



mHealth in Emergency Medicine

Grab your smartphone to get a grip on app-driven clinical decision rules and tools.

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*EB Medicine is pleased to bring you **mHealth in Emergency Medicine**, a Special Report developed in conjunction with our strategic partner MDCalc. Look for the first edition of our jointly published *Calculated Decisions* supplement, which follows this report. It features "Nick's Picks," content from 7 select MDCalc calculators Dr. Genes deems as most essential to emergency medicine. Starting now, *Calculated Decisions* will be published on a regular basis and available free to subscribers of *Emergency Medicine Practice* and *Pediatric Emergency Medicine Practice*.*

With the proliferation of smartphones over the past several years, apps now play a prominent role in many social and work contexts, including medicine. This is enough of a phenomenon to have inspired the abbreviation "mHealth," short for mobile health. The number of app-driven clinical calculators, checklists, and risk scores in common use in the emergency department (ED) has significantly increased and shows no sign of slowing. Thanks to this digital development and innovation, clinical decision support is now just a finger-tap away.

As of 2016, there were approximately 20,000 apps in the "Medical" category of Apple's app store.¹ There are at least 300 apps specifically targeted to emergency clinicians,² and given the variety of patient presentations, general-purpose apps and apps from other specialties likely merit usage in the ED.

Despite the abundance of apps and their potential to improve patient care, the decision of which apps to choose and use is left largely to each clinician, with little guidance on best practices or potential risks. The purpose of this report is to educate emergency clinicians about medical apps that can be utilized to improve patient care during a shift.



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Medical Apps in Context With Traditional ED Tools

Smartphone apps have much in common with other tools commonly employed in the ED. Similar to a laryngoscope or a pigtail catheter, apps have specific indications and limitations. They require varying degrees of familiarity and practice to ensure safe and efficient use in the ED.

Unlike many standard ED tools, however, apps are plentiful and relatively inexpensive (many are free), but using them poses challenges, too. App developers are generally not subject to the same kinds of quality standards and checks as equipment and device manufacturers and distributors. Medical societies and hospitals do not often endorse apps, nor do they provide oversight on what physicians install and use on their phones. Staff members are rarely educated on new apps in the same manner as they are on new equipment or procedures in the ED.

Another key difference between apps and traditional ED tools is that apps are not static. By their very nature, many apps, while functional, are “works in progress.” They are frequently upgraded to revise and update content, add new features, or change the layout and operations. Apps are also more dynamic than other kinds of emergency medicine tools in that many apps require or encourage direct interaction, inviting clinicians to input data, contribute content, or provide comments and suggestions.

Many studies suggest that tools to promote guideline adherence can improve outcomes,³ decrease the incidence of errors,⁴ and reduce costs.⁵ Even a simple checklist, when applied judiciously, has been shown to reduce many healthcare complications, most notably, catheter-related infections in the intensive care unit⁶ and in surgical settings.⁷ In the ED, checklists have been associated with lower inpatient mortality in the setting of pneumonia⁸ and fewer complications in intubated trauma patients.⁹

Electronic health records (EHR) systems have the potential to improve guideline adherence by mandating checklist use through order sets, pop-up alerts, and other forms of clinical decision support, and by automatic integration of patient data (such as age, sex, and test results).¹⁰ However, many EHR-based clinical calculators fail to make use of these capabilities.¹¹ In addition, EHR usage habits vary widely, particularly in an ED. A critically ill patient may be coded for hours, with minimal clinician interaction with the EHR, and thus minimal opportunity for EHR-driven prompts to ensure guideline adherence and the use of checklists. In addition to difficulty with the timing or placement of EHR clinical decision support, critics of using the EHR for clinician prompts cite poor usability and alert fatigue as barriers to effective clinical decision support.¹² Smartphone apps have emerged as an efficient, accessible, usable, and portable alternative to EHR when checklists, calculators, and guidelines are needed at the point of care.

Consider this scenario: In the past, an emergency physician may have used the Cockcroft-Gault equation to determine glomerular filtration rate of an elderly patient, decoded blood gas results in a patient in respiratory failure, or applied the Ottawa Ankle Rule for a lower-leg injury. Today, that same clinician can also be expected to utilize the HEART score (history, electrocardiogram, age, risk factors, and troponin), NIHSS (National Institutes of Health Stroke Scale), the PERC Rule (pulmonary embolism rule-out criteria) and Wells' Criteria, CHADS₂ score (congestive heart failure, hypertension, age, diabetes mellitus, stroke/transient ischemic attack), ABCD₂ score (age, blood pressure, clinical features of transient ischemic attack, duration of symptoms, diabetes), and the Canadian CT (computed tomography) Head Rule—all on a single shift.

Types of Medical Apps

Many apps are designed for and targeted to patients and consumers, and though discussion of these apps is beyond the scope of this article, it would be beneficial for physicians to familiarize themselves with the types of consumer medical apps that are available and to ask patients about the types of apps they may be using.

Medical apps for physicians were originally developed based on pocket guides and references, and they proliferated as personal digital assistants (PDAs), such as Palm and Handspring, became common. As smartphone technology and availability improved, medical apps for physicians also improved. Medical apps for physicians fall generally into 3 categories: (1) apps for aiding clinical decision-making, (2) apps for accessing and viewing patient data, and (3) apps for healthcare communication.

Apps for Aiding Clinical Decision-Making

This largest category of apps can be subdivided into apps that serve as a reference, or apps that facilitate patient examination and care through measurements.



Examples of general-reference apps include **UpToDate**[®], **Medscape**, and **Epocrates**[®], as well as ED-focused reference apps such as **palmEM** and **WikEM**, and the Emergency Medicine Residents' Association (**EMRA**) **Antibiotic Guide**. These apps allow clinicians to quickly check diagnostic pearls, workup plans, medication doses, and more. Content can be categorized by disease, presentation, or specialty. Many of these apps are useful for procedures as well, showing indications, technique, and interpretation of findings.

Clinical calculators are included in many of these apps; however, a few also prioritize clinical calculations and scoring, such as **MDCalc** and QxMD's **Calculate** app. These apps can categorize calculators by specialty or by user-selected favorites and provide additional information to explain the context for appropriate use of the calculator.

Apps that facilitate data collection and patient examinations are an important and growing category of decision-making apps, and like other medical devices, they should be subject to both study and oversight. Simple Snellen visual-acuity charts, technically, fall under this category as well as apps such as Alivacor® **Kardia** or Welsh-Allyn **iEXAMINER™**, which have been approved for use by the United States Food and Drug Administration (FDA).

Apps for Accessing and Viewing Patient Data

Examples of apps that allow clinicians to view and access patient data include Epic **Haiku** (EpicCare) and **Mobile MIM™**, a picture archiving and communications system (PACS). These apps tie into a healthcare system’s EHR, PACS, or appointment scheduling software to pull and present patient data on a mobile platform. Most clinicians use these tools to review patient findings or schedules while away from their desks, but there are applications in the ED as well, such as:



- An emergency clinician can review blood test results or display an x-ray at a patient’s bedside;
- An ED director may quickly assess the boarding situation or waiting-room crowding without having to log in through an institution’s firewall to load the relevant data; and
- Patients can view laboratory results, discharge summaries, medication lists, radiology reports, and even provider notes through expanded patient portals to the EHR via EHR vendor apps. Examples include **MyChart®** (Epic) and **HealthLife** (Cerner). Patients typically receive a unique activation code from their doctor or at the conclusion of their ED or hospital visit that allows access to their records upon app download.

Apps for Healthcare Communication

Examples of apps that facilitate communication in the healthcare setting between care teams or between patient and care team include **TigerText**, **Cureatr**, **Doximity**, **ListRunner** (Desma Health) and **qliqConnect**. Because protected health information is often shared in these messages, these apps offer security features such as encryption and app password protection, and they store protected health information remotely rather than on the device. Furthermore, these app vendors typically enter into a business-associate agreement with EDs, hospitals, or medical practices to comply with the Health Insurance Portability and Accountability Act (HIPAA).



Measures of App Quality

Measures of Quality Within Apps and App Stores

Enabling providers (and patients) to quickly assess the quality of an app is a complex and still-unsolved proposition, though many solutions have been attempted. At a fundamental level, the first step in measuring quality

Online Resources for Evaluating Medical Apps

Resource	Evaluation Tools
Apple App Store	App categories; ratings and reviews from consumers (Link)
Google Play	App categories; ratings and reviews from consumers (Link)
www.iMedicalApps.com	App categories by specialty; ratings and reviews from healthcare professionals
Mobile Application Rating Scale (MARS)	23-item health app score across 5 domains of quality and usability (Link)
www.NODEHealth.org	App categories by specialty; ratings and reviews from healthcare professionals based on published evidence

is simply describing and categorizing an app, but even this is prone to failure. Apps in Google Play, Apple’s App Store, and others, appear in various categories and subdivisions often selected by the developer, but with final approval in the hands of app store reviewers. The categories are loosely helpful, but are often inconsistent and sometimes misleading. For example, the “Medical” category was intended for healthcare professionals, but more than half of the entries are consumer-facing fitness and health guides.¹

App store ratings and reviews may be a marker of quality, but they are also prone to misleading prospective app users. Some reviewers leave a 1-star review if the app is not what they were looking for or if they were not expecting in-app purchases for content, but these are the kinds of factors that may not necessarily reflect the quality of the app.

At a bare minimum, medical apps, like any text or resource, should have clearly displayed authorship and author credentials and provide a means to contact the author and/or the developer. Content should be cited, ideally with hypertext links; uncited text and/or unclear authorship is concerning in an mHealth app.

Apps should be updated regularly, in part to ensure proper functioning with newer phones and operating systems, but also to reassure the user that the content within the app is reviewed and current. App stores generally display a version history; medical apps that have gone for years without an update should present a red flag and are likely low-quality or behind the times.

Select Nongovernmental Organizations That Review or Curate Medical Apps

Beyond reviews, ratings, versioning, authorship, and cited references, there are few reliable clues to quality within an app or app store entry. Providers frequently seek endorsements and recommendations from specialty societies, hospitals, schools, and other health organizations, yet few organizations seem willing to

take on the perceived risk of endorsing apps or supporting providers as they install and operate apps. The organizations that do showcase apps (for patients or providers) are often not transparent about their methods or criteria.¹³

While medical app certification remains elusive in the United States, reviews and scoring systems have been established. The site www.iMedicalApps.com is a popular website that reviews and categorizes mHealth apps for clinicians and patients. The site was founded by and is run by 2 physicians, Iltifat Husain, MD and Satish Misra, MD, with more than a dozen regular contributors. Apps receive a text review, with bullet points of “likes” and “dislikes,” and an overall score based on factors such as user interface, price, and real-world applicability. Links to the Apple App Store and Google Play are available. The date of the review and version used are prominently displayed.

Scoring systems for apps have been proposed in the peer-reviewed literature. For patient-centered apps, the [Mobile Application Rating Scale](#) (MARS) is a 23-item tool to evaluate apps based on 372 explicit criteria identified from a review of 25 previously published papers and resources.¹⁴ App quality in MARS is assessed across 5 broad categories: engagement, functionality, aesthetics, and information quality, as well as a subjective assessment of quality. The tool was applied to 60 randomized iPhone apps and showed quality internal consistency and inter-rater reliability.

The website, www.NODEHealth.org (Network of Digital Evidence in Health) is a new effort that attempts to collect crowd-sourced app reviews from health professionals based on the evidence behind an app’s effectiveness, and it gives an overall score that reflects usability, content quality, and subjective factors. Reviewers are asked to categorize the app, write notes, cite sources, and include other items they feel are pertinent. Reviews will, themselves, be subject to review before publication. This is, in essence, a health-focused app store, with more meaningful ratings and reviews.

Select Governmental Organizations That Oversee Medical Apps

While academic and commercial efforts to review and curate medical apps continue to evolve, government initiatives have also taken shape in recent years. In the United States, app developers need to be conscious of 3 federal organizations:

1. The Office of Civil Rights enforces HIPAA rules on patient privacy and security. Under HIPAA, vendors who integrate patient portals into EHR must enter into business-associate agreements and seek high levels of security for their websites or apps, as these do transmit messages and protected health information between patients and covered entities.
2. The FDA has issued guidelines as to which mobile medical apps they choose to oversee.¹⁵ Specifically, they intend to regulate the following types of apps:

Spotlight 1: Risks With Clinical Reference Apps



It is common practice in the ED to switch a patient to a different opioid medication while maintaining an equivalent analgesic effect (or improving upon it). Clinical apps represent a good resource in these cases, as they are quickly accessible and can account for the many varieties of opioid drugs, their mode of delivery, and other considerations such as patient knowledge, cross-tolerance, or directionality of the switch.

Haffey et al identified 23 apps across various smartphone platforms that might be applicable for this purpose.¹⁷ They noted that more than half had no clear medical authorship and fewer than half referenced primary sources. Nine of the apps converted oral morphine to oral methadone, though there was significant variability in the conversion rates. The apps recommended converting 1 mg of morphine to as little as 0.05 mg of methadone or as much as 0.67 mg of methadone – a more than 10-fold variation. Foley’s 1985 article, “The Treatment of Cancer Pain” in the *New England Journal of Medicine* also noted variation when converting these particular drugs (though not as wide), and ultimately recommended a higher methadone dose (Foley recommended 0.67 mg of methadone; the majority of apps centered around 0.1 mg of methadone).¹⁸ Only 4 of these 9 apps warned about the unpredictability associated with this particular conversion. Currently, the Medscape app gives no conversion from morphine to methadone, and instead recommends consulting a pain specialist.

Haffey et al also examined 9 app recommendations for converting 100 mg of oral morphine to a fentanyl transdermal patch dose. The results ranged from 25 mcg/hr to 60 mcg/hr.¹⁷

While the authors note that variability also exists regarding opioid conversion in medical texts, it was concerning that these apps often made no citation to the literature and often presented the results ambiguously and without discussion.

- (1) medical apps that are an extension of a medical device (eg, an app that controls a blood pressure cuff or displays data from such a device); and (2) medical apps that perform patient-specific analyses and provide patient-specific diagnosis or treatment recommendations (eg, processing CT images to provide radiation therapy treatment plans).
3. The United States Federal Trade Commission (FTC), which investigates and prosecutes deceptive or unfair practices in commerce (including not only privacy practices but also misleading claims about app capabilities), has developed a [helpful interactive guide](#) for app developers to navigate the various agencies and laws that regulate apps.¹⁶ The 10 questions in the guide are instructive for patients and consumers.

Apps of Note

Clinical Decision-Making Aids

MDCalc

MDCalc was created and developed by emergency physician Graham Walker, MD and is maintained through his efforts, along with emergency physician Joe Habboushe, MD, MBA and nearly a dozen other physicians. The company has a Scientific Advisory Board of individuals distinguished in emergency medicine and evidence-based medicine. MDCalc started as a website, and was then developed into a phone- and tablet-friendly web app, and recently launched as free native iOS and Android apps.



Calling MDCalc simply a “calculator” app undervalues the app and its content. There are many standalone clinical calculator apps, and calculators have been integrated into many other apps, websites, and EHRs. Like some other apps of this type, MDCalc categorizes calculators and scores by specialty and allows users to mark favorites for quick reference. However, MDCalc goes beyond that. MDCalc has a larger number of calculators than most other apps, the interface is clean and efficient, and most importantly, the calculators provide additional content and context, such as:

- How and when to use each tool, along with citations of studies showing how the calculators have performed in the studies;
- Information on subsequent-generation calculators that are now clinically preferred (eg, when navigating to the CHADS₂ calculator, MDCalc links to the CHA₂DS₂-VASc calculator);
- How to apply the results after a score has been calculated, as well as follow-up tests and therapies to consider;
- Hyperlinked references to the original literature; and
- Interviews with the researchers who developed the scoring tool, where they answer frequently asked questions, clarify usage, and provide insight into future directions.

MDCalc and the associated app are essential to clinical practice.

EDITOR'S NOTE: EB Medicine recently established a strategic partnership with MDCalc to provide direct access to working calculators and content corresponding to topics covered in *Emergency Medicine Practice* and *Pediatric Emergency Medicine Practice*.

General Medical Apps

As long as emergency medicine remains a generalist specialty, there will be a need for general medical apps. These general-purpose apps are excellent resources for quickly referencing obscure diseases and drugs, yet full-featured enough to be of use in more routine situations. These apps describe common presentations and work-ups, and include clinical calculators and guidelines for many emergency situations. They are frequently updated and extensively referenced.

There are some drawbacks, however. First, apps such as UpToDate® and Epocrates® have an associated fee (vs free), and apps such as Medscape make their money from advertising, which some users may find intrusive. Each app also requires the user to set up an account. But perhaps the biggest drawback is that it takes a lot of tapping to get to the desired information and destination within these apps. They are generally so comprehensive that the content is often buried. Efficient use of these apps in the busy environment of the ED can be difficult and requires familiarity.

Epocrates®

Epocrates® remains the most-downloaded app among healthcare professionals. The company behind the app was purchased by athenahealth in 2013, and, currently, the app has an uncluttered feel, free of pop-ups and sponsored continuing medical education (CME).

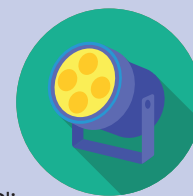
The content on Epocrates® has always centered on drugs – primarily dosing and interactions, indications and warnings, and, in recent years, a pill identification tool. However, it also has an extensive repository of clinical policies and guidelines that are organized by specialty and include guidelines from organizations such as the American College of Emergency Physicians (ACEP). There is also a list of “tables,” various notecard-sized protocols and pathways (such as corticosteroid conversions and advanced cardiac life support for pulseless electrical activity), also organized by specialty.

For \$175 USD per year, additional features are unlocked, including a comprehensive listing of diseases, a differential diagnosis generator, and ICD-10 codes. The main menu of the free version is customizable, so paid options can be moved to another screen. If an institution uses the athenahealth EHR, there are messaging and integrated decision support capabilities as well.

Medscape

The clinical content in the **Medscape** app is based upon the organization of the old eMedicine website, which was founded by 2 emergency physicians in 1996

Spotlight 2: Risks With Physical Examination Apps



Assessing visual acuity is an important part of any ophthalmological workup, and a lower-than-expected visual-acuity score in a trauma patient, for example, may prompt a consultation or imaging studies to be ordered from the ED. Many EDs have Snellen eye charts posted in key locations, but many ED patients complaining of visual changes may have difficulty ambulating to these signs. Since the early days of the Apple and Android app stores, there have been apps claiming to test visual acuity, often adapting a Snellen eye chart for display on a smartphone or tablet screen. Clinicians were instructed to hold the screen at a defined distance (eg, 4 feet away from a patient's eye) to test acuity. The apps were particularly convenient in crowded EDs or with immobile patients.

As new phones with bigger screens have gained popularity, however, many visual-acuity apps were not revised to factor in the change. For example, the iPhone 6 has a larger screen than an iPhone 5, and while the apps transfer smoothly from one device to another, there was no change in the instructions to providers. Users continued to hold the phone 4 feet away from the patient, despite the bigger screen on the newer device, a practice that has led to inflated visual-acuity scores. Similarly, most visual-acuity apps that transfer from an iPad to an iPad mini do not adjust the distance recommendation, which would lead to a report of poorer visual acuity.

These visual-acuity apps were available for many years before a study on their accuracy appeared in the peer-reviewed literature.¹⁹ When 11 apps were compared to correct optotype sizes, errors ranged from 4.4% to 39.9%, with 8 apps showing > 10% inaccuracy. While most apps cost ≤ \$1 USD, only 2 apps had appreciable numbers of reviews in the app store to help guide users in their selection. None of the 11 apps met the authors' threshold for clinical use.

While trials of individual apps have shown promise²⁰ and a new, accurate app designed for ED patients to self-assess visual acuity, **Paxos Checkup**, has been developed,²¹ the fact remains that cheap, inaccurate visual-acuity apps are still widely available. Currently, searches for "visual acuity" or "Snellen" in the iOS App store fail to turn up the evidence-based Paxos Checkup tool and instead point to many discredited apps.

and quickly grew to a massive online site (bought by Medscape's parent company, WebMD, in 2006). The many entries on diseases (called "conditions" in the app) are well-organized and succinct, and the clinical calculators are helpful. Where Medscape really shines, however, is the detailed and comprehensive procedure guides, ranging from proper knee physical examination technique to knee arthrocentesis, in addition to many procedures from other specialties (knee arthroplasty, below-the-knee amputation, etc). Many of the procedure descriptions are supplemented with diagrams, photos, and videos. The procedure guides can be utilized for a quick refresher on rarely performed procedures, to share a clinical pearl with a student, or to secure informed consent from a patient. There is also CME tied to the user's account, which some may find useful.

On the downside, Medscape drug listings are not quite as easy to navigate as Epocrates®, but they are certainly as exhaustive. And, while Medscape is free, it comes with a price: ads from the industry. The ads clutter the main landing page and there are pop-ups during use of the app. Additionally, if the app has not been used in a while, on launch, it prompts the user to download fresh content, which can tie up the user's phone for a few minutes.

UpToDate

UpToDate's writing style is more direct and familiar than typical texts, but just as authoritative and comprehensive. UpToDate is best suited for use on a PC, laptop, or tablet. Accessing the app on a smartphone is not for everyone. The text is small (but can be adjusted), and scrolling is required (though some may prefer that to tapping).

UpToDate is search-driven. When looking up a drug dose or a procedural pearl, it must be typed into the search box. Search results can be difficult to read and may require scrolling to find the appropriate result. However, UpToDate is good to have on hand to search rare conditions. For students and residents lacking an institutional subscription, UpToDate costs \$195 USD per year; for attending physicians, the cost is \$495 USD per year.

Emergency Medicine-Focused Reference Apps

palmEM, WikEM, and ERres

The **palmEM**, **WikEM**, and **ERres** apps are similar in that they feature notecard-style text, bullet points, and mnemonics for common ED scenarios. If the generalist apps previously described are too daunting, with their deep menu navigations and multitude of features, these apps may be more beneficial. There will certainly be fewer taps to get to the content; however, the content is not as robust.

WikEM, the most crowd-sourced (but still peer-reviewed) of the 3 apps, seems to be the most comprehensive, especially when it comes to procedures. **palmEM** comes in at a close second, though it includes more diagrams and photos, and the palmEM app has a more professional feel to it. Still, both WikEM and palmEM can feel like browsing through someone's board review notes. These apps may be best suited for those still in training or early in their emergency medicine careers.

ERres falls in between these apps in terms of price (\$10 USD, as compared to palmEM's \$30 USD and WikEM's freemium model), and, while it has its dedicated usage among residents and educators,² ERres can seem very sparse, with only a handful of clinical calculators and decision rules. Sections such as "Wilderness Med" have only 4 brief entries, and the retro look and feel of the app make it somewhat hard to read and navigate.

Pediatric Emergency Medicine Apps

Upon opening the **palmPEDI** app, the Broselow tape provides expected vital signs and appropriate equipment sizes and medication doses. In a high-stress environment, this streamlined approach works well. Additionally, critical care drugs and their appropriate doses are categorized by ED presentation, and there is also a subsection on procedural sedation medications and dosing.

Kidometer is another classic palmEM app that has been reimagined for the smartphone era. The user can select a category (called a "chapter" in the app) such as vital signs, laboratory values, nutrition guidelines, or developmental milestones, and then enter the child's birthday and sex. Kidometer then displays everything that should be expected for the child, as well as red flags. This app is beneficial for clinicians who do not have a lot of experience with kids, but want to be able to field questions from parents about appropriate development.

Apps for Procedures

Emergency clinicians are credentialed to perform a wide range of procedures. But even the busiest clinician in the busiest trauma center may have years between perimortem cesarean delivery or lateral canthotomies or any number of rare procedures. Therefore, apps that facilitate a fast review of procedures, their indications, the necessary equipment, and the landmarks and techniques, are important. These apps are also great for teaching, and (with discretion) may be worth showing to select patients, in an effort to obtain informed consent.

As previously noted, the **Medscape** app has a great array of procedure descriptions, images, and videos, and the **palmEM** and **WikEM** apps describe procedures in a succinct style that suits emergency medicine. But if a more in-depth description of specific procedures is required, there are some standalone apps that excel.

The **One Minute Ultrasound** app, developed by the physicians who produce the Ultrasound Podcast website

(www.ultrasoundpodcast.com), delivers as promised: 60-second videos crammed full of guidance for positioning your probe, visualizing structures, and identifying pathology. This is a great way for a clinician to prep before heading to the bedside. But if text and still images are preferred, then the EM-focused apps, such as palmEM, could be utilized.

If an emergency clinician needs a quick refresher on intraosseous line insertion technique and landmarks, the makers of **EZ-IO**[®] have an app for performing the procedure on adults and pediatric patients, with succinct animated and filmed videos (with living models) or text descriptions with accompanying pictures.

Several apps to facilitate regional nerve blocks have appeared in recent years, but each lacks some important element. The New York School of Regional Anesthesia has a website (www.nysora.com) and released a promising app in 2014. However, it had only 3 blocks described and has not been updated in years. **RKU Compact** now has the best interface, with a detailed multimedia collection of text, diagrams, photos, and videos for specific nerve blocks; even so, it lacks many blocks most relevant in the ED. **Block GuRU Lite** (confusingly, a non-Lite version does not exist) offers more relevant anatomic locations, but has a clunky interface and excruciatingly slow videos. Given the importance of these procedures, it is likely that this is a segment of apps that will improve.

Critical Care Apps

EMRA's **PressorDex** app (iOS only) provides several ways of conceptualizing critical care medications, by drug, by disease, or by organ system, with easy links between these sections and well-placed links to dosage calculators, dosing instructions, and care pearls. It only takes a few taps to get to the information sought, even for complex dosing regimens such as N-acetylcysteine. On the Android platform, the **Anesthesiologist** app performs a similar role. Though Anesthesiologist has a dense data display, drugs are color-coded by class, which makes this app good for quickly browsing long lists.

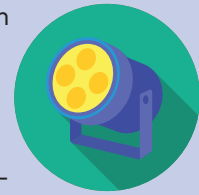
Beyond those standalone apps, palmEM, WikEM, and ERres all have critical care sections, with common critical care medications listed together in notecard fashion. It is recommended that no matter which app is chosen, clinicians should be able to access the necessary sections quickly to find the appropriate information.

Toxicology Apps

Toxicology presentations, antidotes, and pill identifiers are given coverage in generalist and emergency medicine-focused apps. However, apps dedicated to toxicology have advantages, namely, fewer taps and a more fluid interface to get to the information. The website, www.Drugs.com has developed a dedicated pill identifier called **Pill Identifier** (\$.99, though there is also a \$40 version that does not require a WiFi or cellular connection). You can search for drugs by shape, color, or

Spotlight 3: Benefits of Consumer Apps for Medical Decision-Making

Wearable fitness trackers and their companion smartphone apps have become an industry in their own right in the past few years. These devices have sophisticated sensors that can measure movement, heart rate, and other variables to quantify activity levels and give feedback on calories burned throughout the day, the quality of exercise, sleep habits, and more. While some of these fitness trackers have been studied and their comparison to medical-grade devices is often favorable,^{22,23} vendors sell these devices and apps to consumers—not patients—and they are careful to avoid claiming medical benefits.



Against this backdrop, Rudner et al describe a previously well middle-aged adult patient who presented to an ED in New Jersey in rapid atrial fibrillation (AF) after his first seizure.²⁴ He had no symptoms of palpitations in the days and weeks prior to the episode. Without a clear reported onset of the AF, the emergency clinicians were reluctant to cardiovert him. Their protocol, instead, would have recommended rate control and anticoagulation.

However, the patient was wearing a **Fitbit Charge™**, which includes a heart-rate monitor. The accompanying smartphone app was interrogated, and no unexpected paroxysms of tachycardia were identified, other than the episode that led to the seizure and ED presentation. The ED team reviewed this information and decided to cardiovert, and the patient reverted back to sinus rhythm.

The outcome was positive in this case, but it still raises interesting questions: Is it safe to use consumer app data to make medical decisions? Should it be ED policy, or done on a case-by-case basis? Would the doctors be liable if the patient developed a clot? What if the data were ignored, and the patient suffered a poor outcome due to anticoagulation? These scenarios and questions will only become more common as more patients present to EDs with health-tracking data.

imprints, or just type in the name of the drug to confirm its appearance. The app is simple, fast, and effective when a patient states that she “took too many of those orange, oval-shaped pills that say ‘NR’ on the side.” A quick search in the app will determine that it is valproate.

When the type of overdose is known, or clinicians want to review etiologies of the various toxidromes or read pearls from toxicologists, the American Academy of Emergency Medicine (**AAEM Tox Handbook**) app is a complete solution, with information on what the Poison Control Center will recommend. However, it is a bit wordy and priced at \$2.99 USD. So, if just the basics are needed, then apps such as palmEM and WikEM are sufficient.

If clinicians are ever called about a chemical spill or are treating patients with an unusual exposure, the **WISER** (Wireless Information System for Emergency Responders) app is extremely helpful. With this app, clinicians can search by substance or symptoms, or browse categories. There are also guides on how to prepare to receive various chemical burn patients, or how to manage radiation, weapons of mass destruction, and exposures related to the preparation of methamphetamine. It can be reassuring to have this app on hand.

Apps That Facilitate the Physical Examination

VisualDx is a useful app for a viewing a wide array of skin, eye, oral, or nail lesions in various stages. The app developers have branched out into radiology, electrocardiography, and public health as well. VisualDx has a

powerful “differential builder” that allows users to add pertinent patient details (the presence of fever, certain medications, chronicity of symptoms, etc) to help make the diagnosis. Each disease entry has a clinical synopsis and recommended workup, as well as further references. It is relatively expensive without an institutional subscription (\$399 USD per year, or \$263 USD per year for residents and fellows), but makes for a great clinical aid and teaching tool. Even patients can benefit from the visual confirmation of their symptoms, such as seeing how a rash might evolve.

While VisualDx does a great job with the eye, measuring a patient’s visual acuity is a job for another app. **eyeSnellen** has been studied and found comparable to traditional tests of visual acuity, and the app is developed enough to recognize device screen sizes and recommend proper testing distances. (See Spotlight 2, page 7, for more information on visual-acuity testing with apps.)

When it comes to orthopedic testing, **iOrtho+**® is a comprehensive directory of examination maneuvers, organized by joint, to help identify bony and soft-tissue abnormalities. Each test features photos and text descriptors and clearly describes what a positive or negative test means. References, and the test’s sensitivity and specificity, are also included.

Apps to Hone Radiology Interpretation

The **RealWorld Orthopaedics** app shows what a radiologist would look for, in dozens of pathological films. The app provides the images, with the option to overlay key

findings and color-coded annotations. The app is divided into body parts, x-ray findings, or text-only “chapters” of clinical entities, with hyperlinks. This is the app to turn to when there is suspicion for injury on an x-ray. The same color-coded overlaps are applied to chest and abdominal films, in the companion app called **RealWorld Radiology**, though it may not be as enlightening as the subtler joint films in the orthopedics app.

For practicing CT interpretation, **X-Anatomy**® Pro provides head-to-pelvis transaxial CT slices, with labeled anatomical structures that can be tapped on to identify the structures. The app also has a list of structures that clinicians can browse to see the corresponding CT appearance. This app works on a smartphone, but it is even more impressive on a tablet.

Building Your Own Repository of Medical Content

Everyone has some important documents, somewhere “in the cloud.” What is really important, however, is easy access to those documents, whether it is a protocol or paper or presentation. If finding that document requires logging in to webmail and searching for a message, or navigating through PubMed or an organization’s website, then it is probably going to take too long to impact care in the ED.


Several cloud-based file and note repositories, primarily www.dropbox.com and www.evernote.com, have been around for a decade. These services also have apps that allow for local storage on a smartphone or tablet. Investing a little time up front to upload key documents to these free services can allow for quick retrieval on shift, when they are needed.

The Future of Medical Apps

In March 2015, Apple launched **ResearchKit**, a platform that enables investigators to conduct trials via different smartphone apps. Working with local institutional review boards, informed consent for research trials no longer requires in-person consent. Subjects can download the app, provide consent, and securely transmit data to investigators (collected actively or passively via surveys and smartphone sensors).²⁸ While the first ResearchKit apps were focused on specific clinical conditions such as asthma or Parkinson disease, the platform and others like it will allow for study of the apps themselves. Through randomization of app features and careful monitoring of patient data, investigators will be able to determine what components of an app can improve patient outcomes.

While a few apps have already produced evidence as to their efficacy in improving patient biomarkers or outcomes,²⁹ ResearchKit will accelerate the study of digital interventions, such as timely notifications or specific recommendations for therapy based on changing sensor data. A new generation of evidence-based apps will emerge that can be “prescribed” to patients or employed in practice as a medical device. As patients grow accustomed to receiving app prescriptions and tracking their data, emergency clinicians will learn to incorporate

Tips for Organization and Maintenance of Clinical Apps

- Keep only the apps that you really use (except for **WISER**, an app designed to assist emergency responders in case of disaster). 
- Stick to apps that are user-friendly to you, the user. If an app, its functions, or its features are frustrating to you, chances are you can find one more suited to your preferences. If one is not currently available, don't give up; it may be in the pipeline and available soon.
- Limit the number of apps you keep on hand. Apps serve much the same role as pocket guides, but too many can be a hindrance. Maintaining familiarity with a few trusted apps is preferred over having dozens of less-commonly used apps that can all blend together over time. More than a screenful of apps, or more than a handful of app folders, is likely too many.
- Do not neglect apps. Like any tool, apps work best with familiarity and practice. Get to know the menus, navigation, and features of the apps, especially after an update. This will allow for information to be found quickly, as is often necessary in the ED.
- Reach out to app developers to declare your needs and share your ideas. Many app developers are physicians, or work closely with them. Feedback from other clinician users is useful to them and much needed.
- Take advantage of available apps to organize your trusted resources and keep them handy. Content that is referred to on a regular basis—a few important paragraphs, an email, a PDF, a departmental checklist, a society guideline, a good paper, or an issue of *Emergency Medicine Practice*—can be uploaded to any number of data storage apps, such as **Evernote** or **Dropbox**, allowing access on demand from a mobile device.

mHealth app information alongside a bedside history and physical examination. Emergency clinicians will also be able to draw on an increasingly wide array of apps to help process patient information and generate safe, reliable diagnoses and treatment options.



Calculated Decisions

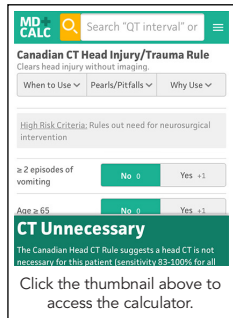
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Canadian CT Head Injury/Trauma Rule

Introduction: The Canadian CT Head Rule (CCHR) was developed to help physicians determine which patients with minor head injury need head CT imaging.



Points & Pearls

- The original validation trial and multiple subsequent studies (Stiell 2001, Stiell 2005, Stiell 2010) each found the high-risk criteria of the Canadian CT (computed tomography) Head Rule (CCHR) to be 100% sensitive for injuries requiring neurosurgical intervention. The CCHR has an 87% to 100% sensitivity for detecting “clinically important” brain injuries that do not require neurosurgery.
- The rule excluded patients who were taking oral anticoagulants and antiplatelet agents, so no data are available for these patients.
- Patients with minimal head injury (ie, no history of loss of consciousness, amnesia, and confusion) generally do not need a CT scan. For example, patients aged > 65 years may not need a CT scan just based on age if they do not have the history mentioned above.
- When a patient fails the CCHR, use clinical judgment on whether a CT scan is necessary.
- One study (Harnan 2011) found the CCHR to be the most consistent, validated, and effective clinical decision rule for minor head injury patients.
- While there is only 1 United States validation study for the CCHR, it was 100% sensitive for clinically important injuries and injuries requiring neurosurgery. A retrospective study in the

United Kingdom found that applying the CCHR would have actually resulted in an increase in the number of patients undergoing CT scans in that particular practice setting. There is debate about whether the goal should be to find all intracranial injuries or to find patient-important ones that would require neurosurgical intervention.

Critical Actions

The CCHR has been validated in multiple settings and has been consistently demonstrated to be 100% sensitive for detecting injuries that will require neurosurgery. Depending on practice environment, it may not be considered acceptable to miss any intracranial injuries, regardless of whether they would have required intervention.

Providers may want to consider applying the New Orleans Criteria for head trauma, as there has been at least 1 trial finding it to be more sensitive than the CCHR for detecting clinically significant intracranial injuries (99.4% vs 87.3%), though this comes at the price of markedly decreased specificity (5.6% vs 39.7%). Furthermore, there are other trials in which the CCHR was found to be more sensitive than the New Orleans Criteria for detecting clinically important brain injuries.

Evidence Appraisal

The validation study (Stiell 2005) included a convenience sample of 2702 patients aged ≥ 16 years, who presented to 9 Canadian emergency departments with blunt head trauma resulting in witnessed loss of consciousness, disorientation, or definite amnesia and a Glasgow Coma Scale score of 13 to 15. Within the sample, 8.5% (231/2707) of the patients had a clinically important brain injury, and

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1.5% (41/2707) of the patients had an injury that required neurosurgical intervention. In the validation trial, the CCHR was 100% sensitive for both clinically important brain injuries and injuries that required neurosurgical intervention, and was 76.3% and 50.6% specific, respectively, for these injuries.

Subsequent studies have all found the CCHR to be 100% sensitive for identifying injuries that require neurosurgical intervention. Applying the CCHR would allow physicians to safely reduce head CT imaging by around 30% (range of 6%-40%, with most studies showing an estimated 30% reduction). In most studies, 7% to 10% of patients had positive CTs, considered "clinically important" brain injuries, but typically, < 2% of patients required neurosurgical intervention. The high-risk criteria have consistently shown 100% sensitivity at ruling out the latter group.

Calculator Creator

Ian Stiell, MD, MSc, FRCPC

[Click here to read more about Dr. Stiell.](#)

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Why to Use

There are more than 8 million patients who present annually to emergency departments in the United States for evaluation of head trauma. The vast majority of these patients have minor head trauma that will not require specialized or neurosurgical treatment. At the same time, rates of CT imaging of the head more than doubled from 1995 to 2007.

When to Use

- Apply the CCHR only to patients with GCS scores of 13-15 with loss of consciousness, amnesia to the head injury event, and confusion.
- Do not use in patients aged < 16 years, patients on blood thinners, or patients with seizure after injury.
- The CCHR is a well-validated clinical decision aid that allows physicians to safely rule out the presence of intracranial injuries that would require neurosurgical intervention, without the need for CT imaging.
- The CCHR has been found to be 70% sensitive for "clinically important" brain injury in alcohol-intoxicated patients (Easter 2013).

Next Steps

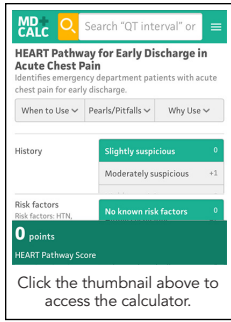
- Remember to always discuss postconcussive symptoms and management with the patient, especially if he or she is being discharged without a head CT. Otherwise, a patient who feels postconcussive symptoms may worry that a CT was needed.
- Educating patients on the symptoms of injuries that require neurosurgical intervention versus postconcussion symptoms can help them feel empowered and reassured.

- Larson DB, Johnson LW, Schnell BM, et al. [National trends in CT use in the emergency department: 1995-2007.](#) *Radiology.* 2011;258(1):164-73.

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Additional Reading

- [Click here to access an *Emergency Medicine Practice* issue reviewing management of mild traumatic brain injury.](#)
- [Click here to access a *Pediatric Emergency Medicine Practice* issue reviewing management of pediatric mild traumatic brain injury.](#)



HEART Pathway for Early Discharge in Acute Chest Pain

Introduction: The HEART Pathway was designed to aid in efficiently evaluating patients with acute chest pain, using the previously validated HEART Score.

Points & Pearls

- The HEART Pathway identifies patients who are safe for early discharge versus those who need observation, admission, and potentially emergent cardiology assessment.
- While patients with ischemic changes on electrocardiogram (ECG) or elevated troponin may be classified as low-risk using the HEART Pathway, the creators recommend against relying on the HEART Pathway in such cases.
- New elevations in troponin or ECG changes require further workup and these patients should not be deemed to be low-risk.
- The creators of the HEART Pathway recommend against using this clinical decision tool in patients with known coronary artery disease, a disease state that puts patients at significant increased risk of acute coronary syndromes (ACS).
- The HEART Pathway was designed for patients presenting to the emergency department (ED) with chest pain, and was not tested in patients with chest pain who are already hospitalized.

Advice

The HEART Pathway is an accelerated diagnostic pathway. It is not designed to replace clinical judgment. Any patient with a concerning presentation or clinical progression should receive workup and treatment based on the clinician's discretion, regardless of the HEART Pathway's predicted risk.

Shared decision-making is a crucial part of further management after ACS risk has been determined, especially in patients with moderate risk who are recommended for observation and comprehensive cardiac evaluation. There is notable risk involved with hospitalization as well as risk of false-positive or nondiagnostic testing that would result in invasive procedures such as cardiac catheterization. The patient should be presented with the risk

Why to Use

Chest pain is one of the most common and potentially life-threatening chief complaints in emergency medicine. Many patients presenting with chest pain undergo unnecessarily extensive and costly evaluations to rule out ACS. The HEART Pathway can reduce the number of prolonged and invasive evaluations, while maintaining high sensitivity and negative predictive value for ACS.

Unlike other scoring systems such as the TIMI Risk Index or the GRACE Risk Score, the HEART Pathway is designed to predict the likelihood of ACS in the patient presenting to the ED with acute chest pain. TIMI and GRACE scores are used to risk stratify patients who have been diagnosed with ACS.

When to Use

- Use in patients aged ≥ 21 years presenting with symptoms suggestive of ACS.
- Do not use in patients with new ST-segment elevation ≥ 1 mm or other new ECG changes, hypotension, life expectancy < 1 year, or noncardiac medical/surgical/psychiatric illness determined by the provider to require admission.

Next Steps

- Low-risk patients with a follow-up troponin (at 3 hours) can be considered for safe discharge home with appropriate follow-up.
- High-risk patients require admission, serial cardiac biomarkers and ECG, and cardiology consult.

Abbreviations: GRACE, Global Registry of Acute Coronary Events [Risk Score]; TIMI, Thrombolysis in Myocardial Infarction [Risk Index].

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of both missed ACS and hospitalization for further workup.

Any patient presenting with chest pain and subsequently discharged should be informed that even with a negative workup, there is still a small risk of ACS. Patients should have close follow-up arranged

and be given extensive return precautions prior to discharge.

Critical Actions

Clinician judgment should prevail, even if patients are deemed to be at low risk by the HEART Pathway. If there is some other cause for concern for an acute cardiac event, workup should be individualized to the patient.

All patients presenting to the ED with chest pain concerning for ACS should receive aspirin unless there is an absolute contraindication, such as known allergy, active bleeding, or if the patient has received a therapeutic aspirin dose prior to arrival.

Evidence Appraisal

The HEART Pathway was developed by Mahler et al in 2015 in a randomized controlled single-center trial. The control arm was managed at the discretion of care providers encouraged to follow American College of Cardiology/American Heart Association guidelines for acute chest pain.

The use of the HEART Pathway in this study was designed to mimic the real world in that it was used as an accelerated diagnostic pathway. Patient care was at the discretion of the healthcare provider and not mandated by the outcome of the HEART Pathway.

There were 282 patients studied, with 141 patients in each treatment group. The primary outcome was the rate of objective cardiac testing (stress test, coronary computed tomography angiogram, or invasive coronary angiography) within 30 days of presentation. Secondary outcomes were early discharge rate, index length of stay, cardiac-related recurrent ED visits, and nonindex hospitalization at 30 days.

The rate of objective cardiac testing in the HEART Pathway group was 12% less than the usual care group. The rate of early discharge in the HEART Pathway was 21% higher than the usual care group. The index length of stay was 12 hours shorter using the HEART Pathway. There was no significant difference between the 2 groups for cardiac-related recurrent ED visits or nonindex hospitalization at 30 days. No patients identified for early discharge in either group had missed a missed major adverse cardiac event (MACE) during the first 30-day follow-up period. The study was not powered to adequately detect differences in MACE between the 2 study groups.

Riley et al in 2017 published a cost analysis of the HEART Pathway compared to usual care, using the same dataset as the original HEART Pathway trial. There were 270 patients studied. Billing data were missing for 12 patients from the original study. Cost metrics considered in each group were index visit cost, total cost at 30 days, cardiac-related

healthcare cost at 30 days, cardiac and noncardiac diagnostic testing cost, ED cost, inpatient cost for index visit, and outpatient cost. HEART Pathway patients had a significantly lower mean and median cost for both index visit and 30-day follow-up. There was no significant difference between the median and mean costs of the other metrics. Average savings per patient was \$216, using the HEART Pathway. On a larger scale, this would mean approximately \$2 billion in savings per year for undifferentiated chest pain.

Mahler et al in 2017 also published a secondary analysis looking at high-sensitivity cardiac troponin I and high-sensitivity cardiac troponin T. The study compared risk stratification using cardiac troponin I versus high-sensitivity cardiac troponin I and high-sensitivity cardiac troponin T in calculating the HEART Pathway score. Blood samples were sent for troponin I, high-sensitivity troponin I, and high-sensitivity troponin T for 133 patients.

All of the troponin assays had poor sensitivity for predicting MACE when used separately from the HEART score. There was no difference in the predicted risk of MACE between the use of serial troponin I and 3-hour high-sensitivity troponin I in the HEART Pathway. Using high-sensitivity troponin T in the HEART Pathway led to 1 patient with a non-ST-segment elevation myocardial infarction being misclassified as low-risk. The study found the HEART Pathway using serial troponin I or 3-hour high-sensitivity troponin I to have sensitivity and negative predictive value of 100% for 30-day MACE. Although hs-cTnT use in the HEART Pathway caused a non-ST-segment elevation myocardial infarction to be misclassified as low risk, the reduction in sensitivity was not statistically significant, given the small study population. The authors recommend further appropriately powered studies to determine small differences in the accuracy of the high-sensitivity troponin assays.

Selected Abbreviations

ACR	Acute coronary syndromes
ECG	Electrocardiogram
ED	Emergency department
MACE	Major adverse cardiac event

Calculator Creator

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LRINEC Score for Necrotizing Soft Tissue Infection

Screens for necrotizing soft tissue infections.

INSTRUCTIONS
If high suspicion for necrotizing fasciitis through clinical history and physical exam, do not calculate a LRINEC score and go straight to operative debridement.

When to Use ▼ Pearls/Pitfalls ▼ Why Use ▼

0 points
If high suspicion for necrotizing fasciitis through clinical history and physical exam, do not calculate a LRINEC score and go straight to operative debridement.

Click the thumbnail above to access the calculator.

LRINEC Score for Necrotizing Soft-Tissue Infection

Introduction: The LRINEC (Laboratory Risk Indicator for Necrotizing Fasciitis) Score was developed to distinguish necrotizing fasciitis from severe cellulitis or abscess.

Points & Pearls

- The original LRINEC (Laboratory Risk Indicator for Necrotizing Fasciitis) study (Wong et al 2004) was a retrospective observational study divided into a developmental cohort and a validation cohort. It included 145 patients with necrotizing fasciitis and 309 patients with severe cellulitis or abscesses admitted to Changi General Hospital.
- The developmental cohort consisted of 89 patients with necrotizing fasciitis and 225 control patients. Necrotizing fasciitis was defined as an operative exploration findings of a presence of grayish necrotic fascia, lack of resistance of normally adherent muscular fascia to blunt dissection, lack of bleeding of the fascia during dissection, and the presence of foul-smelling, "dishwater" pus.
- From the developmental cohort, the study authors derived a scoring system of 6 criteria, each worth 0, 1, 2, or 4 points. The score was then "externally validated" on a separate cohort of 56 consecutive patients with necrotizing fasciitis and 84 control patients with severe cellulitis or abscess seen at Singapore General Hospital during a similar time frame.
- Patients were classified into three groups: low risk (LRINEC score ≤ 5 points, $<50\%$ risk for necrotizing fasciitis), moderate risk (LRINEC score 6-7 points, 50% - 75% risk for necrotizing fasciitis), and high risk (LRINEC score ≥ 8 points, $>75\%$ risk for necrotizing fasciitis). Using a LRINEC score of ≥ 6 points as a cutoff for necro-

Why to Use

The LRINEC score may be helpful in providing an overall gestalt picture of a patient with a potential necrotizing soft-tissue infection, but it cannot rule out this infection.

When to Use

- Use in patients with a concerning history or physical examination (eg, pain out of proportion to examination or rapidly progressive cellulitis).
- It can also be used in patients with an unconcerning story, as it can provide some reassurance if the score is very low.

Next Steps

- Prompt fluid resuscitation and antibiotic administration are crucial in the treatment of necrotizing fasciitis.
- Consider early surgical consultation in borderline cases.

tizing fasciitis yielded a positive predictive value (PPV) of 92% and negative predictive value (NPV) of 96%. Approximately 90% of patients with necrotizing fasciitis had LRINEC scores ≥ 6 points, while only 3.1% to 8.4% of control patients had LRINEC scores ≥ 6 points.

- Ten percent of patients with necrotizing fasciitis still had a LRINEC Score <6 . Also, there have been no prospective trials validating the LRINEC Score, and subsequent validation studies have not replicated the numbers shown in the original study.

Advice

All patients for whom there is a high clinical suspicion for necrotizing fasciitis should receive imme-

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diate surgical consultation for potential operative debridement. Consider calculating a LRINEC score to distinguish patients with severe cellulitis/abscess vs necrotizing fasciitis.

Critical Actions

A LRINEC score ≥ 6 points is a reasonable cutoff to rule in necrotizing fasciitis, but a LRINEC score < 6 points does not rule out the diagnosis.

Evidence Appraisal

A validation study looking only at patients with pathology-confirmed necrotizing fasciitis showed that a LRINEC score cutoff of 6 points for necrotizing fasciitis only had a sensitivity of 59.2% and a specificity of 83.8%, yielding a PPV of 37.9% and NPV of 92.5%. However, the study did show that severe cellulitis had a LRINEC score ≥ 6 points only 16.2% of the time. Other validation studies have shown similarly poor sensitivities and specificities.

A subsequent retrospective analysis of patients with confirmed necrotizing fasciitis also showed that LRINEC scores ≥ 6 points were also associated with statistically significant increases in mortality and amputation rates.

The original derivation study was a retrospective observational study looking at laboratory differences between patients with confirmed necrotizing fasciitis and those with severe cellulitis or abscess. The study derived 6 criteria (C-reactive protein, white blood cell count, hemoglobin, sodium, creatinine, and glucose), with each criterion assigned a point value from 0-4. Using a cutoff of ≥ 6 points for necrotizing fasciitis, the study then retrospectively applied the criteria to separate cohorts of necrotizing fasciitis

and severe cellulitis/abscess patients drawn from a population similar to the derivation study.

The study found that a LRINEC score ≥ 6 points had a sensitivity of approximately 90% and a specificity of approximately 95%, with a PPV of 92% and a NPV of 95%. However, this cutoff still missed 10% of patients with necrotizing fasciitis. Subsequent studies of the LRINEC Score yielded even poorer sensitivities of around 60% and a specificity in the 80% range. A LRINEC score of ≥ 6 points could be used as a potential tool to rule in necrotizing fasciitis, but a score of < 6 points should not be used to rule out the diagnosis.

Calculator Creator

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[Click here to read more about Dr. Ho.](#)

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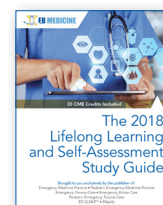
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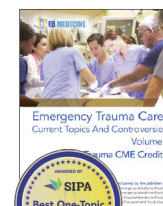
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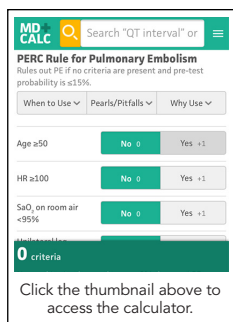
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PERC Rule for Pulmonary Embolism

Introduction: The PERC (Pulmonary Embolism Rule-out Criteria) Rule is utilized by physicians to avoid further testing for pulmonary embolism in patients deemed to be at low risk.

Points & Pearls

- The PERC (Pulmonary Embolism Rule-out Criteria) Rule is a "rule-out" tool – all variables must receive a "no" to be negative.
- The test is unidirectional. While PERC negative typically allows the clinician to avoid further testing, failing the rule does not force the clinician to order tests.
- As rule-out criteria, the PERC Rule is not meant for risk stratification.
- Physicians utilizing this rule must have a gestalt that the patient's risk of pulmonary embolism (PE) is low (the study used $< 15\%$).
- The study was designed with a 1.8% test threshold. This took into account the risks associated with PE workup and treatment, such as computed tomography (CT) radiation, anaphylaxis from contrast, and bleeding from anticoagulation. For patients with a pretest probability below this threshold, the risk associated with starting a workup is equivalent to the chance of missing the diagnosis.

Critical Actions

There is no need to apply the PERC Rule to those patients who are not being evaluated for PE. If the patient is considered low risk, the PERC Rule may help avoid further testing. If the patient is moderate or high risk, then PERC Rule cannot be utilized. Consider D dimer or imaging based on risk. Consider pericardial disease in patients with pleuritic complaints, as well.

Evidence Appraisal

The original article (Kline et al) from 2004 was a prospective study with a derivation section and a validation section. There were 3148 patients from 10 sites included in the derivation. Twenty-one potential variables were included for analysis, with 8 final variables selected from among them. The validation section included 1427 low-risk and 382 very-low-risk

Why to Use

Emergency physicians have a low threshold for testing for PE. The PERC Rule rules out patients who are considered low-risk for PE based on clinical criteria alone. PERC-negative patients do not require utilization of the D dimer, which has a high sensitivity but low specificity. Low-risk patients who are PERC-negative avoid the risks associated with unnecessary testing and treatment for PE.

When to Use

- The PERC Rule can be applied to patients where the diagnosis of PE is being considered, but the patient is deemed low-risk.
- A patient deemed low-risk by physician's gestalt, who is also aged < 50 years, with a pulse rate < 100 beats/min, $\text{SaO}_2 \geq 95\%$, no hemoptysis, no estrogen use, no history of surgery/trauma within 4 weeks, no prior PE or DVT, and no present signs of DVT, can be safely ruled out and does not require further workup.

Next Steps

- In the setting of a low-risk patient who is not PERC-negative, the physician should consider a D dimer for further evaluation.
- If the D dimer is negative, and clinical gestalt determines a pre-test probability is $< 15\%$, then the patient does not require further testing for PE.
- If the D dimer is positive, further testing such as a CT angiography or V/Q scan should be pursued.

Abbreviations: DVT, deep vein thrombosis; V/Q, ventilation/perfusion [ratio].

patients from 2 sites.

In low-risk patients, there was a sensitivity of 96% and specificity of 27%. In very-low-risk patients, there was a sensitivity of 100% and specificity of 15%. The false-negative rate at 90 days in low-risk

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patients was 1.4%, which is below the 1.8% testing threshold.

A second multicenter validation was done by Kline et al in 2008. This expanded upon the initial validation study and defined low pretest probability as < 15%. The study included 8138 patients from 13 sites. Some of these sites were included in the initial paper. Clinical gestalt for a pretest probability of < 15%, 15% to 40%, or > 40% was collected from the providers.

Twenty percent of the cohort was deemed low-risk (< 15%). For patients who were PERC-negative with pre-test probability < 15%, the false negative rate at 45 days was 1.0%, with a sensitivity of 97.4% and specificity of 21.9%.

Calculator Creator

Jeffrey Kline, MD

[Click here to read more about Dr. Kline.](#)

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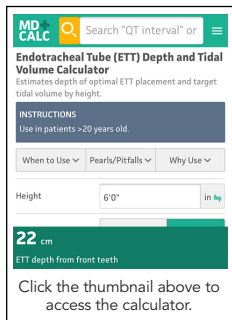
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Validation Reference

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Endotracheal Tube (ETT) Depth and Tidal Volume Calculator

Introduction: The Endotracheal Tube (ETT) Depth and Tidal Volume Calculator estimates depth of optimal ETT placement and target tidal volume by height.

Points & Pearls

- Endotracheal tube (ETT) depth is measured based on the patient's front teeth rather than the molars.
- Larger tidal volumes may be temporarily required for patients with severe metabolic acidosis.

Critical Actions

Obtain chest radiograph and measurement of CO₂ level (eg, end-tidal CO₂ or blood gas analysis) to confirm ETT position and adequacy of ventilation.

Evidence Appraisal

The Chula formula was developed and validated by Techanivate et al (2005) at King Chulalongkorn Memorial Hospital in Thailand. The authors prospectively validated the use of this formula among 100 patients in Thailand. Patients were intubated and the ETT placed according to the formula. Subsequently, a bronchoscope was used to determine the relationship among the ETT, carina, and vocal cords. The distance between the ETT and carina ranged

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Why to Use

Placing the ETT too deep may cause right mainstem intubation, hypoxemia, and pneumothorax. However, placing the ETT too shallow may risk injury to the vocal cords and accidental extubation. Standard approaches to verify ETT depth (eg, bilateral auscultation) are insensitive. Use of lower tidal volumes appears to prevent the development of acute respiratory distress syndrome, even in patients who do not have lung injury.

When to Use

Use in adult patients (aged > 20 years) requiring orotracheal intubation.

Next Steps

- ETT position should still be verified with a chest radiograph for patients who will remain intubated for an extended period of time.
- For tidal volume, 6 to 8 mL/kg ideal body weight is generally a safe initial setting, but further ventilator adjustment may be required, depending on the adequacy of ventilation and airway pressures.

between 1.9-7.5 cm. No patient was at immediate risk of endobronchial intubation. The upper border

of the ETT cuff was always > 1.9 cm below the vocal cords, avoiding risk of laryngeal trauma or inadvertent extubation.

Pak et al in 2010 and Hunyady et al in 2008 developed similar assessments of optimal ETT placement. The average of the 3 scores (Pak, Hunyady, and Chula) is nearly identical to the Chula formula.

Calculator Creator

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Original/Primary References

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- Acute Respiratory Distress Syndrome Network, Brower RG, Matthay MA, et al. [Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome.](#) *N Engl J Med.* 2000;342(18):1301-1308.

Formula

Chula formula: ETT depth = 0.1 * [height (cm)] + 4

Additional Formulas

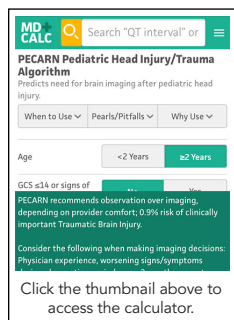
- IBW, men = 50 kg + 2.3 * [height (in) - 60]
- IBW, women = 45.5 kg + 2.3 * [height (in) - 60]
- Usual tidal volume target = 6-8 mL/kg IBW

Abbreviation: IBW, ideal body weight

Other References

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PECARN Pediatric Head Injury/Trauma Algorithm

Introduction: The PECARN Pediatric Head Injury Prediction Rule is a well-validated clinical decision aid that allows physicians to safely rule out the presence of clinically important traumatic brain injuries.

Points & Pearls

- The Pediatric Emergency Care Applied Research Network (PECARN) consortium produced the largest study, to date, aiming to derive and validate clinical prediction rules to identify children with very low risk of clinically important traumatic brain injury (ciTBI) following blunt head trauma, who would not require imaging. ciTBI was chosen as the primary outcome because it is clinically driven and accounts for the imperfect test characteristics of computed tomography (CT).

- In the group of patients aged < 2 years, the rule was 100% sensitive.
- In the group of patients aged > 2 years, the rule had 96.8% sensitivity.
- In those aged < 2 years with a Glasgow Coma Scale (GCS) score of 14, altered mental status, or palpable skull fracture, risk was 4.4%, and CT imaging is recommended.
- Risk with any of the remaining predictors was 0.9%, and < 0.02% with no predictors.
- In those aged > 2 years with GCS score of 14, altered mental status, or signs of basilar skull fracture, risk was 4.3%, and CT imaging is recommended.
- Risk with any of the remaining 4 predictors was 0.9%, and < 0.05% with no predictors. The PECARN Rule outperformed both the CHALICE (Children's Head injury ALgorithm for the prediction of Important Clinical Events) and CATCH (Canadian Assessment of Tomography for Childhood Head injury) clinical decision aids in external validation studies.
- Although it was the largest trial of its kind, the

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PECARN study had low rates of traumatic brain injury (TBI) on head CT (5.2%) and even lower rates of ciTBI (0.9%), suggesting that overall TBI in children is rare. Head CTs were obtained in approximately 35% of patients, lower than the average estimate of 50%.

Critical Actions

ciTBI was a rare event (0.9%) and neurosurgical intervention was even more rare (0.1%). Over 50% of each age cohort did not meet any predictors, and CT imaging is not indicated for the vast majority of these patients, as risk of ciTBI was exceedingly low. Risk of ciTBI was > 4% with either of the 2 higher-risk predictors in each age cohort, and imaging is recommended.

For the remaining 4 lower-risk predictors in each cohort, the risk of ciTBI is approximately 0.9% per predictor, and CT imaging is indicated rather than observation. Judgment may be based on clinical experience, single versus multiple findings, signs of clinical deterioration during the observation period, patient age, and/or parental preference.

Evidence Appraisal

The original PECARN trial included 42,412 children aged < 18 years presenting to one of the 25 North American PECARN-affiliated emergency departments. There were 33,785 patients in the derivation cohort (8502 of whom were aged < 2 years) and 8627 in the validation cohort (2216 of whom were aged < 2 years).

CT scans were performed at the physician's discretion in 35.3%, while medical records, telephone surveys, and county morgue records were used to assess for cases of missed ciTBI in those discharged without imaging. The potential for CT reduction quoted above is likely underestimated, given that CT utilization in this study (35.3%) was significantly lower than the estimated average in North American emergency departments (50%).

TBI occurred in 5.2% of patients. Nine percent of patients were admitted to the hospital. ciTBI occurred in 0.9% of the cohort, neurosurgery was performed in 0.1% of the overall cohort, and 0 patients died. In patients aged < 2 years who were negative for any PECARN risk factor, the aid was 100% sensitive (95% confidence interval [CI], 86.3-100) with a negative predictive value (NPV) of 100% (95% CI, 99.7-1000) for ruling out ciTBI in the validation cohort. In patients aged > 2 years who were negative for any PECARN risk factor, the aid was 96.8% sensitive (95% CI, 89.0-99.6) with 99.95% NPV (95% CI, 99.8-99.99) for ruling out ciTBI in the validation cohort.

External validation studies have demonstrated sensitivity of 100% for ciTBI and any injury requiring neurosurgery. The algorithm has reasonable

Why to Use

Unlike in the adult population, CT imaging of the head in pediatric patients is believed to be associated with an increased risk of lethal malignancy over the life of the patient, with the risk decreasing with age. The estimated lifetime risk of lethal malignancy from a head CT for a 1-year-old patient is 1 in 1000 to 1500, with risk decreasing to 1 in 5000 for a 10-year-old patient.

There are over 600,000 emergency department visits annually in the United States for head trauma among patients aged ≤ 18 years. Applying the PECARN Pediatric Head Injury Prediction Rule allows providers to determine which pediatric patients they can safely discharge without obtaining a head CT.

When to Use

- The PECARN is a well-validated clinical decision aid that allows physicians to safely rule out the presence of clinically important traumatic brain injuries among pediatric head injury patients without the need for CT imaging, including those that would require neurosurgical intervention.
- The PECARN Rule only applies to children with GCS scores ≥ 14.

Next Steps

- In patients with suspected or radiologically confirmed TBI, first assess ABCs and consider neurosurgical and/or intensive care unit consultation or local policies for fluid management, seizure prophylaxis, hypertonic saline/mannitol, disposition, etc.
- Consider observation for 4 to 6 hours for patients who are not imaged, in order to assess for changes in clinical status.
- Reassurance, education, and strict return precautions are warranted for patients discharged without imaging, including direction to follow up with a primary care provider or neurologist, and anticipatory guidance on return to play/school if concussion is suspected.

Abbreviation: ABCs, airway, breathing, circulation.

specificity (53%-60%), considering its extremely high sensitivity.

Sixty of 376 patients (15.9%) with ciTBI under-

went neurosurgery, 8 patients (2.1%) with ciTBI were intubated > 24 hours, and 0 patients died.

As a result of the infrequency of ciTBI, the lower bounds of the CIs of sensitivity started at 86% and 89%, respectively, for the cohorts aged < 2 years and > 2 years. The NPV CIs very closely approximated 100%.

The PECARN Rule has now been externally validated in 2 separate studies. One trial of 2439 children in 2 North American and Italian centers found the PECARN Rule to be 100% sensitive for ruling out ciTBI in both age cohorts. The rates of 0.8% (19/2439) of patients with ciTBI and 0.08% (2/2439) of patients requiring neurosurgery were similar to the rates in the PECARN trial.

A second trial at a single United States emergency department of 1009 patients aged < 18 years prospectively compared the PECARN Rule to 2 other pediatric head CT decision aids, CHALICE and CATCH, as well as to physician estimates and physician practice. In this sample, 2% (21/1009) of patients had ciTBI and 0.4% (4/1009) of patients needed neurosurgery. Again, the PECARN Rule was found to be 100% sensitive for identifying ciTBI.

The PECARN Rule outperformed both the CHALICE and CATCH decision aids, which were 91% and 84% sensitive for ciTBI, respectively). Although the goal was to rule out those with very low risk of ciTBI, the PECARN Rule also performed well to rule out TBI on head CT. In patients aged < 2 years, sensitivity and NPV were 100% for TBI on CT, with narrow CIs. In patients aged > 2 years, sensitivity was 98.4% and NPV was 94% for TBI on CT, with relatively narrow confidence intervals.

Two PECARN Rule subgroup analyses attempted to further risk-stratify patients with single predictors (eg, isolated scalp hematoma in patients aged < 2 years). ciTBI was too uncommon to apply age, hematoma size, or hematoma location predictors. There were several non-statistically significant trends for higher rates of TBI on head CT that may affect imaging tendencies (eg, age < 3 months, nonfrontal hematoma, and large size).

Another subanalysis of those with isolated vomiting (eg, no other PECARN predictors) reiterated the parent study results. In the cohort of patients aged > 2 years, there was a low rate of TBI on head CT (3.2%, 26 of 806 patients) and an even lower rate of ciTBI (0.7%, 10 of 1501 patients), so observation rather than emergent imaging is indicated in the majority of these patients. Number of vomiting episodes and timing of episodes was not helpful in predicting ciTBI or TBI on head CT, as there was a non-statistically significant counterintuitive trend towards less ciTBI/TBI on CT with more episodes.

Selected Abbreviations

CATCH	Canadian Assessment of Tomography for Childhood Head injury [Rule]
CHALICE	Children's Head injury ALgorithm for the prediction of Important Clinical Events [Rule]
ciTBI	Clinically-important traumatic brain injury
CI	Confidence interval
CT	Computed tomography
GCS	Glasgow Coma Scale
NPV	Negative predictive value
PECARN	Pediatric Emergency Care Applied Research Network
TBI	Traumatic brain injury

Calculator Creator

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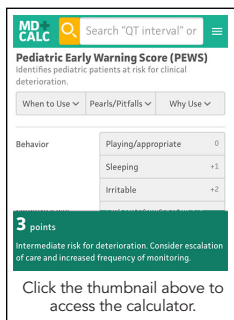
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Additional Reading

[Click here to access a *Pediatric Emergency Medicine Practice* issue reviewing severe traumatic brain injury in children.](#)



Pediatric Early Warning Score (PEWS)

Introduction: The Pediatric Early Warning Score (PEWS) identifies pediatric patients at risk for clinical deterioration and can help less-experienced providers get a sense of which patients may need escalation of care.

Points & Pearls

- The Pediatric Early Warning Score (PEWS) was originally developed to provide a practical and objective method to identify pediatric inpatients at risk for cardiac arrest.
- It can be used by staff and providers at all levels to escalate care for sick patients, including junior physicians and nursing staff.

Evidence Appraisal

The PEWS was developed by expert consensus by a multidisciplinary group at Brighton and Sussex University Hospitals National Health Service Trust in the United Kingdom, in order for nurses and junior medical staff to identify pediatric patients who are at risk for clinical deterioration. It was intended to serve as a pediatric-specific version of the National Early Warning System (NEWS) Score, which was developed in an effort to standardize the approach to detecting clinical deterioration in acutely ill adult patients in the United Kingdom.

Triggers were identified by polling a multidisciplinary group at all levels of patient care on which clinical features they considered concerning, including appearance and vital signs. The criteria were revised based on a pilot that identified patients who deteriorated but were not identified by the original score.

Several studies have validated the PEWS, including one by Duncan et al in 2006 that found an AUROC (area under the receiver operating characteristic curve) of 0.90, with 78% sensitivity and 95% specificity at a score of 5.

The PEWS has been adapted for use in multiple settings, including academic centers and community hospitals.

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[Click here to read more about Mr. Monaghan.](#)

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Why to Use

The PEWS provides an objective measurement for patients who "look sick." It can help less-experienced providers get a sense of which patients may need escalation of care. It can be used in pediatric patients of all ages.

When to Use

Use in pediatric patients admitted to the hospital.

Next Steps

Consider escalation of care in patients with high PEWS (≥ 3), including endorsing to senior staff, increasing frequency of vital signs measurements and clinical assessments, and/or consultation to an intensive care unit.

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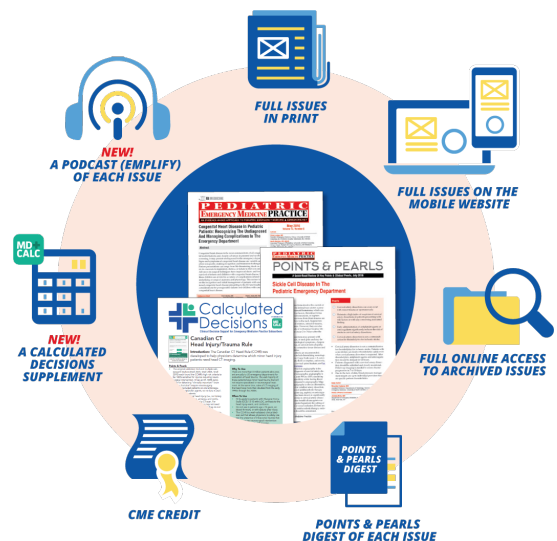
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