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Operational assumptions underlying extracorporeal resuscitation eligibility models

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In their manuscript published in the *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, Grimm et al. present a single-region temporospatial modelling study evaluating the potential reach of different extracorporeal resuscitation (ECPR) delivery strategies in a mixed urban-rural German region [1]. Using a 10-year cohort of 1,696 patients with out-of-hospital cardiac arrest and attempted resuscitation, the authors estimated that 20.5% of patients met their local ECPR eligibility criteria at the time of emergency medical services (EMS) arrival, whereas only 8.8% met a more restrictive modified ELSO definition [2]. They subsequently modelled three ECPR delivery strategies: simultaneous dispatch of a dedicated prehospital ECPR team, dispatch after 10 min of on-scene evaluation by the primary EMS team, and an in-hospital ECPR strategy, incorporating both geospatial and procedural time estimates. Although approximately one in five patients were initially considered eligible under the local protocol, fewer than 1% could receive hospital-based ECPR within the recommended 60-minute low-flow window [2]. In contrast, 95% of eligible patients could receive ECPR within 60 min with simultaneous dispatch of a dedicated prehospital ECPR team, compared with 72% when dispatch occurred only after 10 min of on-scene evaluation by the primary EMS team. These findings provide important data regarding the potential impact of alternative ECPR delivery strategies and represent a valuable addition to the growing body of literature informing ECPR system design.

Extracorporeal cardiopulmonary resuscitation is increasingly recognized as a promising therapy for carefully selected patients with refractory out-of-hospital cardiac arrest [3, 4]. As survival is closely linked to low-flow duration, timely access to ECPR remains one of the greatest challenges to successful program implementation [5]. Rapid transport to ECPR-capable centres is often constrained by geography and logistics [6, 7]. Furthermore, initiating transport early during ongoing cardiac arrest may compromise resuscitation quality and reduce the opportunity for patients to achieve return of spontaneous circulation with continued on-scene resuscitation [8, 9]. Prehospital ECPR may offer a solution by bringing extracorporeal support directly to the patient [5]. Given the

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complexity, cost, and resource intensity of ECPR, temporospatial modelling studies have become valuable tools for estimating case volumes and geographic accessibility, comparing alternative delivery strategies, and informing regional system design [6, 7, 10]. However, the interpretation of these studies depends heavily on the operational assumptions embedded within their models.

While all modelling studies necessarily rely on assumptions, the operational parameters underpinning ECPR eligibility models are generally represented as fixed values within each scenario. In the study by Grimm et al., key variables such as dispatch timing, transport duration, procedural intervals, and ECPR initiation time are predefined for each delivery strategy, allowing meaningful comparisons across alternative models [1]. In reality, however, these parameters are inherently variable and influenced by numerous operational factors, including recognition of ECPR eligibility, scene accessibility, patient extraction, building characteristics, weather conditions, competing emergency calls, team availability, and procedural complexity. Many of these delays are likely to follow positively skewed distributions, with a practical lower limit but occasional, clinically important delays. Because the principal outcome of these models is whether ECPR can be initiated within a fixed 60-minute low-flow threshold, even modest variation in one or more operational parameters may alter whether an otherwise eligible patient is considered reachable within the modelled treatment window. Consequently, deterministic models inevitably compress the true operational variability and produce point estimates rather than probability estimates. Although probabilistic modelling approaches could better characterize this uncertainty, their validity depends on the availability of empirical data to inform the distributions of key operational parameters, such as transport time or cannulation duration. Other parameters, including the time required to recognize ECPR eligibility and to access the patient, remain poorly characterized or inherently difficult to measure. In addition, other operational factors influencing ECPR delivery, such as competing ECPR missions, may not yet be explicitly represented in current models. The resulting estimates should therefore be interpreted as the performance of an idealized operational scenario rather than precise predictions of real-world ECPR system performance.

A second consideration relates to how ECPR eligibility itself is modelled. In the study by Grimm et al., eligibility was determined using variables available in the retrospective registry, including age, witnessed status, no-flow duration, arrest aetiology, and initial rhythm [11]. While these variables allow consistent retrospective classification, they represent only part of the information used to determine ECPR candidacy in clinical practice. As acknowledged by the authors, potentially important factors such as comorbidities and physiological parameters were not available and could further reduce the number of patients ultimately considered eligible [1]. For variables that are available retrospectively, however, models benefit from verified information that may have been incomplete or inaccurate when ECPR decisions were made in real time. Lunz et al. recently illustrated this discrepancy: among 213 patients cannulated after being considered eligible on scene, only 137 (64.3%) continued to fulfill all predefined eligibility criteria after subsequent verification [12]. Notably, discrepancies frequently involved fundamental variables such as whether the arrest was witnessed and the estimated duration of no-flow. Finally, even when such information is available, predefined criteria may not translate directly into treatment decisions. Demers et al. reported that 30 of 41 (73%) patients undergoing ECPR had at least one deviation from their institutional decision-making algorithm [13]. Thus, retrospectively modelled eligibility, eligibility perceived in real time, and actual ECPR treatment represent related but distinct populations, with potentially important implications for estimates of treatment volume and resource requirements.

The PRECARE program provides a rare opportunity to examine how these modelling assumptions translate into prospective experience. Before implementation, Kruit et al. applied historical OHCA data to a simulated prehospital ECPR strategy and identified 699 arrests that would potentially trigger team activation, of which 488 were ultimately classified as refractory and ECPR-eligible. With optimal team positioning, the model estimated that 437 (90%) of these patients could receive ECPR within 60 min [14]. Subsequent prospective evaluation revealed the complexity of this operational pathway. Over 103 recruitment days, the PRECARE team was dispatched to 298 suspected cardiac arrests, attended 123 confirmed arrests undergoing resuscitation, and ultimately performed ECPR in 12 patients, or approximately one cannulation for every 24 dispatches [11]. Operational times also varied substantially: dispatch-to-arrival ranged from 9 to 29 min and decision-to-ECMO flow from 10 to 34 min [11]. Although differences in study definitions and denominators preclude direct comparison between modelled and observed eligibility, the prospective experience illustrates dimensions of ECPR delivery that are difficult to fully capture through retrospective modelling alone, particularly activation burden and variability in operational intervals.

As prospective experience with prehospital ECPR accumulates, comparisons between modelled predictions and observed performance will be particularly valuable. Such studies can identify where and why models diverge from clinical experience, better characterize operational variability and patient selection, and ultimately inform more realistic future simulations. They may also clarify which aspects of ECPR delivery remain difficult to capture through modelling. Extracorporeal resuscitation eligibility models should be viewed as decision-support tools rather than precise forecasts, with careful consideration of the operational assumptions underlying their estimates.

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Author contributions
A.C. drafted the manuscript. All authors contributed to its critical revision. A.C. takes responsibility for the manuscript as a whole.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Competing interests
The authors declare no competing interests.

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