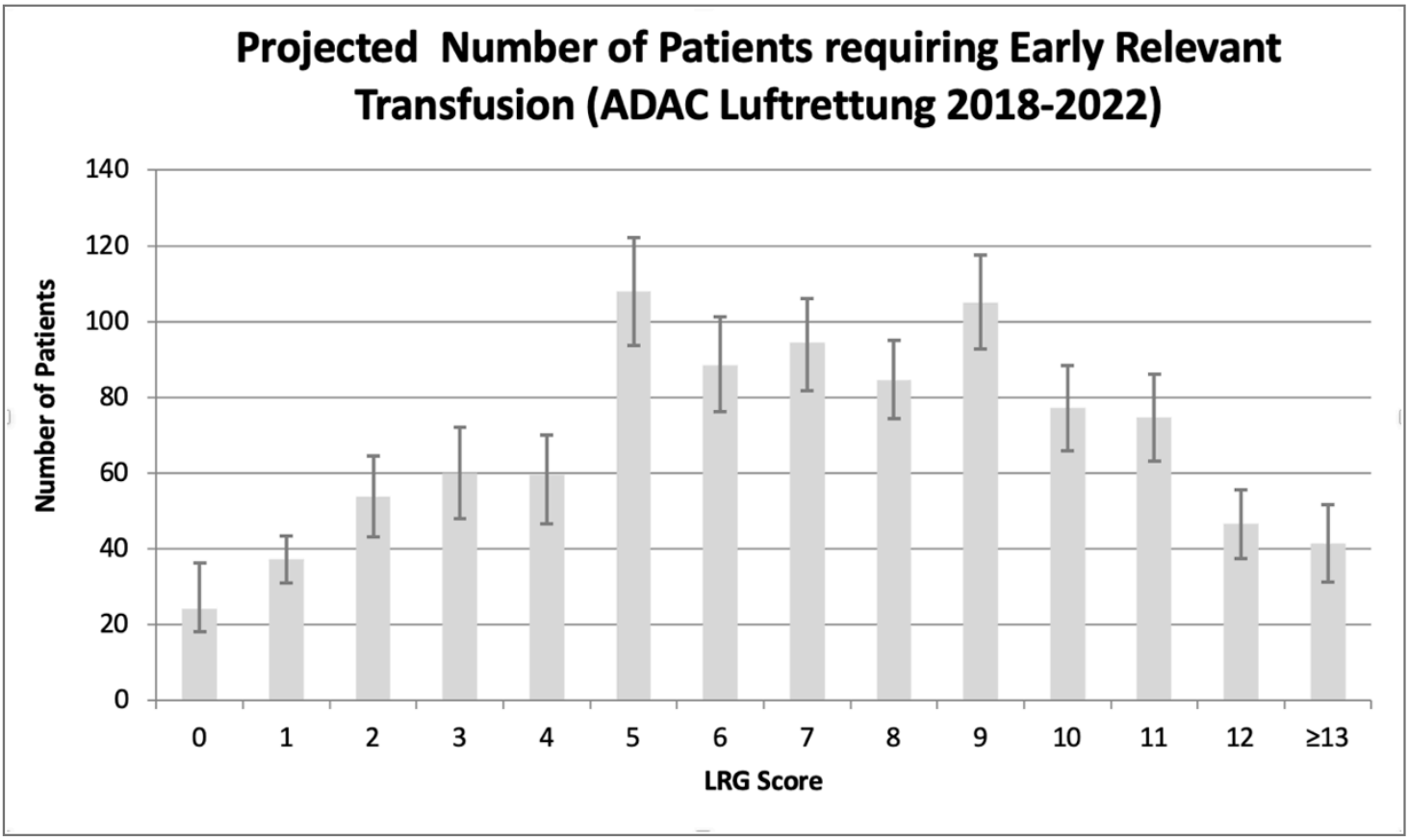



**Figure 1**

**Distribution of ADAC HEMS trauma patients by LRG Score category (2018–2022)**

***Legend Fig. 1:*** *Total number of trauma patients stratified by LRG Score, applied to the ADAC HEMS cohort (n = 28,990).*
*Most patients had scores between 0 and 3. Higher scores were progressively less frequent, reflecting the expected distribution of clinical severity in a large civilian trauma cohort. The LRG Score was developed to estimate the probability of early relevant transfusion (ERT; ≥5 units of PRBC prior to ICU admission based on prehospital parameters. The red curve displays the observed probability of relevant transfusion by LRG Score, based on patient data from the German TraumaRegister DGU®. Error bars represent 95% confidence intervals. The probability increases sharply with higher scores.*

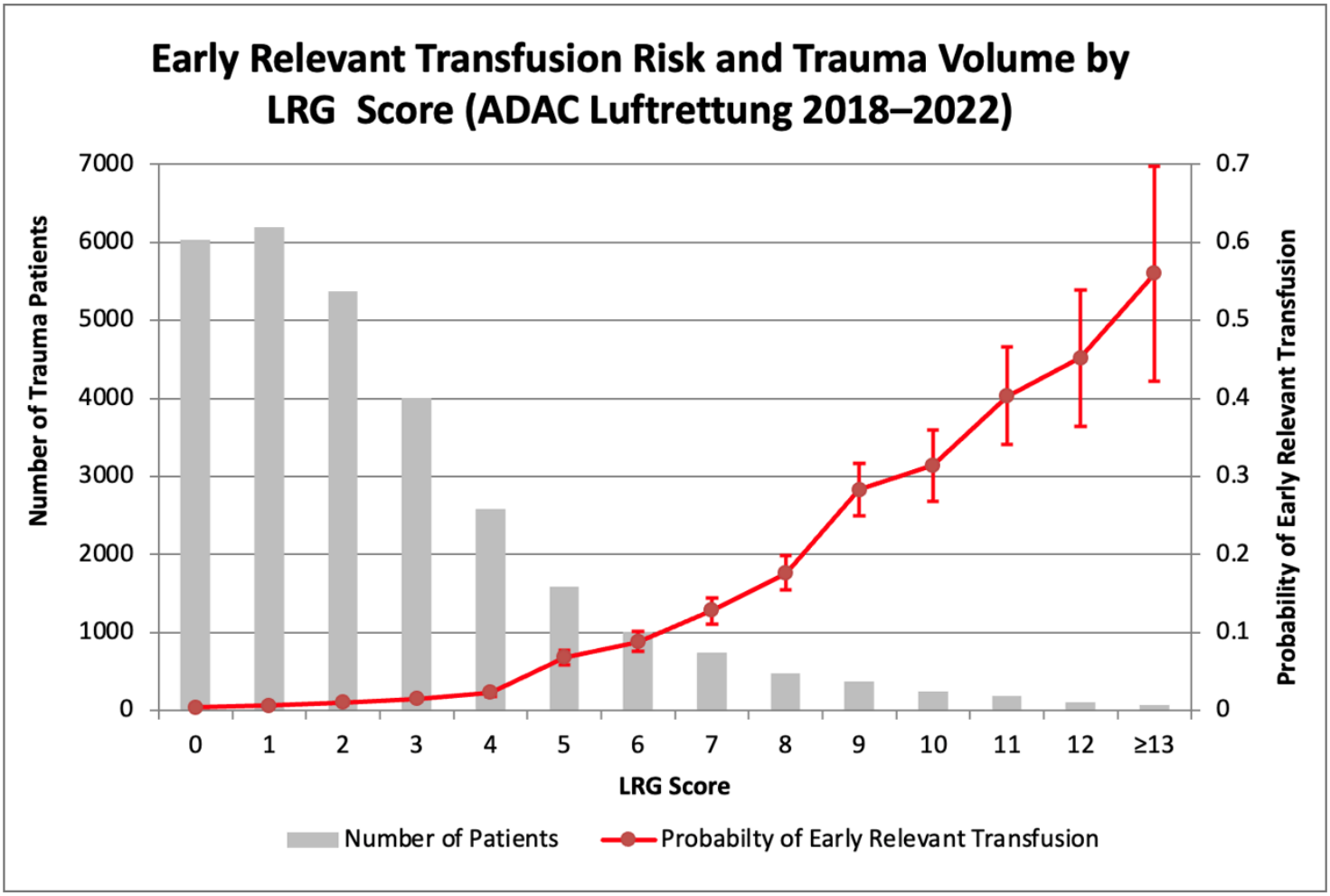



**Figure 2**

**Estimated probability and frequency of Early Relevant Transfusion (≥5 PRBC units)**

**by LRG Score category**

***Legend Fig. 2:*** *Estimated number of ADAC trauma patients requiring relevant transfusion (≥5 units of PRBC) from 2018 to 2022, stratified by LRG Score. Bars show the expected number of patients per score group, calculated by applying observed transfusion probabilities (derived from the TraumaRegister DGU®) to the ADAC cohort (n = 28,990). Error bars represent 95% confidence intervals. The peak transfusion burden appears in patients with scores between 5 and 9, reflecting both increased transfusion risk and a substantial patient volume in these strata.*