Does Every Code Need a "Reader?" Improvement of Rare Event Management With a Cognitive Aid "Reader" During a Simulated Emergency

A Pilot Study

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Introduction: Prompt treatment is necessary to assure patient survival during crisis. Obstetric cardiac arrest (OCA) and malignant hyperthermia (MH) are rarely occurring crises. Cognitive aids (CAs) consolidate management and assist treatment decisions. We investigated a novel method to encourage resident physician CA use during simulated crises.
Methods: Resident physicians were examined during 31 simulated crises of OCA and MH. CAs reviewed in a prior lecture were placed on resuscitation carts. The confederate emergency management team consisted of two anesthesiologists, two critical care nurses, and a medical student who was assigned to act as the CA "Reader." If the subject failed to manage the crisis, the Reader would prompt the subject to use the CA. If the subject still failed to manage the crisis, the Reader would read the aid aloud to the subject. Steps were scored if completed; physiologic variables were recorded. Subject performance was examined before and after Reader introduction.
Results: OCA: No subjects performed all critical steps before introduction of the Reader. Twenty-two percent of Anesthesiology (AN) and 31% of Obstetrics (OB) trainees used the CA. MH: All subjects (AN) correctly diagnosed MH and administered the first dantrolene dose at 7.3 ± 2.5 minutes (PETCO2 72 ± 8 mm Hg, temperature 41.5°C ± 1.3°C) but skipped critical treatment steps. Thirty-three percent of subjects used the CA. After Reader introduction, all critical actions for both OCA and MH were completed.
Conclusions: Reader introduction resulted in execution of all critical actions. During the debriefing of the simulated scenarios, subjects acknowledged the benefit of the Reader.
(*Sim Healthcare* 7:1–9, 2012)

Key Words: Education, Patient safety, Simulation, Cognitive aids, Malignant hyperthermia, Obstetric cardiac arrest, Crisis resource management.

Physicians may be required to treat life-threatening catastrophic events that they have not encountered during training.[1] Patient well-being and perhaps even survival during these events requires prompt recognition, diagnosis, and treatment of these clinical situations. This resuscitation must often be accomplished by physicians and nurses working together as a coordinated team.[1–3] Two examples of such rare perianesthetic events are obstetric cardiac arrest (OCA) and malignant hyperthermia (MH). Maternal cardiac arrests occur in approximately 1:30,000 pregnancies. Survival may require adherence to a proscribed sequence of treatment steps. Even with correct treatment of the event, the survival rate remains poor.[1,3,4] In this situation, providers must manage a critical, life-threatening event, perhaps for the first time in their career.[1,5] Reports of maternal deaths indicate that >50% had some aspect of substandard care inconsistent with national guidelines.[6] To date, there remains little training in acute obstetric emergencies.[7]

Malignant hyperthermia (MH) is another rarely occurring major patient crisis not likely to be experienced by most physicians during training that they may be required to treat in practice.[2] Successful resolution of MH also requires rapid, accurate diagnosis and treatment to avoid serious morbidity or mortality, such as renal damage, muscle damage,

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Supported by the Department of Anesthesiology, Cooper University Hospital, Camden, NJ, Michael E. Goldberg, MD, Professor and Chairman of Anesthesiology, Cooper Medical School of Rowan University; Professor and Chief of Anesthesiology, UMDNJ/Robert Wood Johnson Medical School, Camden, NJ.

The authors declare no conflict of interest.

Presented in part at the meeting of the American Society of Anesthesiologists, Orlando, FL, October 18, 2008.

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DOI: 10.1097/SIH.0b013e31822c0f20

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and a protracted intensive care unit stay. The incidence of suspected MH may be 1:16,000 to 1:62,000, and 5% to 10% of affected individuals may die despite proper treatment.[2,8]

Survival during rare, critical events largely depends on rapid recognition and implementation of a precisely accurate series of complicated treatment steps.[9] Even if physicians have received training in these resuscitation scenarios, most have never experienced them first-hand or are not able to recall all guidelines and skills learned.[10] This knowledge decays quickly, particularly during times of stress.[10,11] Thus, clinician memory is not reliable, which may result in a catastrophic outcome.[12]

Cognitive Aids

The development of crisis algorithms, checklists, mnemonic aids, or cognitive aids (CAs) has consolidated and simplified the application of evidence-based treatment.[10] CA may be written checklists or computerized presentations of important diagnostic and treatment information. Both novice and experienced caregivers find that CAs improve adherence to best practice.[13–18] However, these aids are often not used correctly despite demonstrated benefits in medicine and critical care.[14,15,17,18] Integration into practice has not been widespread.[13] Skillful use of CAs has been shown to improve performance in management of a simulated MH emergency.[14]

CAs are only one important component in the execution of a successful resuscitation.[13,14] Effective teamwork during the critical event is also recognized as an essential factor.[15] This effort requires that the entire team share an awareness of the emergency, the treatment plan, and the available resources to perform the resuscitation.[15,18,19]

Does Every Code Need a "Reader?"

In an earlier work, we noted that trainees often failed to use CAs during a simulated emergency.[16] Residents in other studies reported that they found it difficult to think about the patient's information and communicate to the team while simultaneously attempting to read the CA and review and perform the proscribed steps.[13,14,16] This difficulty with resident physician CA use led us to consider the role of a "Reader." This study therefore investigated a novel method to encourage the use of CAs by resident physicians during simulated crisis management. The intervention studied was the introduction of a CA Reader to assist the subject (Leader) by reading critical actions from the CA. The Reader would read the steps aloud and would then acknowledge completion of each step. A secondary objective was to evaluate the interaction between the Reader and the Leader. We hypothesized that the introduction of a Reader to the crisis management team would improve performance of critical actions.

MATERIALS AND METHODS

After Institutional Review Board approval and written informed consent, 28 resident physicians participated in 31 individual simulation sessions at our institution. All 13 postgraduate year 1–4 Obstetrics/Gynecology (OB) residents (10 males and 3 females) and 6 Clinical Anesthesia year 1–3 (AN) residents (4 males and 2 females) participated in the OCA sessions. Six AN residents (5 males and 1 female) participated in the MH sessions. Three AN subjects (2 males and 1 female) participated in both the OCA and MH scenarios. These subjects were scheduled at 1-year intervals in an attempt to test each subject and event separately. All scenarios were recorded on video, and each subject was debriefed using the video recordings immediately after the scenario.

The CA from the American Heart Association (AHA, Appendix A)[20] for the OCA scenario was circulated to a group of five experienced academic obstetricians and five experienced academic anesthesiologists. The CA from the Malignant Hyperthermia Association of the United States (MHAUS, Appendix B)[21] was circulated to a group of 10 experienced academic anesthesiologists. The groups reached consensus and checklists of critical actions from those CAs were created (Appendices C and D). Two anesthesiologists separately examined all audiovisual recordings of the simulation scenarios and rated and scored each subject's performance using that checklist of critical actions for each scenario.

The simulation scenarios were conducted from 2006 to 2009, at the Cooper University Hospital Simulation Laboratory, using the Laerdal SimMan High-Fidelity Patient Simulator (Laerdal, Wappingers Falls, NY). A team of confederate experienced clinicians responded as the code team during each of the scenarios after they were summoned by the subject. If the subject did not call for help, the code team was sent to assist the subject 10 minutes after the crisis began.

Simulated Obstetric Cardiac Arrest Scenario

The simulated patient was a 32-year-old, 33-week G2P1 previously healthy female admitted to the obstetric floor in active labor. The subject was called to interview the OB patient as a new admission to the labor floor. The patient was first portrayed by a standardized patient, who became agitated during the interview and moved to the bathroom 5 minutes into the interview. In the bathroom, she became unresponsive and collapsed. The standardized patient was then replaced by a mannequin for the remainder of the scenario. The subject was expected to recognize the simulated patient's distress, call for help, and lead the cardiac arrest team in the diagnosis and management of the OCA. The subject was told to verbalize all requests of the team.

The OCA code team consisted of two anesthesiologists, a labor and delivery nurse, and a critical care nurse. A third-year medical student was assigned to play the role of the Reader and also responded as part of the code team. The team was instructed to provide the Leader with any requested information or assistance.

Each resident physician subject of this study (OB and AN) had aminimum of one clinical month on the labor floor and attended a lecture on OCA and Crisis Resource Management (CRM) before the start of the study; they all were also certified in Advanced Cardiac Life Support (ACLS). All subjects were individually introduced to the patient simulator and read a brief clinical obstetric scenario before entering the simulated labor and delivery room. The CA from the American Heart Association for pregnant women

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(Appendix A) was reviewed in the OCA lecture and was prominently placed on the cardiac resuscitation cart, in direct sight of the subjects during the simulation.

Simulated Malignant Hyperthermia Scenario

The subject assumed care of a simulated patient who was undergoing a laparoscopic appendectomy. The simulated operation had just begun under a general anesthetic. Approximately 5 minutes after the subject assumed care of the simulated patient, malignant hyperthermia began to develop. The subject was expected to recognize MH, call for help, and lead the emergency response team in treating the MH crisis.

The MH emergency response team consisted of two experienced anesthesiologists, an operating room nurse, and a critical care nurse. A medical student also responded as part of the team and was again assigned to play the role of the Reader. The team was again instructed to provide the Leader with any requested information or assistance.

All resident physician subjects (AN only) who participated in the study attended a lecture on MH and a lecture on CRM and were individually introduced to the patient simulator; they all were also certified in Advanced Cardiac Life Support (ACLS). The subjects read a brief clinical scenario before entering the simulated operating room. The Malignant Hyperthermia Association of the United States (MHAUS) malignant hyperthermia CA (Appendix B) was reviewed in the lecture and was placed prominently on the wall next to the anesthesia machine and on the MH resuscitation carts.

Introduction of the Reader

The Reader was introduced into both OCA and MH scenarios as part of the emergency response team. If the Leader failed to use the CA and did not complete all critical actions (Appendices A and B), the Reader was instructed to prompt the subject to use the CA at 5-minute intervals during the simulated patient crisis. During the scenario, the Team and the Reader would perform any tasks requested by the Leader. The Reader was instructed to prompt the Leader to use the CA by asking the following questions:

Five Minutes after Code Team arrival: "What is this paper? Will it help you?"

Ten Minutes after Code Team arrival: "This paper looks like it might help you. Would you like to use it?"

Fifteen Minutes after Code Team arrival: "I think this paper has useful information. I'm going to read it out loud."

Leader-Team, Leader-Reader, and Leader-Reader-Team Interaction Analysis

A communication matrix was constructed to evaluate the interaction between the team Leader (L), team Reader (R) and the Team (T), as well as use of the CA. The matrix was based on the work of Entin et al[22–24] and served to capture the time-based elements and information the individuals were considering to assess their decision making and actions. A video analysis rating criteria was created to capture any critical information or action requests defined as "information," "action requests," and "transfers" at 1-minute intervals over two 10-minute periods consisting of the immediate pre- and post-Reader introduction. "Information requests" were defined as any time the Leader requested information from the Team; "Information Transfers" were defined as any time the Leader acknowledged receipt of this requested information from the Team. "Action Requests" were defined as any request by the Leader for the Team to complete a critical action, and "Action Transfers" were any time the Leader acknowledged that the action was completed. Every request and transfer was tracked and summed for each 1-minute interval for the 10-minute time periods immediately before and after the introduction of the Reader. The video analysis was performed by the principal author and cross-checked by a second examiner familiar with simulation scenarios. Questionable ratings were marked and reviewed by the two examiners to obtain a final score on that specific measure. The frequency of questionable ratings or disagreements in scores was <4%, and all were resolved without difficulty.

Data Analysis

The full sessions were videotaped for each subject, and observational data were captured on checklists and scored as action completed or missed and timed. During data review of the recordings, any inconsistencies between the two reviewers or any steps considered to be inconclusive were verified by a third reviewer. Physiologic parameters including blood pressure, heart rate, oxygen saturation, and temperature were recorded continuously during the scenarios, using the Laerdal SimMan simulation software. Descriptive statistics were used to summarize overall scores, and results are presented as percentages and means ± SD. Two-level nominal data extracted from the checklists were analyzed using the nonparametric Kruskal-Wallis test. For the Team and Leader interaction analysis, a two-way analysis of variance with repeated measures was used to identify significant differences among matrix variable scores across the pre- and post-Reader periods and between the two resident groups. The statistical analyses were performed using Systat version 11.00.01 (Systat Inc., Chicago, IL), and a P value <0.05 was set for statistical significance.

RESULTS

A total of 28 subjects participated in 31 simulation sessions in this study from 2006 to 2009. These residents were all videotaped and debriefed immediately after the scenario.

Simulated Obstetric Cardiac Arrest Event Pre-Reader

None of the subjects completed all the required critical steps for appropriate treatment of the simulated OCA before the introduction of the Reader. Thirty-three percent of AN and 31% of OB subjects correctly diagnosed the abnormal cardiac rhythm, and 33% of AN and 15% of OB residents correctly managed the parturient's airway and intubated the simulated patient. Twenty-two percent of AN and 15% of OB residents correctly changed the patient's position to left uterine displacement. Eleven percent of AN and 23% of OB residents correctly identified the arrest and executed pregnancy-appropriate CPR. Eleven percent of AN and 31% of OB residents identified the need for hysterotomy. None

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identified that it was indicated to improve the maternal hemodynamic compromise. Twenty-two and 31% of AN and OB subjects, respectively, used the available CA. Of those subjects, 66% read it silently and replaced it on the cart. Thirty-three percent of subjects picked it up again, read it briefly, and again replaced it on the cart. These subjects stopped communicating with the team during the period of time they read the aid.

Simulated Malignant Hyperthermia Event Pre-Reader

All subjects diagnosed MH correctly, called for help, and subsequently administered the dantrolene, but none completed all the required critical steps for treatment of the simulated MH before the introduction of the Reader. No subjects asked to call the "MH Hotline." Mean time to MH diagnosis was 4.2 ± 1.1 minute with a mean PETCO2 of 58 ± 5.7mmHg and mean temperature of 39.9°C ± 0.6°C. The first dose of dantrolene was administered at 7.3 ± 2.5 minutes after diagnosis when the mean PETCO2 was 72 ± 8 mm Hg and mean temperature of 41.5°C ± 1.3°C. Forty-four percent of subjects knew the correct dose, and 33% knew the correct mixture for administration. Eighty-eight percent of subjects discontinued the volatile anesthetic agent. Time to discontinuation of volatile agent was 10.2 ± 11 minutes with a mean PETCO2 of 68 ± 10mmHg. Thirty-three percent of subjects made use of the available CA. Of those subjects, 66% read parts of it silently to themselves; 32% read the CA once and placed it back on the cart. These subjects stopped communicating with the team while they read the CA.

Introduction of the "Reader"

Analysis of performance before and after the introduction of the Reader showed significant improvement. During the OCA scenario, the most improved corrective actions noted included left uterine displacement ($P < 0.001$), correctly managing and intubating the parturient's airway ($P < 0.001$), completion of hysterotomy, and correctly stating the clinical indication for that hysterotomy ($P < 0.001$) (Table 1).

Introduction of the Reader during the MH scenario prompted all subjects to use appropriate dantrolene doses and mixture ($P < 0.001$), as well as the institution of high-flow oxygen ($P < 0.02$) (Table 2). While most subjects discontinued the volatile agent that triggered MH, those who did not do so remedied this action immediately after the introduction of the Reader. Although this finding lacks statistical significance ($P = 0.3$), it has vital clinical importance, as in those scenarios it was not accomplished until 30 minutes after the crisis began, and it is well known that effective treatment of MH requires discontinuing the triggering volatile agent.

Table 1. Introduction of the Reader Showed Significant Performance Improvement in Critical Actions in the Obstetric Cardiac Arrest Simulation (N = 22)

Critical Action	Before Reader % Performance	After Reader % Performance	*P*
Call for help	81	100	0.03
Correct hypoxemia	72	100	<0.01
CPR	81	100	0.03
Left uterine displacement	18	100	<0.001
Intubation	54	100	<0.001
Hysterotomy	22	100	<0.001

Table 2. Introduction of the Reader Showed Significant Performance Improvement in Some but Not All Critical Actions in the MH Simulation (N ± 9)

Critical Action*	Before Reader % Performance	After Reader % Performance	*P*
Discontinuation of volatile anesthetic	88	100	0.31
Correct dantrolene dosage	44	100	0.01
Correct dantrolene mix	33	100	<0.01
Second dosage of dantrolene	77	100	0.14
Provision of cooling measures	66	100	0.06
Provision of high flow oxygen	55	100	0.02

*All subjects called for help, informed the surgeon about the presumed diagnosis of MH, and asked for the MH Cart. All indicated that the correct treatment was dantrolene. No subjects called the MHAUS hotline.

Communication Between Leader and Team, and Leader and Reader

Communication matrix variables (means, SD, and median scores) across the pre- and post-Reader periods and between the two resident groups are presented in Table 3. The first variables examined were those at the start of the scenarios relating to the Leader's use of the CA and requests and transfers of critical actions and information. Significant differences ($P < 0.001$) were found in the initial information request variables (Info RQST) from the Leader (no Reader, column 1) and after introduction of the Leader (L + R, column 9). When the CA (C) was used early by the Leader, the information requests (Info RQST, column 2) were significantly lower ($P < 0.001$) compared with frequency of information requests once the Reader was introduced (L ± R Info RQST, column 9). Once the Reader was engaged, the information transfer to the Team occurred by way of the Leader. This can be seen in columns 10 and 11 (mean information transfer episodes of 0 vs. 8.22). The action requests and transfers follow a similar pattern shown by a significantly higher ($P < 0.001$) frequency of action requests and transfers in the presence of a participating Reader (columns 12, 14, and 15) compared with the Leader's use of a CA (columns 7 and 8). Figure 1 illustrates the significant effect of the introduction of the Reader with no overall changes between the two groups of residents.

Debriefing Sessions

During the video debriefing that immediately followed each scenario, the subjects indicated that they found it difficult to assess the patient situation, communicate with the team, and prioritize treatment steps. During the emergent event, before the introduction of the Reader, 48% of the subjects exhibited a variety of emotions. Of those subjects, 40% raised their voices, 33% became tearful, and 13% began talking to themselves. All subjects reported that they behaved as if they were taking care of a real patient and thought the scenario was realistic. They also reported being aware of the availability of the CA and that it contained information that could help them treat the simulated

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Table 3. Data Summary From the Communication Matrix Used to Capture Information, Action Requests and Transfers, Pre- and Post-Reader Introduction, and Between the Two Resident Groups

	Pre-Reader Period						Post-Reader Period			
	L alone Info RQST (1)	L + C Info RQST (2)	L + T Info TRF (3)	L + T Action RQST (4)	L + T Action TRF (5)	L + R Info RQST (6)	L + R + T Info TRF (7)	L + R Action RQST (8)	L + R + T Action RQST (9)	L + R + T Action TRF (10)
Anesthesia residents										
Mean	3.17	0.56	2.56	1.89	1.33	7.94	8.22	8.06	8.61	8.61
SD	1.82	0.86	1.89	1.18	0.77	1.16	0.81	0.94	0.85	0.85
Median	3.00	0.00	2.50	2.00	1.00	8.00	8.00	8.00	9.00	9.00
OB residents										
Mean	5.15	0.31	0.92	1.08	0.23	8.00	8.23	8.15	8.38	8.38
SD	1.34	0.48	0.95	1.04	0.44	0.71	0.44	0.55	0.51	0.51
Median	5.00	0.00	1.00	1.00	0.00	8.00	8.00	8.00	8.00	8.00

Data are expressed as means ± SD and medians. The pre- and post-reader effects were highly significant ($P < 0.01$) for all paired variables with no significant differences found between resident groups. Columns have been numbered to facilitate reference to the communications variables in the article.
L indicates leader; C, cognitive aid; Info, information; RQST, request; TRF, transfer; T, team; R, reader; OB, obstetric.

patient. Those who used the CA and those who did not use the CA also indicated that the use of the CA by the Leader was difficult during the simulated crisis.

Among Those Who Did Not Use the CA, the Following Patterns Emerged

Twenty-three percent reported that they did not think they would be able to read the CA, assess the patient situation, and communicate with the team at the same time.

Sixteen percent reported that they thought it was not appropriate to use the CA during emergent patient care. All those subjects reported that they did use CAs during nonemergent patient care. Twenty-nine percent of the subjects who did not use the CA reported that they were unable to stop working during the scenario to begin to read.

Among those who used the CA during the resuscitation, 77% reported that reading the CA was distracting. They noted that to read the CA, they needed to stop assessing the patient and communicating with the team. They also said that they needed time and found it difficult to change from thinking and talking to reading and back to thinking and talking again. Twenty-two percent of the subjects who used the CA said it was difficult to resume talking with the team after they began to read the CA. They reported that they did not consider reading the aid aloud or asking someone on the team to read the aid.

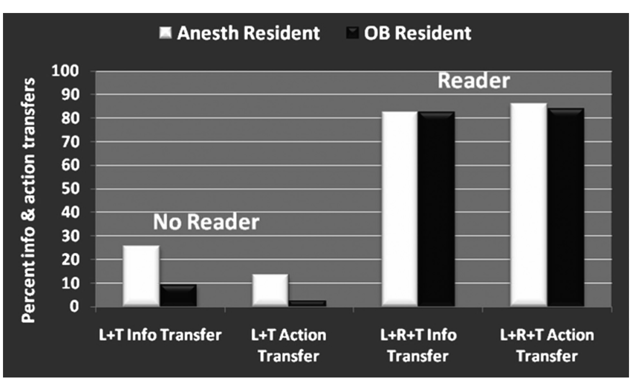

Figure 1. Communication among the Leader (L), Team (T), and Reader (R) expressed as a percent of critical information and action transfers before and after introduction of the Reader. Data are taken from the video analysis communication matrix using 1-minute segments during the "Reader" and "no Reader" periods (two 10-minute periods immediately before and after the introduction of the Reader). Analysis of the raw data show significant ($P < 0.001$) differences between information and action transfers between the pre- and postintervention periods shown as "No Reader" and "Reader" on the figure.

Those subjects who were tested in both scenarios reported that they did not think it was appropriate for them to ask someone to read the CA aloud. They further reported that they expected to face resistance from the team and that this request would make them seem unprepared to care for the patient. All subjects reported that the introduction of the Reader was helpful and that the Reader helped them navigate the CA, assess and treat the simulated patient, and communicate with the team.

DISCUSSION

Simulated sessions of two very different rare critical events revealed that physician recall alone may not prove sufficient to achieve all critical steps during an emergency. Debriefing sessions disclosed difficulties the resident physicians encountered in attempting to use a CA during critical events. Even subjects who used the CAs reported that they were reluctant to use them, stating that they thought it was not appropriate to use memory assistance tools. Those who did attempt to use the CAs during the event expressed great difficulty in reading the aid while gathering clinical information and communicating with the team. They reported that it was difficult for them to change from a cognitive process to a dynamic process. The subjects noted that the introduction of a Reader helped them overcome these problems and resulted in the appropriate execution of all critical actions.

Our search of the literature did not reveal any other studies that assigned a Reader, an individual to read the CA to the Leader. In one study, team members read out segments of the CA loud to other team members who responded. The coordinated efforts of this team probably led to increased awareness and better performance by all team members.[14,17]

In another study, a machine with a voice synthesizer was employed to verbalize the elements of a CA or checklist to use during a general anesthetic for an emergency cesarean

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delivery. The subjects, who were experienced anesthesiologists, reported that although use of the checklist helped them prepare for the emergent operation, the checklist was difficult to navigate and confusing, and the voice synthesizer was not helpful.[18]

In another investigation of resident physician CA use during emergent events, some subjects made the wrong diagnosis, chose the wrong CA, and failed to resuscitate the patient.[19] Complicated, difficult to navigate CAs may have been a limiting factor for our subjects as well. Subjects may have also found it difficult to know which CA to choose, although this was not studied. It is possible that the subjects, who were to act as the Leaders in the emergent events, would have been able to quickly select and navigate simpler, more direct CAs without the assistance of the Reader. Further studies are planned to determine whether a simpler, more concise CA will be easier for the Leader to use.

One particularly critical area for the Leader and the team during an emergency is finding the appropriate balance between diagnosis, decision making, and task distribution activities. We sought to combine the benefits of a CA and a person to help the Leader make best use of the CA to improve the resources of the emergency management team. This individual was designated the "Reader." All subjects acknowledged the benefit of the Reader. The team Leader (subject) used the Reader to navigate the CA more effectively and then to work with the team to perform the resuscitation. The Reader helped the Leader appropriately manage the simulated emergency. Postevent incident analysis, as well as video debriefings, demonstrated that most subjects were able to articulate some of their failed steps. They reported being unable to "observe, remember, act, and explain" the situation and plan to the team during the event and were extremely frustrated. Most reported satisfaction with availability of the Reader. The majority of subjects reported that the Reader allowed the Leader and the rest of the team to better appreciate the full situation. The Reader facilitated examination of elements of the aid and, at the same time, helped the Leader review the clinical situation and communicate with the team.

These observations reveal difficulties faced by resuscitation teams during rapidly evolving critical situations. The cardiac arrest or emergency resuscitation team concept was introduced in the 1930s and grew with the advent of effective CPR and defibrillation.[25,26] The ultimate introduction of the education and team management process of ACLS and BLS has since evolved. Originally, these teams were outgrowths of resuscitation experiences in the operating room. The team components and the member roles have gradually changed over time.[26] Effective resuscitation requires the integration of multiple cognitive and procedural skills within a rapidly changing unstable critical situation. Efficient leadership and management of the team is critical. Data concerning measurement and improvement of teamwork are currently a topic of intensive research.[27] Despite its delayed development in the healthcare industry, implementation of formal teamwork training was one of the recommendations in the Institutes of Medicine summary of healthcare safety.[28] Weplan further investigations to determine whether team situational awareness and subsequently performance improve with the addition of a Reader to assist the Leader.

In the study presented in this article, the Reader reads the CAs to the Leader and the team. This intervention appeared to minimize omission of critical steps. Preliminary results for all subjects, those who used the CAs and those who failed to use the CA, demonstrate the Leader's reduced ability to execute all appropriate steps during a simulated emergency. Introduction of the Reader led to improved management of these simulated critical events, reduced diagnostic errors, and minimized omissions of critical steps.

Our study was limited by the small number of subjects and by testing one subject at a time. It is possible that if multiple subjects were tested together as a team, the results may have been different. We chose to test each of our subjects individually as a sole provider, a situation not infrequently encountered in practice. It is also possible that had the subjects been attending physicians and not residents, the results would have been different. Also, we used a medical student as the Reader for our scenarios. We cannot identify the ideal level of expertise for the Reader from this work. We plan to investigate the use of different healthcare personnel in the roles of Leader and Reader in future studies.

We recorded the actions of the subjects on a video and debriefed them immediately after the sessions. We therefore only know the thoughts expressed by the subjects during debriefing.

Even though this study was conducted using a mannequin simulator, the subjects exhibited significant effort with emotional involvement. Postsimulation debriefing sessions revealed that all subjects reported that they behaved as if they were in a real patient situation. They indicated that they knew they were not performing the appropriate steps to resolve the crisis. They said they felt relieved when the Reader began to assist them and expressed increased confidence that their patient might survive.

Another limitation of this study is that the patient simulator was housed in a laboratory setting rather than the clinical environment. While there is a growing body of work to support the use of a human patient simulator to assess performance, we cannot determine whether the subjects' actions would be different during a real patient emergency. Furthermore, we cannot conclude what the effect on patient outcome would have been as a result of missed steps in the process. We can, however, assume that omitting major steps from the treatment of an OCA and MHwould have led to poor patient outcomes.

Given these limitations, it is interesting to note the improvement in management of both the OCA and MH events and in communication between the Leader and the Team after the introduction of the Reader. The introduction of the Reader resulted in all critical steps being performed, and the subjects reported a better understanding of the event as well as the elements of management. More indepth discussions about global event management evolved among the team from reading and discussing the critical actions together.

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APPENDIX A: OBSTETRIC CARDIAC ARREST (OCA) COGNITIVE AID

ACLS FOR PREGNANT WOMEN[20]

Airway

Preoxygenation critical—hypoxia develops quickly
May need airway adjunct; ventilation may be difficult
Smaller endotrachial tube—airway edema; rapid sequence intubation with cricoid pressure

Select agents to minimize hypotension/monitor for bleeding

Breathing

Gravid uterus elevates the diaphragm—hypoxemia develops quickly

FRC decreased/oxygen demand increased

Circulation

Position before starting chest compressions: left uterine displacement—relieve pressure on inferior vena cava

Use wedge under woman's right side

Or

Have one rescuer kneel next to woman and pull uterus laterally

Use standard ACLS medications

Defibrillation

No change in dose or pad position Remove fetal and uterine monitors before shock delivery Defibrillation does not transfer significant current to fetus

Decisions

Decide about emergency hysterotomy:

Infant > 24 weeks gestation/begin 4 minutes after cardiac arrest

Delivery of baby empties uterus and relieves both venous obstruction and aortic compression; allows for effective CPR

Differential Diagnosis

Identify and treat reversible causes of arrest

Consider causes related to pregnancy

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APPENDIX B

MH Hotline
1-800-644-9737
Outside the US:
1-315-464-7079

Effective May 2008

EMERGENCY THERAPY FOR MALIGNANT HYPERTHERMIA

DIAGNOSIS vs. ASSOCIATED PROBLEMS

Signs of MH:

- Increasing $ETCO_2$
- Trunk or total body rigidity
- Masseter spasm or trismus
- Tachycardia/tachypnea
- Mixed Respiratory and Metabolic Acidosis
- Increased temperature (may be late sign)
- Myoglobinuria

Sudden/Unexpected Cardiac Arrest in Young Patients:

- Presume hyperkalemia and initiate treatment (see #6)
- Measure CK, myoglobin, ABGs, until normalized
- Consider dantrolene
- Usually secondary to occult myopathy (e.g., muscular dystrophy)
- Resuscitation may be difficult and prolonged

Trismus or Masseter Spasm with Succinylcholine

- Early sign of MH in many patients
- If limb muscle rigidity, begin treatment with dantrolene
- For emergent procedures, continue with non-triggering agents, evaluate and monitor the patient, and consider dantrolene treatment
- Follow CK and urine myoglobin for 36 hours.
- Check CK immediately and at 6 hour intervals until returning to normal. Observe for dark or cola colored urine. If present, liberalize fluid intake and test for myoglobin
- Observe in PACU or ICU for at least 12 hours

ACUTE PHASE TREATMENT

1 GET HELP. GET DANTROLENE – Notify Surgeon

- Discontinue volatile agents and succinylcholine.
- Hyperventilate with 100% oxygen at flows of 10 L/min. or more.
- Halt the procedure as soon as possible; if emergent, continue with non-triggering anesthetic technique.
- Don't waste time changing the circle system and CO_2 absorbant.

2 Dantrolene 2.5 mg/kg rapidly IV through large-bore IV, if possible

> To convert kg to lbs for amount of dantrolene, give patients 1 mg/lb (2.5 mg/kg approximates 1 mg/lb).

- Dissolve the 20 mg in each vial with at least 60 ml sterile, preservative-free water for injection. Prewarming (not to exceed 39º C.) the sterile water may expidite solublization of dantrolene. However, to date, there is no evidence that such warming improves clinical outcome.
- Repeat until signs of MH are reversed.
- Sometimes more than 10 mg/kg (up to 30 mg/kg) is necessary.
- Each 20 mg bottle has 3 gm mannitol for isotonicity. The pH of the solution is 9.

3 Bicarbonate for metabolic acidosis

- 1-2 mEq/kg if blood gas values are not yet available.

4 Cool the patient with core temperature >39ºC, Lavage open body cavities, stomach, bladder, or rectum. Apply ice to surface. Infuse cold saline intravenously. Stop cooling if temp. <38ºC and falling to prevent drift < 36ºC.

5 Dysrhythmias usually respond to treatment of acidosis and hyperkalemia.

- Use standard drug therapy **except calcium channel blockers, which may cause hyperkalemia or cardiac arrest in the presence of dantrolene.**

6 Hyperkalemia – Treat with hyperventilation, bicarbonate, glucose/insulin, calcium.

- Bicarbonate 1-2 mEq/kg IV.
- For **pediatric,** 0.1 units insulin/kg and 1 ml/kg 50% glucose or for **adult,** 10 units regular insulin IV and 50 ml 50% glucose.
- Calcium chloride 10 mg/kg or calcium gluconate 10-50 mg/kg for life-threatening hyperkalemia.
- Check glucose levels hourly.

7 Follow $ETCO_2$, electrolytes, blood gases, CK, core temperature, urine output and color, coagulation studies. If CK and/or K^+ rise more than transiently or urine output falls to less than 0.5 ml/kg/hr, induce diuresis to >1 ml/kg/hr and give bicarbonate to alkalanize urine to prevent myoglobinuria-induced renal failure. (See D below)

- Venous blood gas (e.g., femoral vein) values may document hypermetabolism better than arterial values.
- Central venous or PA monitoring as needed and record minute ventilation.
- Place Foley catheter and monitor urine output.

POST ACUTE PHASE

A Observe the patient in an ICU for at least 24 hours, due to the risk of recrudescence.

B Dantrolene 1 mg/kg q 4-6 hours or 0.25 mg/kg/hr by infusion for at least 24 hours. Further doses may be indicated.

C Follow vitals and labs as above (see #7)

- Frequent ABG as per clinical signs
- CK every 8-12 hours; less often as the values trend downward

D Follow urine myoglobin and institute therapy to prevent myoglobin precipitation in renal tubules and the subsequent development of Acute Renal Failure. CK levels above 10,000 IU/L is a presumptive sign of rhabdomyolysis and myoglobinuria. Follow standard intensive care therapy for acute rhabdomyolysis and myoglobinuria (urine output >2 ml/kg/hr by hydration and diuretics along with alkalinization of urine with Na-bicarbonate infusion with careful attention to both urine and serum pH values).

E Counsel the patient and family regarding MH and further precautions; refer them to MHAUS. Fill out and send in the Adverse Metabolic Reaction to Anesthesia (AMRA) form (www.mhreg.org) and send a letter to the patient and her/his physician. Refer patient to the nearest Biopsy Center for follow-up.

Non-Emergency Information

MHAUS
PO Box 1069 (11 East State Street)
Sherburne, NY 13460-1069

Phone
1-800-986-4287
(607-674-7901)

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Email
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Website
www.mhaus.org

Since 1981
MHAUS
MALIGNANT HYPERTHERMIA ASSOCIATION OF THE UNITED STATES
Dedicated to Patient Safety

CAUTION: This protocol may not apply to all patients; alter for specific needs.

ORPO 5/08/5K

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APPENDIX C: CHECKLIST FOR OBSTETRIC CARDIAC ARREST (OCA)[20]

- Call for Help
- Manage Airway—ventilate, prepare to intubate
  - ○ Get help with airway—likely to be difficult
- Place patient in Left Uterine Displacement (LUD)
- Circulation—perform parturient appropriate CPR
  - ○ Different hand position
  - ○ Displace uterus
- Rhythm
  - ○ Identify Pulse/No Pulse and treat
- Perform hysterotomy four minutes after arrest
  - ○ Get help for procedure

APPENDIX D: CHECKLIST FOR MALIGNANT HYPERTHERMIA (MH)[21]

- Get Help
- Identify condition as MH
- Turn off volatile agent
  - ○ Rule out other possible etiologies for high Temperature, Tachycardia and Hypercarbia
- Call MH Hotline
- Tell Surgeon; stop surgery as soon as possible
- Get MH Cart
- Give Dantrolene
  - ○ Correct Dose
  - ○ Correct Mix
  - ○ Correct timing of first and repeat doses
- Send Blood Gas, Electrolytes, CK
  - ○ Assess Acid/Base Status
  - ○ Assess Electrolytes
- Cool Patient
- Assess Rhythm
  - ○ Treat Rhythm Disturbances
- Continue to follow Blood Gases, Electrolytes, CK, Temperature

ACKNOWLEDGMENTS

The authors thank Carolyn Bekes, MD, Michael Kirchhoff, MD, Jocelyn Mitchell-Williams, MD, PhD, Kendra L. Simpson, CRNA, MSN, Patricia Gorman, CRNA, Trisha McFarlane, CRNA, George Dy, BS, and Ashley Shapiro, BA, for their much appreciated advice and technical assistance with this study.

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