# Debriefings on Prehospital Care Scenarios in MedDbriefer—A Tool to Support Peer Learning

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**Abstract.** Across the healthcare professions, many students don't get enough practice doing simulated clinical interactions during course labs to feel confident about passing certification exams and treating actual patients. To address this problem, we are developing MedDbriefer, a web-based tutoring system that runs on a tablet. MedDbriefer allows peers to engage in supplemental clinical scenarios on their own. With its current focus on paramedic training, one student "voice treats" a simulated patient as the leader of a mock emergency medical services team while a peer uses MedDbriefer's checklists to log the team leader's verbalized actions. The system then analyzes the event log and generates a debriefing, which highlights errors such as assessment actions and treatment interventions that the team leader missed or performed late. This paper focuses on how the system analyzes event logs to generate adaptive debriefings.

**Keywords:** Simulation-based Training, Debriefing, Healthcare Training

## 1 Introduction

Simulation-based training (SBT) provides students in the healthcare professions realistic clinical experiences without risk to actual patients [1]. Some exercises focus on psychomotor skills such as intubating a patient's airway, administering fluids through an intravenous line, and transferring a patient safely to an ambulance. Other exercises immerse students in realistic clinical scenarios that challenge them to apply psychomotor, clinical reasoning, and team coordination skills. Although simulation cannot replicate all benefits of interacting with actual patients, such as emotional engagement, its effectiveness for developing clinical knowledge and skills is well established [e.g., 2].

Students who struggle to acquire these skills can benefit from supplemental simulation-based practice, outside of their course labs. Unfortunately, instructors who are trained to facilitate simulation exercises are in short supply [e.g., 1,3]. Many instructors are themselves active clinicians (e.g., doctors, nurses, paramedics), which limits the time they can devote to teaching. To address this problem, instructors often encourage peer learners to do clinical scenarios on their own, without an instructor present. However, peer-to-peer learning needs to be supported to be effective. Left unguided, it can become fraught with problems [4]. For example, students often can't find or invent clinical scenarios that are as challenging as those they will be tasked to perform during certification exams and on the job. With limited clinical knowledge and skills, especially during early stages of training, students sometimes call out unrealistic patient findings and other information their peers request while treating the scenario's patient(s). Most seriously, students typically can't provide helpful feedback on their peers' performance, and explanations that require a sufficient understanding of human anatomy, physiology, etc. to produce.

In response to these limitations of peer-to-peer simulation-based training, we are developing MedDbriefer—a web-based tutoring system that runs on a tablet. It allows two or more paramedic trainees to practice realistic prehospital care scenarios and immediately receive an automated debriefing on their performance. While one student treats a simulated patient as the leader of a mock emergency medical services (EMS) team, a peer uses the tablet's checklists to log the team leader's actions. The team leader may be assisted by one or more peers (see Fig. 1). Immediately after the scenario, the system analyzes the event log and generates an adaptive debriefing that highlights errors—for example, missing patient assessment steps and interventions, inappropriate interventions, and errors in how interventions were performed. Our ultimate goal is for MedDbriefer to be more scalable, to support peer-to-peer simulation-based training across the healthcare professions.

**Fig. 1***:* MedDbriefer in use during a clinical scenario. Peer members of a mock EMS team treat a virtual patient (at right); session observer, at left, uses a tablet to log the team's actions.

The next section presents an overview of MedDbriefer. Previous papers provide more detailed descriptions of the two approaches to debriefing that MedDbriefer implements [5, 6]. At this writing, a randomized controlled trial to compare the effectiveness of these approaches is in progress. This paper focuses on how the system analyzes event logs of students' actions during scenarios to generate adaptive debriefings.

## 2 MedDbriefer

MedDbriefer focuses on developing paramedic trainees' clinical reasoning skills, which includes identifying clinical problems, determining which interventions to perform to manage these problems and how to perform them. For example, paramedics need to be able to recognize symptoms of hypovolemic shock such as significant blood loss; pale, cool, moist skin; hypotension; and rapid, shallow breathing. This diagnosis should trigger the decision to administer intravenous fluids unless other circumstances render fluids contraindicated (e.g., the patient is a near drowning victim). The paramedic also needs to decide how to perform this intervention—for example, which type of fluid to administer when more than one option is available, at what dosage, how large a catheter to use, etc.. Whereas psychomotor skills must be repeatedly rehearsed "hands on" to be mastered—for example, by starting an IV and administering fluids in patient manikins—clinical reasoning skills can be practiced by "voice treating" simulated patients, which can be anything tangible: a manikin (if available from a simulation lab), doll, peer, etc. Voice treating entails verbalizing the actions the "EMS team" would perform, how they would perform them, which actions the team leader would delegate to partners, etc. Students often mime actions and use readily available equipment (e.g., a stethoscope); however, costly simulation equipment is unnecessary.

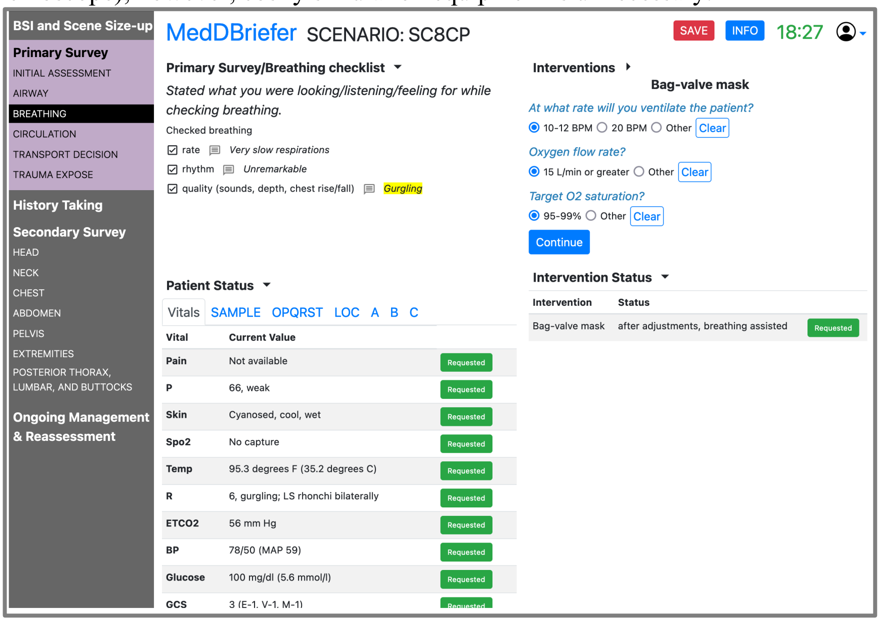


**Fig. 2:** MedDbriefer's Observer Interface

Since MedDbriefer runs on a tablet, students will be able to use the fully developed version to do practice scenarios just about anywhere—for example, in a small meeting room or dorm room. As shown in Fig. 1, a peer who is neither the EMS team leader nor a team member plays the role of "session observer," using MedDbriefer's checklists to record the team leader's verbalized actions. MedDbriefer's *Observer Interface* (OI) provides two main checklists. The *assessment checklist* (Fig. 2, left) is patterned after one of the scorecards used to assess candidates during the National Registry of Emergency Medical Technicians' (NREMT) paramedic certification exam [7]. When the observer checks an assessment step, the system displays a finding to call out. For example, if the team leader states that he is checking breathing quality, the observer is cued to call out "gurgling," highlighted in yellow in Fig. 2. The *intervention checklist* (Fig. 2, right) includes treatments and other actions that EMS providers perform such as ventilating a patient with a bag-valve mask and securing a patient onto a longboard.

Interspersed throughout the checklist menus are prompts for the observer to issue if the team leader fails to provide sufficient detail while voice treating. For example, the right side of Fig. 2 displays an Airway Management intervention, bag-valve mask ventilation, along with questions the observer should ask a student who fails to specify the ventilation rate, oxygen flow rate, and/or target $O_2$ saturation level.

As noted previously, MedDbriefer implements two approaches to automated debriefing. The first is a step-by-step walkthrough of students' actions, color coded to signal correct (green) and incorrect (red) actions (see Table 1). This is the standard approach to debriefing taken in computer-based simulation systems such as vSim for Nursing [8]. The second approach adapts one of several protocols that have been developed to guide simulation instructors in conducting effective debriefings: DEBRIEF [5, 6, 9]. This acronym stands for **D**efine the debriefing rules; **E**xplain the learning objectives; specify the performance **B**enchmarks; **R**eview what was supposed to happen; **I**dentify what actually happened; **E**xamine why things happened as they did; and **F**ormalize the "take home" points. MedDbriefer uses the same procedures to analyze event logs, and presents identical feedback, across these two debriefing approaches.

Table 1 presents a sample of debriefing feedback in the first approach, a timestamped walkthrough of a mock EMS team's scenario solution. The scenario involves the near drowning of a four-year-old boy left unattended in a swimming pool. Note that the system flagged an error in how the team ventilated the patient (line 15), failure to check for external bleeding (line 17), and late assessment of the patient's pulse (line 21).

MedDbriefer's development was informed by extensive observations of actual simulation-based training sessions, facilitated by human EMS instructors; feedback from experienced EMS and nursing educators; and field trials of the system that included paramedic trainees as participants. As a first step, we videotaped, transcribed, and analyzed over 100 hours of simulated scenarios that took place during the University of Pittsburgh's 2020-2021 Emergency Medical Services program. Analysis of session transcripts enabled us to identify common errors that EMS trainees make while assessing and treating patients and the feedback that instructors provide to address these errors. Guided by this analysis, a physician authored most of the feedback that MedDbriefer provides during debriefings, as part of her graduate research project. She also analyzed the data from an initial field trial [6].

This trial revealed several "bugs" to address, and unclear feedback to revise, before we could conduct the randomized trial currently in progress. For example, we discovered that several decision rules deployed during event log analysis had to be refined, to prevent students from receiving negative feedback for correct actions. To illustrate, one temporal constraint stated that students should complete all assessment steps in the Primary Survey, and address all identified life threats, before starting the Secondary Survey (see Fig. 2). However, paramedics often need to examine the patient's head, neck and/or chest to identify and manage respiratory problems. Hence, we revised this rule so that students would not be told that they assessed the patient's upper body too early, in scenarios that require them to identify and manage compromised breathing.

## 3 Related Work

Other tools to support peer-to-peer and self-directed simulation are available on the market. For example, nursing educators at the University of Stavenger, Norway, experimented with using Laerdal's® Simpad to support peer-centered simulation-based training [4]. Like MedDbriefer, SimPad and its successor, Simpad Plus, provide check-

**Table 1**: Excerpt from a step-by-step debriefing that followed a near-drowning scenario (slightly modified for improved readability)

| ID | Timestamp | Action description | Feedback |
|---|---|---|---|
| **Breathing** | | | |
| 15 | 01:56 | ⊗ Performed bag-valve mask ventilation. **Purpose:** Oxygenation **Oxygen flow rate:** 15 liters/min or greater **Target O2 saturation rate:** 95-99% **Ventilation rate:** 10-12 BPM | *Incorrectly administered intervention*. You were incorrect about ventilation rate. This patient should have been ventilated at a rate of 20 breaths per minute, which is the recommended rate for a child aged 2-12. When performing BVM ventilation, you use 15LPM O2 in order to both oxygenate and ventilate the patient to a target SpO2 >90%. |
| **Circulation** | | | |
| 16 | 02:01 | ☺ Checked skin condition (moisture). **Found:** *Wet* | |
| 17 | | ⊗ Performed a gross blood sweep. **Found:** *No major external bleeding* | *Missing assessment step*. A gross blood sweep, which was negative in this patient, will help you identify any life-threatening bleeding you may have missed earlier when forming your general impression. |
| 18 | 02:02 | ☺ Checked skin color. **Found:** *Cyanosed* | |
| 19 | 02:02 | ☺ Checked skin temperature. **Found:** *Cool* | |
| 20 | 02:09 | ☺ Which pulse? **Pulse to check:** carotid and radial | |
| 21 | 02:09 | ⏰ Checked pulse rate. **Found:** *Slow* | *Mistimed assessment step*. All unconscious patients should have a pulse check before starting the ABCs. However, paramedics often check breathing while doing a pulse check. If the patient is pulseless, you will start high-quality CPR immediately… |

lists on a tablet-based interface that a student can use to log their peers' actions during a scenario. However, unlike MedDbriefer, SimPad and Simpad Plus don't debrief students on their performance. Instead, they provide tools that instructors can use for debriefing, such as a Log Viewer that displays a history of students' actions during a simulation session. Including the human instructor in the loop may cause delays in students' receipt of feedback. MedDbriefer emulates the log analysis and debriefing skills of human instructors, so students can receive immediate, high-quality feedback.

MedDbriefer also emulates human instructors' tendency to prompt students for additional details while voice-treating a simulated patient when students' verbalized actions are vague. These additional specifications allow the system to provide more detailed, adaptive debriefings than it otherwise could. To our knowledge, other systems do not probe for important missing specifications.

Several computer-based simulation platforms generate debriefings, such as the American Heart Association's Heartcode™ BLS and ACLS programs to train basic and advanced cardiac life support skills, respectively, and vSim for Nursing [8]. The latter engages nursing students in realistic clinical interactions with patients in a hospital setting. Like MedDbriefer, these tutoring systems analyze the log of students' actions immediately after a simulation session, in order to generate a debriefing. However, unlike MedDbriefer, they do not afford hands-on interaction with a tangible, 3D "patient". Preliminary research suggests that interaction with tangible simulated patients such as manikins, peers acting as patients, etc. may predict superior patient care performance than interaction with screen-based simulated patients [11].

## 4 Analyzing Scenario Logs to Generate Debriefings

### 4.1 Overview

Once a student completes a scenario as an EMS team leader, the event log is automatically analyzed to identify what was done well and what needs improvement. The event log (EL) includes the observer's checked-off actions and is analyzed in three phases, as described in this section. Each phase utilizes the event log, the assessment hierarchy (AH) and the management hierarchy (MH). These hierarchies represent knowledge specified offline by domain experts and stored in a database for use during analysis.

The AH is a downward branching tree whose parent node is the goal of completing a full patient assessment and branches are assessment phases and subphases. For example, a thorough trauma patient assessment consists of an initial *Scene Size-up* to determine whether the scene is safe, how many patients there are, the mechanism of injury, etc.; a *Primary Survey* to qualitatively assess the patient's airway, breathing, and circulation (e.g., Is his airway clear? Is he breathing? Does he have a pulse?); *History Taking,* which includes taking baseline vital signs, finding out as much as possible about what happened and the patient's medical history; a *Secondary Survey* or focused head-to-toe assessment to check for injury and anatomically specific conditions, such as jugular venous distension at the neck; and ongoing reassessment and management. Fig. 2 at left shows the top two levels of the assessment hierarchy. Lower levels are displayed when the observer selects a menu item. For example, Fig. 2 shows the checklist that appears when the observer selects Breathing in the *Primary Survey* menu.

Like the Assessment Hierarchy, the Management Hierarchy (MH) is a downward branching tree whose parent node is the goal of managing the clinical problems identified during patient assessment, the children are separate problems (e.g., severe bleeding, hypovolemic shock), and grandchildren are interventions necessary to address these problems, including acceptable alternatives. For example, in the scenario that involves a child drowning, the main management goals are to control the child's compromised airway and breathing. Managing the airway requires suctioning and intubation. The latter, in turn, entails inserting one of several appropriate airway adjuncts.

### 4.2 Analysis Phase 1: Interpreting the Event Log

During the first phase of analysis, the observed events in the EL are interpreted by comparing them to two models: the expected patient assessment actions specified in the AH and solutions to clinical problems specified in the MH. In addition, the system scores any responses to the observer's request for additional details. In our current implementation, domain experts manually specify the MH for each scenario instead of generating these solutions automatically. Interventions (the leaf nodes) in the MH are designated as either "required" or "optional" and, as noted previously, there may be more than one acceptable alternative for required interventions. Interventions that are not part of any solution are simply designated as "not indicated."

Finer distinctions could be made within this "not indicated" category—for example, irrelevant vs. "contraindicated"—that is, the intervention doesn't apply to the current scenario or is potentially harmful, respectively. For example, in the near-drowning scenario referred to previously, tourniquet usage would be considered irrelevant because the patient is not bleeding. However, administering IV fluids would be considered contraindicated because a drowning victim likely has too much fluid already in their system. We chose not to make these distinctions at the representational level in the current prototype. However, they are addressed in the feedback that domain experts authored. While it usually suffices to point out that an irrelevant intervention is unnecessary—for example, "this patient is not bleeding, so a tourniquet is unnecessary"—contraindicated interventions often require more complex explanations—for example, how IV fluids could cause pulmonary edema in a drowning victim.

Some interventions must be performed in an expected order to be effective, whereas timing is less critical for other interventions. For example, in the child drowning scenario, it is important to suction the child's airway so that it is clear before intubating and ventilating him. In our system, we represent these temporal constraints as rules and use these rules to assess the ordering of interventions recorded in the event log.

There is usually a simple one-to-one mapping between assessment actions in the EL and the AH, and between interventions in the EL and the lowest levels and leaf nodes in the MH. However, there are two complex cases. First, some interventions can appear multiple times in the EL and/or the MH, because the same intervention could be used to address multiple instances of the same type of problem. For example, there might be multiple wounds on the patient's body, which could all be managed by applying sterile dressings. In the current implementation, the session observer is prompted to specify the body part(s) that the student applies dressings to. Future versions of the system will attempt to infer which wound(s) sterile dressings are being applied to.

The second challenging analysis case is when the same intervention could be performed to satisfy more than one management goal in the MH. For example, establishing an IV might be indicated by protocol (i.e., it is standard practice for a trauma patient) and by the need to administer fluids to address shock. The analysis system chooses the solution path with the best fit to the EL. The accumulated findings up to the point when an intervention occurs in the log could also provide clues about which goal the student intends to address. However, we have not yet implemented semantic relationships between findings and goals. Alternative interventions (e.g., alternative advanced airways) are handled similarly to multiple instances of the same intervention. The analysis system picks the solution path that best fits the EL.

By associating events in the EL with items in the AH and the MH, knowledge is gained about the possible role of each event, such as what to expect some time before or after a particular event and the purpose of that event. This information facilitates recognizing assessment sections and management goals that may not have been completed during one contiguous time frame—for example, the student interrupted an assessment section to start a different one and returns to the interrupted section later. It is also used as part of checking temporal constraints in the second analysis phase and organizing the final debriefing presentation in the third phase, as described presently.

The AI in Analysis Phase 1 is this matching process, a search to find the solution path that best explains the events logged. Similar approaches have been used in other intelligent tutoring systems such as Andes [12] and the Cognitive Tutors [e.g., 13]—that is, generate solutions and do plan recognition by matching observations of what the student did to possible solutions [14].

As noted previously, in addition to assessment and treatment actions, the EL includes observer prompts for additional details about how to perform these actions. For example, when ventilating a patient with a bag-valve mask, the team leader is prompted to state the ventilation rate, oxygen flow rate, and target $O_2$ saturation, if he doesn't volunteer these details (see Fig. 2, right). The observer interprets the team leader's responses and selects the multiple-choice items in the interface that best match what the student said. Because the observer is expected to be a peer, not an instructor, the system determines whether the selected responses are correct during Analysis Phase 1.

### 4.3 Analysis Phase 2: Applying temporal constraints

In the second phase of analysis, the identified actions, assessment sections and management goals from the EL are analyzed relative to a set of temporal constraints. Note that assessment sections and goals are a collection of actions, so we need to consider temporal intervals when checking constraints [15]. Temporal representations and constraints, and constraints in general, are part of problem solving and plan recognition and thus are important in reasoning [14-17].

Although the AH and MH imply orderings for actions, these suggestions are ignored during this phase because instructors allow flexibility when ordering is unimportant. For example, the relative ordering of actions within the *Secondary Survey* (see Fig. 2, left) is not an instructional priority. As a case in point, it is not critical for a student to check the patient's head for injury before checking the patient's neck or chest, although proceeding in a "head-to-toe" fashion is recommended to help ensure a thorough, systematic patient assessment. Thus, temporal constraints represent those orderings that are a priority for instructors. Most constraints focus on managing life threats identified during the *Primary Survey* before doing anything else. For example, if the patient has severe bleeding from an extremity, apply a tourniquet before taking vital signs, starting the *Secondary Survey*, etc..

Most temporal constraints apply globally, across scenarios. However, some constraints apply conditionally—that is, they depend on the patient's state. For example, by default, one should check the patient's airway before checking breathing and circulation, an "ABC" ordering. However, if the patient is assessed to be unconscious, then check the pulse prior to assessing airway and breathing, a "CAB" ordering. If the arguments (i.e., actions or intervals) for a constraint are present in the annotated EL from the first phase of analysis and a temporal constraint fails, then the argument that is "late" in the constraint representation is annotated as being mis-ordered. For example, if the constraint, "Check an unconscious patient's pulse before checking airway and breathing" fails because the student checked the patient's airway and breathing before checking his pulse, but the student does (eventually) check the patient's pulse, then the action "Checks pulse" is marked as "late" (e.g., see Table 1, line 21).

### 4.4 Analysis Phase 3: Identifying and marking missing actions

In the final phase of analysis, missing assessment actions are identified and inserted into the section in the annotated EL in which they best fit and are assigned a status of "missing." The suggested orderings implied by the AH and MH are utilized so that missing actions are inserted in the annotated debriefing log where they are inferred to be most appropriate (see Table 1, line 17). The insertion heuristic first tries to locate other events related to the same assessment phase or management goal and inserts the missing one relative to the ordering specified in the AH or MH. If a management goal is missing entirely from the student's solution, the missing intervention is inserted at the end of the assessment section in which the MH indicated it should appear.

For example, if the student doesn't check the patient's pulse at all—as opposed to checking the pulse late—"checks pulse" would be inserted in the *Primary Survey*/Circulation sub-phase of the debriefing narrative and tagged as a "missing assessment step" with a red X (e.g., see Table 1, line 17). Missing interventions are likewise identified and inserted into the annotated debriefing log based on the solutions specified for their management goal in the MH and relative to where they best fit in the student's solution (the EL). For example, if the student failed to administer oxygen to the near-drowning victim and eventually intubate him, these interventions would be inserted in the *Primary Survey*/Breathing and *Primary Survey*/Airway sub-phases, respectively.

## 5 Conclusion

Using the approach to analyzing event logs described in this paper, we developed a prototype tutoring system that can serve as a platform to compare alternative approaches to debriefing [5, 6]. Although we do not yet know which of the two approaches that MedDbriefer implements will predict higher learning gains, if either, students' feedback on a post-participation survey has been highly positive and constructive. For example, all participants in the randomized trial to date agreed with the statement that MedDbriefer, when fully developed, will be useful for EMS training. To illustrate:

> Yes, I believe this will be useful for EMS training. The only way to improve the skills is to apply them, and sometimes our lab sessions aren't enough practice. I can see this system being extremely useful outside of the classroom with friends or people who aren't as familiar with EMS, because they are still able to proctor the simulation…The instant feedback prompts me to incorporate the objectives I missed in the previous simulation.

Study participants have also pointed out bugs and limitations of the system that we plan to address. For example, in some scenarios, vital signs fail to improve after the student performs suitable interventions. In addition, the system needs to better accommodate variations in state EMS protocols. Recently, several students enrolled in a paramedic program in the state of California participated in the RCT. Their feedback highlights the need to enhance the rules and routines that drive MedDbriefer's analysis of event logs so that the system can provide students with feedback that reinforces their state's EMS protocols.

More work needs to be done to make MedDbriefer more scalable in other ways besides accommodating different groups of users—in particular, streamlining content development. As noted previously, EMS experts manually specify each scenario's management goal hierarchies. We are exploring the possibility of implementing a "problem-solver" that uses a scenario's findings to determine what clinical problems need to be addressed and, correspondingly, which interventions are indicated to address them. Since state protocols specify how to manage most clinical problems that EMS providers encounter in the field, they could drive development of an automated problem solver, supported by related work on solution generation [e.g., 12, 13, 18].

In addition to saving domain experts the time needed to manually enter possible solutions for each scenario, automated solution generation could enable instructors to quickly alter the findings in an existing scenario. This would afford students practice with managing variations of clinical problems. For example, although the student recognized and applied an intervention that was indicated in the current scenario (e.g., apply direct pressure), perhaps in a variant of this scenario the same intervention would not control the patient's bleeding, so other interventions should be tried (e.g., apply a tourniquet). Such versatility in scenario design and solution generation would enhance training across the healthcare professions.

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