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Short Communication

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Runsheet: Development Of A Self-Contained, Browser-Based Reference Tool For Medication Reconstitution And Clinical Reasoning In Paramedic Education

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Abstract

Medication reconstitution — combining a powdered drug with a diluent to reach an administrable concentration — sits at the intersection of mathematics, pharmacology, and fine motor skill, and represents a persistent source of error in prehospital and hospital care alike. Paramedic students in particular have been shown to struggle with drug calculation generally, and reconstitution adds a further layer of concentration math, drug-specific technique, and infrequent practice on top of that existing weakness. This paper describes the development and design rationale of RUNSHEET, a free, self-contained, browser-based educational reference tool built to help paramedic students and EMS providers practice symptom-to-condition reasoning alongside medication dosing, reconstitution, and field treatment information. The tool uses a weighted matching system that takes user-entered signs and symptoms and returns ranked likely conditions, each linked to associated risk factors, field treatment steps, oxygen therapy guidance, and — where applicable — medication dosing and reconstitution instructions. This paper situates the tool's design within the existing literature on paramedic dosage calculation performance, the effect of stress on calculation accuracy, and the role of e-learning in supplementing hands-on skills training. No formal evaluation of student outcomes has yet been conducted; this paper is intended as a descriptive account of the tool and a foundation for future pilot evaluation.

Keywords: Emergency Medical Services, Paramedics, Education, Medication Systems, Dosage Calculation, Drug Compounding, Patient Safety, E-Learning, Clinical Decision Support, Point-Of-Care Systems

1. Introduction

Medication administration errors in the prehospital setting are well documented. In a survey of paramedics in San Diego County, 9.1% of respondents reported committing a medication error in the previous 12 months, with dose-related errors accounting for the largest share (63%) and contributing factors including infrequent use of the medication in question and dosage calculation error [1]. Reconstitution — the process of mixing a powdered medication with a diluent to reach a usable concentration — compounds these risks, since an error introduced at the preparation stage propagates into every subsequent calculation and administration step even when later arithmetic is performed correctly.

Hospital-based research illustrates how substantial these preparation-stage errors can be. A prospective observational study at a Dutch university hospital found errors in well over half of intravenous admixtures observed, with incorrect preparation technique and incorrect diluent volume among the most frequent problems identified before the medication reached the patient [2]. A separate Brazilian study of drug preparation and administration errors identified instances in which medication was diluted to a volume below the manufacturer's recommendation, directly compromising the intended dose [3]. While these studies were conducted in hospital rather than prehospital settings, the underlying mechanism — an error at the mixing stage undermining every downstream step — applies directly to EMS medication preparation as well.

Two additional factors specific to EMS education make reconstitution a persistent challenge. First, dosage calculation is already a documented area of difficulty for paramedic students independent of reconstitution: research examining mathematics anxiety and numerical ability among paramedic students found that math education prior to university entry and numerical ability

were significant predictors of drug calculation performance, and that many students experience measurable anxiety around calculation tasks [4]. Second, calculation accuracy has been shown to deteriorate under stress. In a simulator-based study, paramedics' accuracy in calculating drug dosages fell substantially in stressful scenarios compared to calm conditions, regardless of the participant's level of experience [5]. Reconstitution in EMS practice is rarely performed under calm, unhurried conditions — it typically occurs mid-call, alongside patient assessment and communication demands, which is precisely the kind of environment shown to degrade calculation performance.

Taken together, these findings suggest that reconstitution-related error in EMS is not attributable to any single deficiency, but to the layering of several factors: baseline calculation difficulty, infrequent practice of drug-specific mixing steps, and performance degradation under operational stress. Traditional paramedic education typically addresses reconstitution through a single skills-station demonstration, which offers limited opportunity for the repeated, low-stakes practice that these findings suggest is needed. Digital tools may help close this gap: a recent randomized, quasi-experimental study of paramedic students found that a blended online-and-classroom model produced significantly greater improvement in dosage calculation scores than video-based e-learning alone, suggesting that structured digital practice can meaningfully improve this specific skill set [6]. This paper describes RUNSHEET, a browser-based tool developed to provide this kind of repeatable, self-directed practice.

2. Tool Description

RUNSHEET is a self-contained HTML, CSS, and JavaScript application that runs entirely in a web browser, requiring no server, account creation, or installation. It was designed for paramedic and EMT students to reference and practice medication and clinical reasoning content outside of scheduled lab or classroom time. Content included in the tool — specific medications, dosing ranges, and treatment protocols — was developed with reference to the National EMS Scope of Practice Model published by the National Highway Traffic Safety Administration (NHTSA), which outlines the knowledge, skills, and medication categories associated with each EMS provider level. Because actual scope of practice, medications carried, and specific protocols vary by state regulation, medical director approval, and local EMS agency, the tool is intended as a general study reference rather than a substitute for an individual program's protocols.

3. Core Features

Search functionality: Users can search directly for a medication, symptom, or condition rather than browsing a static list, mirroring the speed with which information typically needs to be retrieved in the field.

Condition calculation based on signs and symptoms: The core function of the tool is a weighted matching system. Users enter observed signs and symptoms along with vitals, organized across these categories (respiratory, cardiac/circulatory, neurological, skin/allergic, and gastrointestinal/general) (heart rate, blood pressure systolic/diastolic, respiratory rate, spO2, temperature, and blood glucose level) , and the system returns a ranked list of likely underlying conditions. This is intended to give students practice with the less-rehearsed half of clinical reasoning — working backward from a presentation to a probable cause — rather than only reviewing information about a condition that has already been named.

Medication cards: Each medication is presented in a consistent card format listing indications, contraindications, standard dosing, and route of administration, so that information remains scannable and comparable across the full medication set. Reconstitution instructions: For medications requiring reconstitution, each card includes step-by-step instructions specifying the correct diluent, volume, and resulting concentration, allowing repeated review of the exact process for infrequently used drugs such as glucagon.
Dosage calculation practice: The tool includes built-in dosage calculation exercises tied to specific medications, giving users a low-stakes setting in which to repeatedly practice the underlying arithmetic rather than only reading about it.

Risk factors: Each condition and medication entry lists relevant patient-specific risk factors (e.g., age, weight, comorbidities, contraindicated combinations) that may increase the likelihood of an adverse outcome or point toward a specific diagnosis.

Field treatment: Each condition entry includes a recommended sequence of field interventions, from initial assessment priorities through medication administration, linking diagnostic reasoning to a concrete treatment pathway. Oxygen treatment: Relevant condition entries include oxygen therapy guidance — target saturation range, delivery method, and flow rate — reflecting that even high-frequency interventions require patient-specific decision-making.

4. Potential Benefits for Paramedic Education

Because reconstitution and dosage calculation are skills that appear to decay with infrequent use [1], a resource that students can access repeatedly and without cost may help provide the kind of low-stakes repetition that a single in-person skills station cannot. The symptom-to-condition matching feature is intended to give students additional practice with diagnostic reasoning specifically, rather than only pharmacological recall, and the integration of risk factors, field treatment, and medication information into a single workflow is intended to mirror how these elements are used together on an actual call rather than as isolated topics of study.

5. Limitations

This tool has several limitations that should be considered. It is a static, browser-based application and therefore cannot replicate the physical component of reconstitution, such as drawing up fluid, mixing technique, or needle handling — skills that require hands-on laboratory practice. The symptom-matching algorithm reflects general clinical patterns encoded by the developer and is not a validated diagnostic instrument; it is intended solely as a

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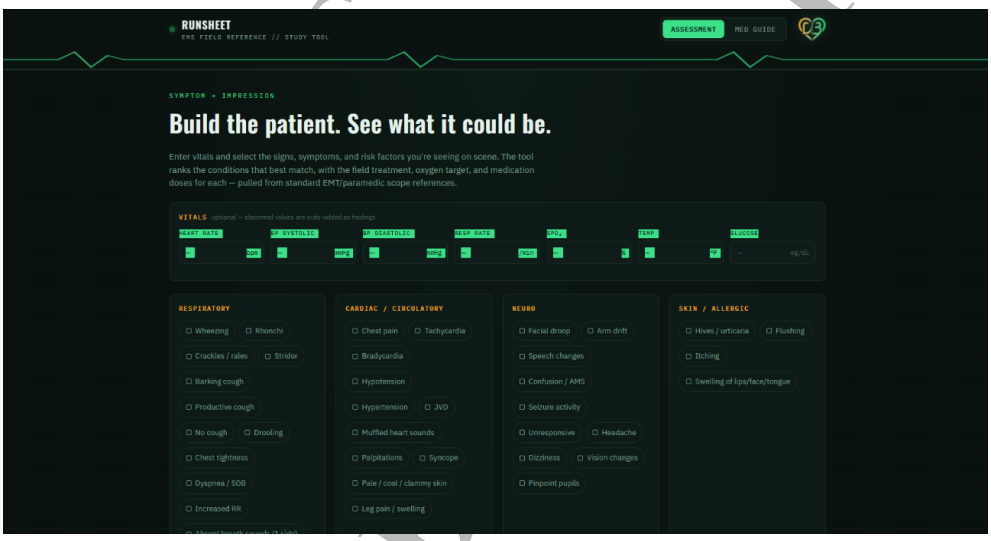
study aid. The tool was developed and is maintained by a single individual rather than a clinical education team or institution, and its content has not undergone formal peer review, multi-site testing, or validation against paramedic education outcomes. Most importantly, no formal evaluation of student performance or learning outcomes with this tool has yet been conducted; the benefits described above are proposed based on alignment with existing literature rather than demonstrated empirically.

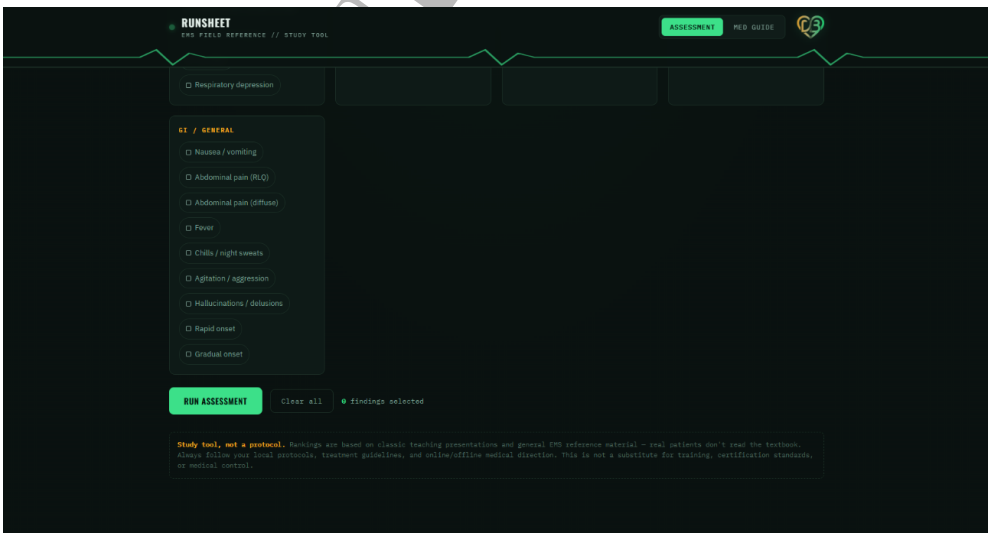
6. Future Directions

Planned future work includes formal pilot evaluation of the tool — for example, comparing dosage calculation or condition-recognition performance among paramedic students who use the tool against those who do not, following a design similar to prior blended-learning research [6]. Additional planned enhancements include timed or scenario-based practice modes intended to introduce a controlled degree of time pressure, given that stress has been shown to degrade calculation accuracy even among experienced providers [5]; periodic expansion and updating of the medication and condition library to remain aligned with evolving protocols; and the addition of performance tracking to identify individual students' recurring areas of difficulty.

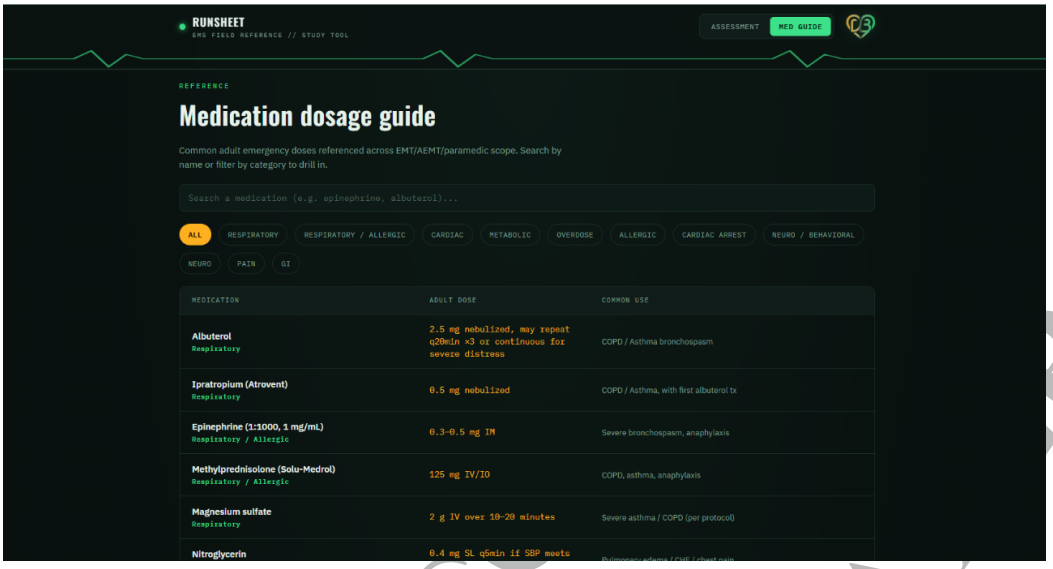
7. Conclusion

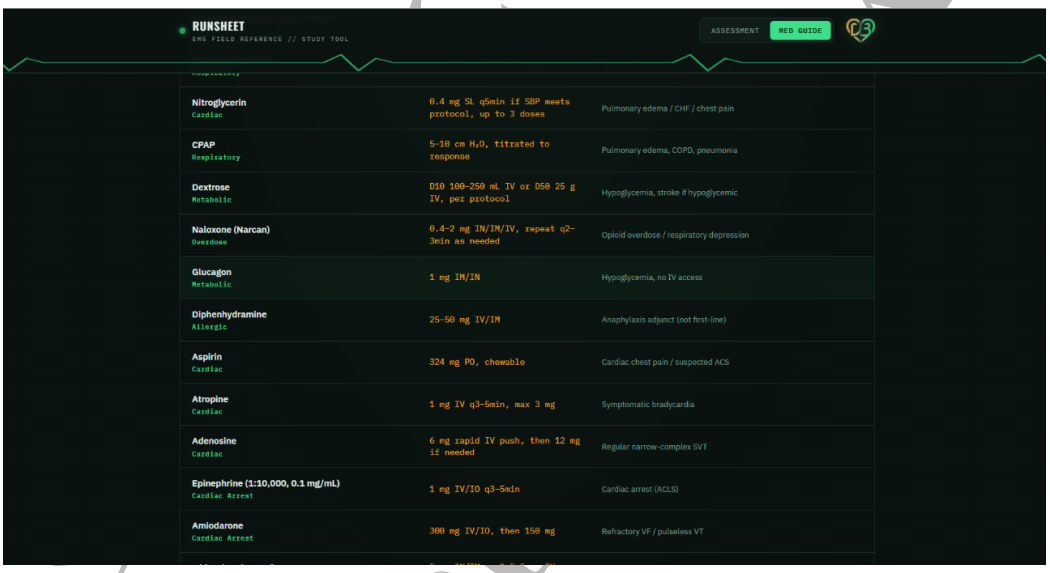
Medication reconstitution occupies a difficult intersection of mathematics, pharmacology, and physical technique, compounded by the infrequency with which many relevant medications are used and by the performance-degrading effects of operational stress. Existing literature indicates that dosage calculation is already a measurable weak point among paramedic students, that preparation-stage errors are linked to serious patient harm, and that infrequent practice is a recurring contributing factor in real-world medication errors. RUNSHEET was developed as a freely accessible, self-contained tool intended to provide the kind of repeatable, low-stakes practice suggested by this literature, combining diagnostic reasoning, risk factor review, field treatment, and medication dosing and reconstitution practice into a single workflow. It is intended as a supplement to — not a replacement for — hands-on laboratory instruction and clinical supervision, and its educational value remains to be formally evaluated.

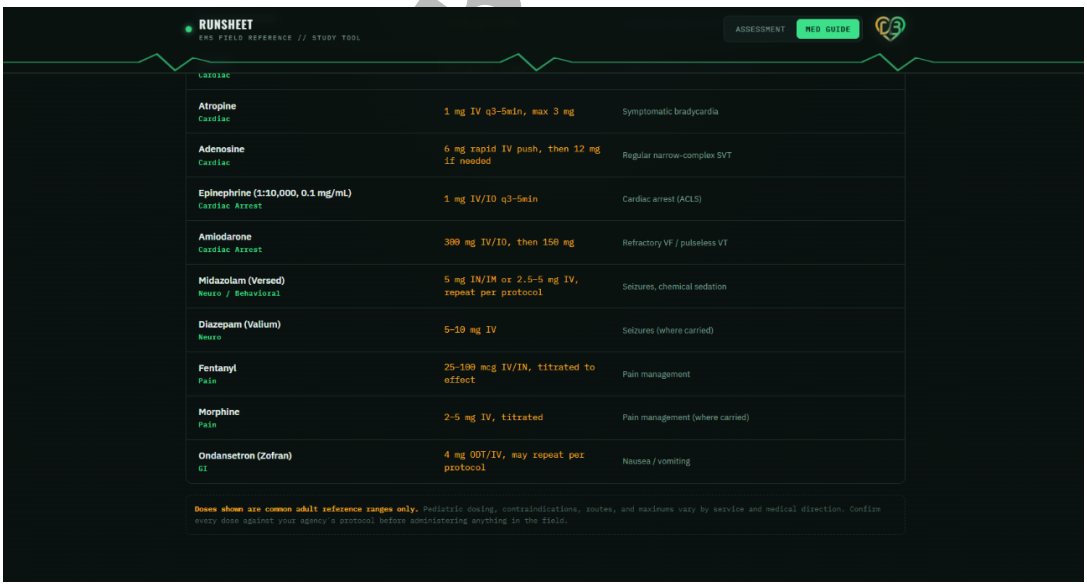


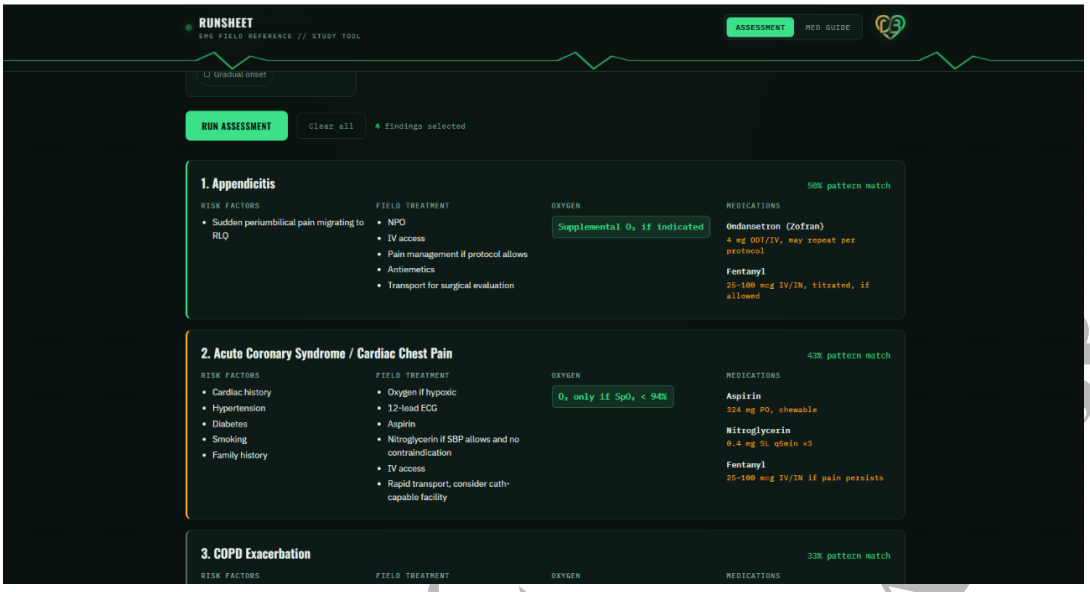


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RUNSHEET
EMS FIELD REFERENCE // STUDY TOOL
ASSESSMENT
MED GUIDE
REFERENCE
Medication dosage guide
Common adult emergency doses referenced across EMT/AEMT/paramedic scope. Search by name or filter by category to drill in.
Search a medication (e.g. epinephrine, albuterol)...
ALL
RESPIRATORY
RESPIRATORY / ALLERGIC
CARDIAC
METABOLIC
OVERDOSE
ALLERGIC
CARDIAC ARREST
NEURO / BEHAVIORAL
NEURO
PAIN
GI
MEDICATION
ADULT DOSE
COMMON USE
Albuterol
Respiratory
2.5 mg nebulized, may repeat q20min ×3 or continuous for severe distress
COPD / Asthma bronchospasm
Ipratropium (Atrovent)
Respiratory
0.5 mg nebulized
COPD / Asthma, with first albuterol tx
Epinephrine (1:1000, 1 mg/mL)
Respiratory / Allergic
0.3–0.5 mg IM
Severe bronchospasm, anaphylaxis
Methylprednisolone (Solu-Medrol)
Respiratory / Allergic
125 mg IV/IO
COPD, asthma, anaphylaxis
Magnesium sulfate
Respiratory
2 g IV over 10–20 minutes
Severe asthma / COPD (per protocol)
Nitroglycerin
0.4 mg SL q5min if SBP meets


RUNSHEET
EMS FIELD REFERENCE // STUDY TOOL
ASSESSMENT
MED GUIDE
Nitroglycerin
Cardiac
0.4 mg SL q5min if SBP meets protocol, up to 3 doses
Pulmonary edema / CHF / chest pain
CPAP
Respiratory
5–10 cm H₂O, titrated to response
Pulmonary edema, COPD, pneumonia
Dextrose
Metabolic
D10 100–250 mL IV or D50 25 g IV, per protocol
Hypoglycemia, stroke if hypoglycemic
Naloxone (Narcan)
Overdose
0.4–2 mg IN/IM/IV, repeat q2–3min as needed
Opioid overdose / respiratory depression
Glucagon
Metabolic
1 mg IM/IN
Hypoglycemia, no IV access
Diphenhydramine
Allergic
25–50 mg IV/IM
Anaphylaxis adjunct (not first-line)
Aspirin
Cardiac
324 mg PO, chewable
Cardiac chest pain / suspected ACS
Atropine
Cardiac
1 mg IV q3–5min, max 3 mg
Symptomatic bradycardia
Adenosine
Cardiac
6 mg rapid IV push, then 12 mg if needed
Regular narrow-complex SVT
Epinephrine (1:10,000, 0.1 mg/mL)
Cardiac Arrest
1 mg IV/IO q3–5min
Cardiac arrest (ACLS)
Amiodarone
Cardiac Arrest
300 mg IV/IO, then 150 mg
Refractory VF / pulseless VT


RUNSHEET
EMS FIELD REFERENCE // STUDY TOOL
ASSESSMENT
MED GUIDE
Cardiac
Atropine
Cardiac
1 mg IV q3–5min, max 3 mg
Symptomatic bradycardia
Adenosine
Cardiac
6 mg rapid IV push, then 12 mg if needed
Regular narrow-complex SVT
Epinephrine (1:10,000, 0.1 mg/mL)
Cardiac Arrest
1 mg IV/IO q3–5min
Cardiac arrest (ACLS)
Amiodarone
Cardiac Arrest
300 mg IV/IO, then 150 mg
Refractory VF / pulseless VT
Midazolam (Versed)
Neuro / Behavioral
5 mg IN/IM or 2.5–5 mg IV, repeat per protocol
Seizures, chemical sedation
Diazepam (Valium)
Neuro
5–10 mg IV
Seizures (where carried)
Fentanyl
Pain
25–100 mcg IV/IN, titrated to effect
Pain management
Morphine
Pain
2–5 mg IV, titrated
Pain management (where carried)
Ondansetron (Zofran)
GI
4 mg ODT/IV, may repeat per protocol
Nausea / vomiting
Doses shown are common adult reference ranges only. Pediatric dosing, contraindications, routes, and maximums vary by service and medical direction. Confirm every dose against your agency's protocol before administering anything in the field.



Conflicts of Interest

None declared

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