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Pre-Hospital Seizure Management in Children: Optimizing Paramedic Response and OR technicians Coordination with Pediatric Neurology Teams

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Abstract

Seizures are among the most common time-critical neurological emergencies in childhood, and the pre-hospital interval is the first and often the most decisive therapeutic window. In that window, paramedics must simultaneously recognize seizure semiology, protect the airway, correct reversible precipitants, and deliver weight-based first-line therapy, normally a benzodiazepine, while navigating scene stresses, limited pediatric exposure, and dosing complexity; their actions directly influence downstream pediatric neurology decisions, escalation to second-line therapy, and, in rare but high-stakes scenarios, urgent neurosurgical preparedness requiring coordination with operating room (OR) teams. Despite robust guidance on status epilepticus (SE) defining the 5-minute "t1" threshold for benzodiazepines and endorsing non-intravenous routes when IV access is delayed, real-world pre-hospital care still shows under-dosing, route inconsistency, and variable protocol adherence that prolongs convulsions and increases the risk of respiratory compromise and intensive care admission (1–4,12–13). Recent randomized and comparative effectiveness trials clarify that intramuscular midazolam is at least as effective as intravenous lorazepam in the field, that intranasal midazolam is a practical and acceptable alternative to rectal diazepam for children, and that ED second-line choices (levetiracetam`m , valproate, fosphenytoin) offer similar efficacy after benzodiazepine failure, findings that should harmonize EMS formularies and training with hospital algorithms (3,9–11,21–22). Systems solutions—pediatric readiness initiatives for EMS agencies, checklists and dosing aids that go beyond simple length-based tapes, structured EMS-to-ED handover (e.g., SBAR/IMIST-AMBO), and predefined activation pathways that incorporate neurology and OR technicians for refractory cases—represent the most credible levers to improve outcomes at scale (5–8,14–18,27). This review synthesizes pathophysiology, epidemiology, pharmacologic options and dosing pitfalls, communication and handover, and rare neurosurgical escalation, and proposes a pragmatic, multidisciplinary coordination model connecting paramedics, pediatric neurologists, anesthesiology, and OR technicians to shorten time to effective therapy and limit neuroinjury.

Introduction

Pediatric seizures occupy an outsized share of pre-hospital workload because they occur across the pediatric age spectrum, from febrile seizures in toddlers to first unprovoked seizures and known epilepsy exacerbations in school-age children and adolescents, and because they are clinically dramatic, time-sensitive, and logistically demanding. From the moment an emergency call is placed, the clock is ticking: modern definitions of convulsive status epilepticus emphasize that persistent convulsions beyond approximately five minutes (the “t1” operational threshold) are unlikely to stop spontaneously and mandate benzodiazepine therapy without delay; the longer seizures continue beyond this point, the more likely they are to become pharmacoresistant, to inflict neuronal injury, and to require ICU-level care (1–2,12–13). In this context, the pre-hospital arena is not a prelude but the first act of definitive care: if paramedics can recognize true convulsions, secure the airway positionally with suction and oxygen as needed, correct glucose when low, and deliver an adequate weight-based dose via a route that works on the scene (intramuscular or intranasal when IV is difficult), they compress the therapeutic timeline in ways that no subsequent hospital intervention can fully recapture (2–3,9–11,12–13). Yet, the practice gap is stubborn: national and single-system registries repeatedly show that many children receive subtherapeutic benzodiazepine doses, or non-preferred agents, or unnecessarily delayed therapy, translating into more ED redosing, longer seizures, and higher resource utilization—problems whose roots include low pediatric case volume for individual crews, anxiety, uncertainty in weight estimation, and protocol heterogeneity (4,19). These gaps are not simply clinical; they are systems issues that require “pediatric readiness” in EMS agencies (pediatric champions, QA/QI, dosing tools, pediatric-sized equipment, and continuous education), and communication issues that require a structured, complete, and rapid EMS-to-ED handoff so pediatric neurology and ED teams can escalate without information loss (5–8,20,27). Finally, although most pediatric seizures are medically controlled, a small subset progress to refractory or super-refractory SE; when focal lesional pathology is the driver, early neurosurgical consultation and occasionally urgent operative management are legitimate considerations—rare, yes, but crucial enough to demand predefined OR technician readiness for neuro-monitoring, sterile setup, anesthesia support, and equipment availability so that time-critical procedures are not delayed by logistics (24,26). Together, these realities make a compelling case for a multidisciplinary pathway that begins in the living room or at school with paramedics and ends, if necessary, with a ready operating room, coordinated end-to-end by pediatric neurology leadership and a shared, rehearsed script across services (2–3,5–8,12–13,24,26). (Definition and t1 threshold from ILAE updated framework; the implementation urgency and treatment phases are widely reflected in AES and NCS guidance.)

Review

Definitions, epidemiology, and implications for the field

Status epilepticus has evolved from a rigid 30-minute historical definition to a practical, action-oriented construct with t1 at ~5 minutes for convulsive SE (treatment should have started) and t2 at a longer horizon beyond which long-term injury risk rises; for paramedics, t1 is the mandate: if a generalized tonic-clonic seizure is ongoing on EMS arrival or has persisted beyond five minutes by reliable history, treat now (1–2,12–13). In children, febrile seizures remain the most common seizure type in the pre-hospital setting and are usually brief, but a non-trivial fraction is prolonged or complex; children with known epilepsy, metabolic derangements, CNS infections, trauma, or toxicologic triggers add etiologic diversity to EMS caseloads and should prompt glucose testing, temperature assessment, quick review of antiepileptic adherence, and attention to intercurrent illness. The clinical implication is that rapid pattern recognition, ABCs, and a single-minded focus on early benzodiazepines are the anchor moves in the field, with the explicit understanding that route matters less than speed and dose adequacy; these imperatives are now embedded in high-grade guidelines and pediatric SE algorithms and should be reflected in every EMS seizure protocol (2–3,12–13).

First-line pharmacology, routes, and the evidence for route pragmatism

Benzodiazepines are decisively first-line in pre-hospital pediatric seizure care. Among them, midazolam has become the operational favorite in EMS because it can be given IM or IN with rapid absorption and without the delay of IV cannulation, a practical advantage crystallized by the RAMPART trial which established that IM midazolam was non-inferior to IV lorazepam for pre-hospital SE, with similar safety and more reliable on-time delivery when IV access was elusive (3). In children, intranasal midazolam compares favorably to rectal diazepam in feasibility and caregiver/clinician acceptability, with studies showing either equivalence in efficacy at home settings or advantages for IN midazolam in pre-hospital cohorts for seizure control and fewer respiratory complications and admissions; taken together, these findings justify EMS formularies that prioritize midazolam with IN and IM routes and reserve rectal diazepam for limited circumstances (9–11). This route pragmatism does not negate IV utility—if a line is already present or can be established immediately, IV lorazepam or diazepam remain effective—but time to drug in the brain remains the dominant goal, and the data endorse choosing the route you can deliver now rather than chasing the theoretically ideal route and losing minutes (3,9–11,12). (Midazolam route evidence from RAMPART and pediatric IN vs rectal studies; algorithmic preference for timely non-IV routes features across pediatric SE guidance.)

Despite clarity on what to give and how to give it quickly, how much remains a stumbling block. Multiple registry and system studies report that a large proportion of children receive inappropriately low initial benzodiazepine doses in the field, a practice pattern linked to the need for additional doses and longer seizure durations; contributors include weight uncertainty, fear of respiratory depression, and cognitive load in high-stress pediatric scenes (4,19). Traditional length-based tapes (e.g., Broselow) help, but their performance degrades in heavier children and in populations with higher prevalence of under- or overweight, and they can introduce medication calculation steps that invite arithmetic error; newer or enhanced dosing systems (e.g., PAWPER, Mercy method, or comprehensive dosing rulers) and pre-calculated, color-matched syringe systems reduce time and error in simulation and field studies and should be favored in EMS pediatric readiness plans alongside standardized weight estimation plus pre-drawn dose strategies (14–18). A practical systems approach is to combine: (a) a single first-line agent (midazolam) with weight-banded pre-calculated doses for IN and IM routes; (b) a no-hesitation redose rule at 5 minutes if the child remains convulsing; (c) cognitive off-loading via checklists or dosing cards mounted on drug boxes; and (d) crew simulation with pediatric manikins to entrench muscle memory. These are not cosmetic tweaks: paramedic dosing reliability is a core patient-safety issue in pediatric seizures, and comprehensive dosing systems beat standalone length tapes in reducing >20–25% dosing deviations (14–18). (Under-dosing prevalence and consequences from multicenter pediatric analyses; dosing-aid performance and error reduction from comparative simulation and implementation studies.)

Although second-line antiseizure drugs are usually initiated in the ED or PICU, pre-hospital practice benefits from understanding the hospital algorithm that pediatric neurology will follow. The ESETT program (NEJM 2019; Lancet 2020) demonstrated that in benzodiazepine-refractory convulsive SE, levetiracetam, fosphenytoin, and valproate are similarly effective, each stopping seizures and improving responsiveness by 60 minutes in roughly half of patients, with no clear winner and broadly comparable adverse events across age groups down to two years (21–22). For EMS, the practical message is twofold: first, do not delay or dilute benzodiazepine therapy while contemplating downstream agents—those decisions will come in the ED; second, communicate precisely what drug(s), dose(s), and routes were given and at what times so ED teams can apply ESETT-aligned pathways without repeating or mis-sequencing therapy. Where local protocols permit, some systems may carry levetiracetam for "bridge" therapy in prolonged transport, but this remains uncommon; the priority remains fast, adequate benzodiazepine and a clean handover that allows the ED/neurology team to move immediately to second-line agents if needed (12,21–22). (Comparative effectiveness across age groups and lack of superiority among second-line agents from ESETT.)

Communication that compresses timelines: handover structure and content

The EMS-to-ED handoff for a seizing child is a narrow bottleneck in the care pathway; disorganized or incomplete transfer wastes minutes, duplicates therapy, and erodes situational awareness. Structured handover tools—in particular SBAR (Situation, Background, Assessment, Recommendation) and ED-tailored variants (e.g., IMIST-AMBO)—improve completeness and safety in multiple settings and are recognized by safety agencies and quality bodies; importantly, handoff studies in pediatric resuscitations and observational analyses of EMS-to-ED transitions show that duration, completeness, and role clarity are often suboptimal without a script (7–8,20,27). For pediatric seizures, a minimum handoff dataset should include: onset time and total duration; semiology; precipitating factors (fever, trauma, known epilepsy, missed meds, toxins); pre-hospital glucose and temperature; exact benzodiazepine doses and routes with timestamps; airway maneuvers (oxygen, suction, adjuncts); response to therapy; and any complications (desaturation, hypotension). When refractory convulsions persist, the handoff should also include ETA and any en-route redosingplanned so that neurology and ED can mobilize a status pathway (room readiness, pharmacy pull, EEG tech notification) before wheels-down. (Evidence for SBAR-associated safety improvements and observed variability in EMS-ED handoffs.)

Pediatric readiness for EMS agencies: from policy to practice:

"Pediatric readiness" in EMS moves beyond equipment checklists to a whole-system posture: pediatric champions within agencies; pediatric-specific QA/QI; data feedback loops; dosing tools; age/size-appropriate equipment; and interagency agreements for destination policies and team activation. Technical reports and toolkits from the Emergency Medical Services for Children (EMSC) program and the Prehospital Pediatric Readiness Project outline the key components, emphasizing designation of a Pediatric Emergency Care Coordinator (PECC), access to pediatric medical direction, and standard operating procedures for safe transport and interfacility transfer; these frameworks should be explicitly embedded into seizure protocols with concrete metrics such as time-to-first benzodiazepine, proportion of adequate initial doses, and complete handoff documentation rates (5–6). Agencies that operationalize pediatric readiness principles close measurable gaps in care and create the infrastructure that clinical training alone cannot supply. (Prehospital pediatric readiness components and PECC roles.)

The rare but real escalation: coordinating with OR technicians and neurosurgery for refractory cases:

Most pediatric seizures, including many episodes of SE, are controlled medically; nonetheless, refractory or super-refractory SE due to lesional focal pathology may warrant early neurosurgical consideration. Contemporary systematic reviews and case series suggest that, in selected children with concordant electro-clinical localization and structural lesions, emergency surgical interventions—from focal resection to hemispherectomy or disconnection procedures—can terminate SE and lead to seizure freedom, although the evidence base is limited and heterogeneous (24). For hospitals that receive such patients, OR technicians are crucial: they ensure rapid sterile field setup, availability of neurosurgical trays, neuro-monitoring equipment, and EEG interfaces for intraoperative decision-making; they also synchronize with anesthesiology on pediatric airways and invasive monitoring, and with pharmacy for antiepileptic infusions and anesthetic agents. Neurosurgical emergencies from trauma (e.g., mass-effect hematomas) demand similar readiness; pediatric best-practice guidelines for TBI codify how coordinated neurotrauma teams, including OR staff, improve timeliness of decompressive procedures when indicated (26). From a pathway standpoint, EMS recognition of refractory convulsions should trigger an early alert to pediatric neurology; in transit the hospital can convene a SE huddle (neurology, ED, anesthesia, neurosurgery, OR tech lead) to pre-assign roles and verify room availability, limiting late clinical delays if medical therapy fails. (Evidence of surgical options and TBI OR readiness supporting the concept of time-sensitive OR coordination.)

Continuous EEG and ICU transitions: why pre-hospital data matter

For children who require admission after prolonged convulsions, continuous EEG is often recommended to confirm electrographic seizure cessation, detect non-convulsive SE, and guide anesthetic titration in refractory cases; because time to EEG and clarity on prior benzodiazepine exposure affect sedative needs and interpretation, the accuracy of EMS documentation (timed doses, responses, glucose) materially influences neurology decisions in the ICU (12,23). Pre-hospital records should therefore be structured to capture timestamps and responses in a way that seamlessly populates hospital pathways and electronic orders. (Rationale for continuous EEG and its dependence on pre-hospital information continuity.)

DISCUSSION

The pre-hospital management of pediatric seizures is a quintessential test of system readiness, cognitive off-loading, and cross-disciplinary choreography. Clinically, the science is straightforward: treat generalized convulsions at five minuteswith a sufficient benzodiazepine dose now, through any effective route you can execute quickly, and redoseappropriately if seizures persist; do not stall for an IV, do not under-dose, and do not skip glucose. That first five to ten minutes determines whether ED teams inherit a child who is already stopping or one whose brain has been seizing long enough to become pharmacoresistant. The field evidence aligns: IM midazolam performs at least as well as IV lorazepam in real-world pre-hospital conditions, and intranasal midazolam is a practical default in children when vascular access is not immediately available; ESETT-era data remove any pressure to "optimize" a particular second-line choice and instead encourage smoother handoffs that preserve momentum from EMS to ED to neurology (3,9–11,21–22). And yet, under-dosing remains pervasive—this is not a matter of individual paramedic willpower but of system design. Agencies that rely on generic length-based tapes without comprehensive dose mapping, that carry duplicative benzodiazepines with different dosing schemes, or that lack pediatric simulations are setting crews up to fail. The solution stack is known: single-agent standardization (midazolam), weight-banded, pre-calculated volumes for IN and IM, color-matched or pre-drawn syringes, laminated dosing cards on drug boxes, pediatric PECC leadership, and regular pediatric megacode simulations with seizure scenarios. Implementation should be audited with hard metrics (time-to-first benzo; proportion adequately dosed; need for ED redosing; intubation rates temporally related to dosing) and looped back through QA for incremental improvement (4–6,14–19).

Just as important is communication. Handover is too often treated as an afterthought; pediatric studies show variable completeness and unstructured exchanges that dilute crucial details such as timing of therapy and observed responses, forcing ED teams to repeat benzodiazepines "just to be safe," inadvertently doubling sedation burden. SBAR/IMIST-AMBO is not a bureaucratic add-on but a time-compression tool; when paramedics deliver a crisp summary—"Generalized convulsions witnessed at 19:05, still seizing on our arrival 19:10; dextrose 94 mg/dL; intranasal midazolam 0.2 mg/kg at 19:12, IM midazolam 0.1 mg/kg at 19:17 for persistent seizure; airway supported with NRM; SpO_2 nadir 90%, now 97%; convulsions reduced but ongoing; ETA 3 minutes"—neurology and ED can pull second-line therapy, notify EEG, and mobilize PICU immediately; this is how you beat the clock (7–8,20,27). Hospitals should reciprocate by scripting their receiving behavior: a designated listener writes down dose, route, and times during the handoff; a runner orders second-line medication if needed; neurology is called with the exact EMS details; and if seizures persist, a status huddle is initiated with anesthesia and OR techs before the child hits refractory thresholds. (Benefit signals for structured handover tools and documentation.)

Finally, although rare, refractory/super-refractory SE in children with focal, lesional etiologies is real, and waiting days to weeks to consider surgery may prolong neuronal injury and ICU sedation exposure. The evidence base remains limited and prone to selection bias, but a growing body of reports and systematic syntheses indicate that emergency surgical options—from lesionectomy to hemispherectomy—can terminate SE in selected cases; practically, that means hospitals should build contingency pathways that, when neurology and EEG suggest focal refractoriness with concordant imaging, can activate neurosurgery and OR technicians rapidly, with clear default instrument sets, EEG-compatible anesthesia plans, and imaging transfer workflows (24,26). From the EMS perspective, this translates into early notification ("refractory convulsions after two adequate benzodiazepine doses") so the hospital can assemble the chessboard while the child is inbound. Even when surgery is not the answer, having OR technicians and anesthesia looped in accelerates procedures such as placement of invasive monitors or rapid access in complex children, decreases chaos, and keeps the human factors favorable when minutes matter. (Surgical options and neurotrauma OR readiness as conceptual frameworks for escalated pathways.)

Conclusion

Pre-hospital pediatric seizure management is simultaneously simple in aim—stop the seizure fast and safely—and complex in execution because it demands precise dosing under stress, deft route selection, scene management around anxious caregivers, and instantaneous, structured communication to the hospital. The evidence base and consensus guidelines point to a practical formula: (1) define and act at five minutes—don't wait; (2) use midazolam via IN or IMif IV is not immediately available, and dose adequately using robust, crew-friendly aids; (3) redose without delay if convulsions persist; (4) handover with SBAR/IMIST-AMBO including timestamps and responses; (5) align with hospital second-line neutrality (levetiracetam, valproate, fosphenytoin all reasonable) and notify neurology early; (6) embed these steps within an EMS pediatric readiness framework that includes dosing systems beyond basic length tapes, pediatric champions, and QA/QI; and (7) maintain a rare-event escalation pathway that can bring anesthesia, neurosurgery, and OR technicians to bear when refractory, lesional SE is suspected. Executed together, these measures shorten time-to-effective therapy, reduce under-dosing and duplication, improve airway safety, and preserve neurologic outcomes. The agenda now is implementation science: measure, iterate, and scale these solutions across EMS agencies and hospitals, with pediatric neurology as the clinical owner and OR teams as ready, rehearsed partners for the uncommon but unforgiving scenarios where surgery might save a brain. (Key data undergirding this synthesis include ILAE/AES/NCS definitions and algorithms, RAMPART for route pragmatism, ESETT for ED second-line neutrality, pediatric readiness frameworks for EMS, and handover literature for safety and completeness.)

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