Data Driven Competitive Motivation Strategies in a Longitudinal Simulation Curriculum for Trauma Team Training

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OBJECTIVE: A novel approach to trauma team simulation was used to enhance team performance in a cohort of general surgical residents. We implemented data driven debriefing using performance report cards and video footage of the simulations. We wanted to evaluate the technical and nontechnical skills developed by teams using this approach.

DESIGN: All surgical residents in an academic program were divided into 5 equal "trauma teams". Throughout the academic year, each team took part in 4 standardized, high fidelity trauma simulations. Rubrics to assess technical efficiency were scored. Each team received individualized feedback in the form of report cards following each simulation. Video recordings of each simulation were analyzed by blinded raters using a validated instrument to assess nontechnical skills/Crisis Resource Management (CRM) skills.

SETTING: An academic level 1 trauma hospital in Canada.

RESULTS: Five teams comprising five residents participated in four simulations each. Learner feedback was universally positive and learning during simulation was rated higher than learning during didactic lecture. The effect of data driven report cards and anonymized ranking was cited by trainees as a motivating factor to improve. CRM scores improved over the course of the academic year for all teams but without reaching statistical significance. A strong positive correlation was measured between technical and CRM skills for all teams.

CONCLUSIONS: Adding data driven debriefing using performance report cards that assess both technical and CRM skills to a trauma team curriculum is a feasible and acceptable way to influence trainee performance using positive competitive motivation. More data are required to confirm the early patterns of improvement uncovered in CRM scoring. A positive correlation between technical skills and CRM skills raises important questions for future research. (J Surg Ed 76:1122−1130. © 2019 Published by Elsevier Inc. on behalf of Association of Program Directors in Surgery.)

KEY WORDS: Simulation, Trauma, Crisis resource management, Debriefing, Surgical Education

COMPETENCIES: Medical Knowledge, Interpersonal and Communication Skills, Practice-Based Learning and Improvement

INTRODUCTION

Trauma team training is a critical component of quality improvement and assurance at all trauma centers. One of the canonical methods of training for trauma resuscitation is through simulation. Simulation provides many advantages for training. There is no risk to patients, any scenario can be designed, aiding training of uncommon events, and errors can be allowed to play out.[1] The outcomes that are measured in simulation studies fall broadly into two categories: technical skills, and nontechnical skills Many studies have demonstrated improvements in technical performance.[2−4]

Nontechnical skills are the set of behaviours and processes involved in team performance. Initially developed

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by the aviation industry as crew resource management, crisis resource management (CRM) is a growing field of study in medical and surgical training.[5] Importantly, a large proportion of medical errors are reported to be caused by nontechnical skill failures.[6–10] Therefore addressing nontechnical skills in the context of the already useful simulation environment is a potentially critical component to trauma team training. Recent studies assessing the impact of simulation on nontechnical skills in surgeons and medical trainees demonstrated effective improvement.[11–13] The interrelationship between nontechnical skill and technical performance in trauma resuscitation is complex, but there appears to be an integral positive correlation between the two domains of skill.[14–17] In particular Steinemann et al.[15] demonstrated improvements in technical and nontechnical performance among anesthesia crisis simulations.

However, many studied programs evaluated only a short duration of training, sometimes only a few hours in length. One of the key advantages of simulation training is that it allows for repeated exposure to events, and moves away from "see one, do one, teach one" education. The longitudinal application of simulation training allows rehearsal, and practice in responding to a variety of scenarios. For these reasons, we developed and analyzed a longitudinal program of trauma simulation at a single trauma hospital in Canada. The aim of this study was to demonstrate the impact of a longitudinal program of trauma team simulation within a teams competition environment on technical skill, nontechnical skill, and interrelationship of the two among dedicated trauma teams.

METHODS

Setting, population, and study design

We conducted a prospective observational study at Western University and the Canadian Surgical Techniques and Advanced Robotics (CSTAR) center between July 2016 and June 2017. Participants in the study were the general surgery residents from Western University. The study was conducted as part of an ongoing quality improvement effort for an advanced curriculum in simulation training for general surgery residents. Participants provided written informed consent for videography prior to initiation of the training program. The Health Sciences Research Ethics Board of Western University reviewed the project and determined the work to be quality assurance/quality improvement in nature and therefore exempt from research ethics approval. Western university has a total of 25 active general surgery residents. Each resident was randomly assigned to one of 5 simulation "trauma teams". Each team has an equal distribution of residents from all post graduate years and these teams are kept consistent throughout the academic year and throughout the duration of residency training. As chief residents graduate from the program, each team is re-stocked with an incoming first year resident. Teams participate in trauma simulations utilizing high fidelity human patient simulators (HPS) within a hospital based simulation center. The simulation curriculum was designed to improve the team and individual performances of general surgery residents at Western University. The curriculum is delivered longitudinally with multiple simulation sessions distributed over the course of the academic year. Each simulation session is video recorded for the purpose of formative feedback. Video consents (Appendix A) are obtained for the purpose of formative assessment and quality assurance.

At the conclusion of each simulation scenario a traditional, in person debriefing session is conducted with the participants by the instructors. Additionally, video recordings of the simulations are then annotated and voiceover commentary is made by the instructors and made available to participants for the purpose of reflection on performance. Finally, detailed performance report cards are created and distributed to each team. These report cards indicate the timeliness and completeness of the objectives of the simulation. These report cards also provide feedback to each team about where their own performance ranks in comparison to the other 4 teams who recently completed the same simulation. The goal of providing ordinal data to the trauma teams is to promote friendly competition and a desire for improvement on the part of each team and each team member.

Measured outcomes

Four unique trauma simulation scenarios were deigned for the academic year. Each scenario was designed by a team including a trauma surgeon, trauma fellow, and anesthesiologist simulation fellow. Objectives and rubrics for each simulation were developed *a priori* by consensus among the same creators. Rubrics for each simulation were specifically designed to assess technical success at various critical tasks at different points in the scenario. Technical efficiency was then calculated by the elapsed time each team required to effectively manage the case, and the degree of completeness for these critical behaviours. Technical efficiency rubrics were used as the basis for formative assessment after each simulation was completed.

Separate from the technical skill evaluation, non technical skills were analyzed after the simulations were completed. A separate team of raters reviewed video recordings of each simulation and assigned a score based on the Ottawa Global Rating Scale for Crisis Resource Management (Ottawa GRS). The Ottawa GRS is a tool with independent validation evidence for assessing nontechnical skills of trauma teams.[18] The team of raters were trained by the senior trauma surgeon using a set of previous simulation videos from a different set of simulations performed elsewhere. In addition the raters were blinded to the technical skills scores and to the order in which the simulations were completed by the teams. Inter-rater agreement was determined by Cronbach's Alpha (0.669, $p < 0.05$). Data for all sub-scores of the Ottawa CRM-GRS were averaged to produce a single set of data for nontechnical skills.

Statistical analysis

Statistical methods applied to both the technical and nontechnical were aimed at testing two distinct hypotheses: (1) Is there a correlation between technical and nontechnical skills of trauma teams in simulation, and (2) Is there evidence of improvement in either technical skills, nontechnical skills, or both over the duration of the study period. In the first instance a question of correlation for ordinal variables was tested using Spearman's rank order correlation between technical and each nontechnical score. Differences in scores over time were tested using a two-way mixed model repeated measures ANOVA and the first and last simulation were compared using Wilcoxon rank sum test. Statistical analysis was performed on SPSS (IBM, Armonk, NY).

RESULTS

Four trauma simulated scenarios were performed by 25 residents divided into 5 teams. Technical skills scores for each team are shown in Figure 1. Scores for each team and each simulation are shown in the order they were performed by each team. There were no statistically significant improvements in scores over time ($p = 0.88$). Variations in scores occurred over time for each team, possibly reflecting variations in individual experience in cases similar to each simulation. No team scored significantly higher or lower than the others in all simulations.

Nontechnical skills scores over time are shown in Figure 2. There were no statistically significant improvements in these scores over time, however all sub-scores demonstrated apparent upward trends in scores over time.

Figure 3 shows the relationship between technical score and selected nontechnical skills scores. The Ottawa CRM-GRS sub-score "Overall Performance" and the average of all sub-scores are shown. The median Overall Performance score for all teams was 5 ± 1 out of 7 suggesting all teams

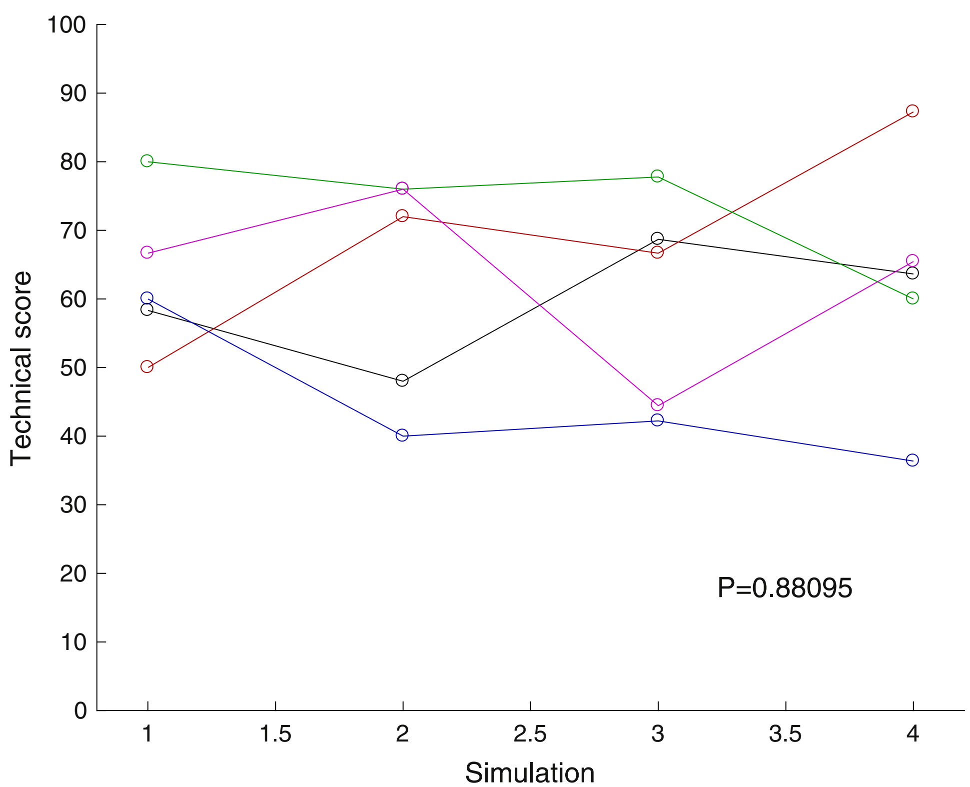

FIGURE 1. Technical skills scores for each simulation over time. Each team's scores are plotted in a different color. There were no statistically significant difference among the teams or over time. Some teams appeared to show an upward trend in their scores, while others did not.

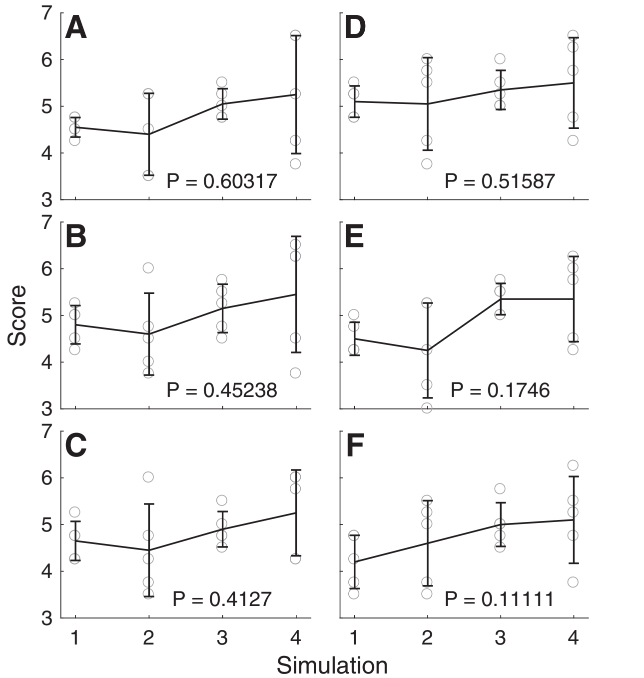

FIGURE 2. Nontechnical skills scores for each simulation over time. Each simulation is shown on the x-axis of each panel. Individual team scores (circles) are shown along with the mean score of all teams for each simulation (black line). A: Overall Performance demonstrated an apparent increase in mean score over the duration of the program, although this was not statistically significant. B: Leadership skill score. C: Resource management score. D: Communication skills score. E: Problem solving skills score. F: Situational awareness score. In each case, the Ottawa CRM-GRS subscores had variable upward trends over the duration of the program, although there was no statistically significant improvement over time.

were competent in management of crisis scenarios. The two nontechnical scores closely mirrored each other in all teams. Furthermore both of the nontechnical skills scores were highly related to the technical score achieved for each team in any given simulation (Shown in Fig. 4). There was an apparent correlation between the technical and nontechnical skills scores achieved by each team during each simulation. Good technical performance was echoed by higher nontechnical scores, and similarly poor performance in one domain of skills was reflected in the other.

Correlation between technical skills scores and each CRM-GRS sub-score are shown in Figure 4. This demonstrates a strong positive correlation between most of the sub-scores and technical scores. The individual correlation *rho* and p-values are stated in the figure. In particular, there were statistically significant correlations between technical scores and Overall performance, Resource management, and Situational awareness scores.

DISCUSSION

The main results of this study are that a longitudinal, team competition-based trauma simulation curriculum demonstrates a strong positive correlation between development of technical and non-technical skills. Furthermore, this program was well-received by residents who participated. There also appeared to be some elements of improvement in skills over time, although this was not statistically significant. Pedagogically, the elements which set this curriculum apart from all others include the competitive incentive built into its execution and the novel use of narrated feedback videos to allow delayed and distributed debriefing on the participants own time.

Simulation has become a ubiquitous and, arguably, indispensable tool in medical education. Despite ample

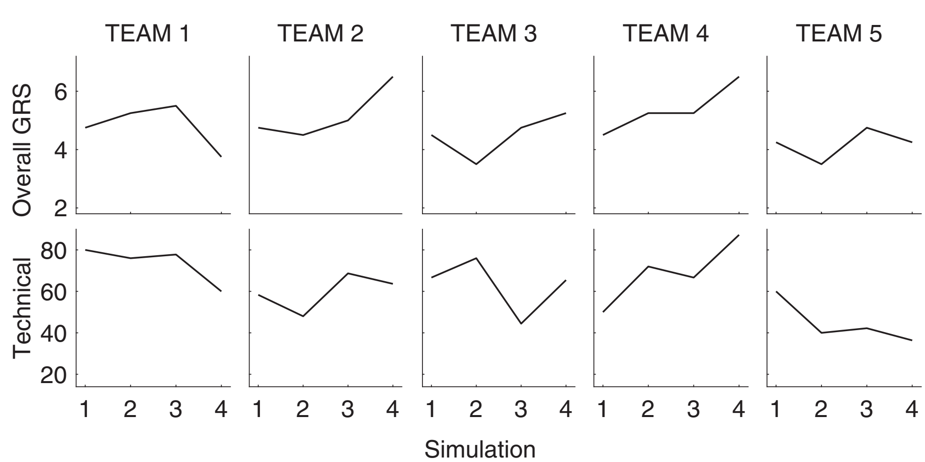

FIGURE 3. Scores for each team measured during twenty simulations.Top: Scores for the Ottawa CRM-GRS sub-score 'Overall Performance'. Each panel represents the scores for a single team across the four simulations in which they participated. Middle Scores for the average of all sub-scores in the Ottawa CRM-GRS. It is clear from this data that the Overall Performance score and the average of all scores closely reflected each other in all teams. Bottom: Scores for technical skill efficiency normalized to a score out of 100. For the majority of teams it is evident that the technical score achieved in each simulation scenario was highly correlated with the nontechnical skills score during the same simulations. Teams that improved over time in one domain of scores appeared to also improve in the other.

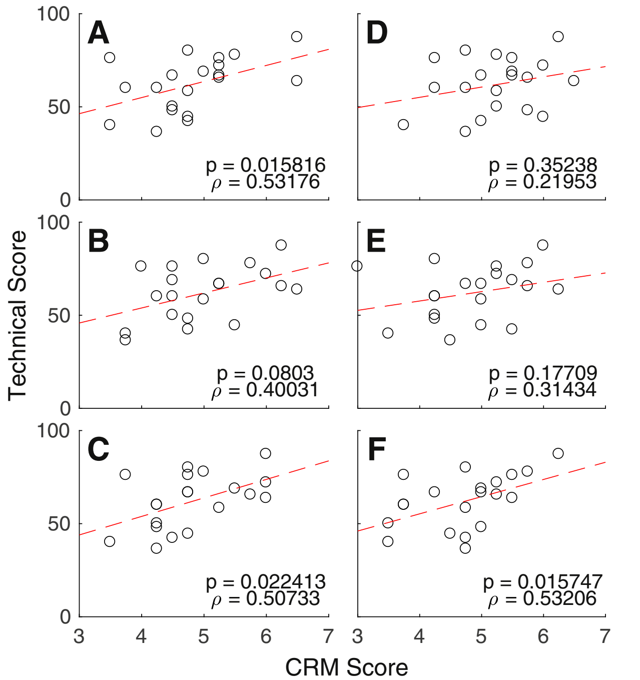

FIGURE 4. Correlation between Technical skill scores and nontechnical skills scores. Each panel shows individual data for each team and each simulation (**circles**). The Searman correlation between the same technical skill scores and each sub-score in the Ottawa CRM-GRS are shown in each panel as the dashed line. A: Overall performance sub-score was significantly positively correlated with technical skill performance. B: Leadership skills score was not statistically correlated with technical skill performance. C: Resource management skills score was significantly associated with technical performance. D: Communication skills scores were not significantly correlated with technical skill performance. E: Problem solving skills scores were not correlated with technical performance. F: Situational awareness scores were significantly correlated with technical skills performance.

literature in the field, rigorous evidence of improved clinical outcomes remains relatively elusive, beyond a limited number of specific indications (ACLS adherence and laparoscopic surgery)[19]. Simulation educators should therefore view it as a professional responsibility to thoughtfully design and rigorously examine the results of all new simulation curricula. In this spirit, we describe a novel trauma simulation curriculum and present both technical and nontechnical skills data from the first full year of the program. Although clear evidence of improved resuscitative skill sets cannot yet be demonstrated by the present data, the evidence of correlation between technical and nontechnical skills demonstrated in this study is interesting, potentially important, and certainly hypothesis generating.

Utilizing competitive incentive to drive positive change among surgical residents is not a novel concept. Dating back to the time of Halsted, when surgical training was built on an apprenticeship model, trainees naturally competed with one another through work ethic and surgical skill in order to gain advancement and employment.[20] As quality improvement and patient safety culture has taken root in North American surgery, a resurgence of individualized feedback that appeals to the competitive nature of surgical providers may have a growing role. In a recent report, from Dr. Halsted's hospital, Lau et al.[21] demonstrated that individualized performance feedback, in the form of report cards, could be used to influence the prescribing pattern of surgical residents for the prophylaxis of venous thromboembolic (VTE) disease and substantially improve the rate of correct VTE prophylaxis prescription.

A recent study demonstrated a similar concept to ours, reported by Ingrassia et al.[22] The authors described a two-day competition event, including didactic discussions and OSCE-style simulations. This was not restricted to trauma, and the teams encountered multiple scenarios representing multiple medical scenarios. During this program, participants were surveyed on satisfaction as well as self-assessment of effectiveness and knowledge gain. In agreement with our study, participants enjoyed the program and felt that they benefitted from participation.

Another element of the novel curriculum which was well received by trainees was the narrated video feedback. In brief, the authors edited video recordings of the simulated resuscitations and added voice-over and on screen direction to guide trainee understanding. Much like a coach might analyze game tape, placing arrows on the screen and offering judgements about choices made by the players, so too are the surgical trainees now able to look back at their performance. Given the fact that these videos are distributed online and easily viewable on portable electronic devices, the trainees are able to access the data in asynchronous fashion and undertake delayed and distributed introspection. Rather than simply having the stand-alone impact of a given simulation exercise, the trainees have the opportunity to continue to reflect on particular scenarios and deepen their understanding over multiple viewing sessions. Based on the laudable work of Carol-Ann Moulton,[23] among others, it is abundantly clear that repeated and distributed education leads to superior skill translation as compared to stand-alone educational interventions. By demonstrating the feasibility of this video feedback concept for trauma resuscitation, it is hoped that future studies will be able to identify similar improvements in retention and transfer of resuscitative skills.

Most interestingly and importantly, this study demonstrates the correlation between technical and non-technical skills across trauma teams. In Figure 1 we see the technical scores of each trauma team over the course of the academic year. Remembering that these scores are achieved competitively, *e.g.* there can only be one first place team for any given behavior on each rubric, it is easy to hypothesize about the relative skill, or experience, of a given team. For example, where team 1 consistently performed highly team 5 consistently performed poorly. Where teams 2 and 3 seemed to vacillate about the median over the course of the year team 4 clearly seemed to be striving and improving their performance as the year went on. Little and less can be generalized from these data since they are so unique to the individual teams and scenarios, however, a careful assessment of Figure 3 leads to a much more meaningful line of thinking about the relationship between technical and nontechnical skill. In Figure 3 we see the technical efficiency scores for each of the 5 teams over each of the 4 simulation scenarios plotted vertically with the corresponding nontechnical skills for each team on each scenario. For simplicity of display the authors have chosen to show the Ottawa CRM GRS Overall score, widely felt to be the most important, as well as a mean of the other sub-categories on the Ottawa CRM GRS. Although the technical skill scores may go up and down with the skill of the residents and the difficulty of the sim it is difficult to deny the fact that the nontechnical skills seem to mirror those same trends over time. In spite of the fact that technical and nontechnical scores were collected by different people at different times and assessing different aspect of performance there seems to be a certain correlation between these two seemingly distinct concepts.

To further characterize the correlation of technical and nontechnical skills the authors performed a Spearman's rank order correlation between each sub-category of the Ottawa CRM GRS and the overall technical efficiency score. Presented in Figure 4, the scatter plots and linear fit of the data (red hashed line) indicate a positive relationship across all sub-categories with the sub-category of resource management reaching statistical significance ($p = 0.02$). One interpretation of this data is that teams who perform well technically also tend to perform well in a nontechnical fashion, and vice versa. This data tends to challenge the notion of the surgeon with "terrible bedside manner" but "hands of gold". In trauma resuscitation, in particular, it may be that teams who are adept at the soft skills also achieve the best hard numbers and bottom line outcomes. Given the dynamic, inter-professional, and complex nature of trauma resuscitation it simply may not be possible to achieve technical excellence without also mastering the art of crisis resource management. This line of thinking is especially salient in light of a recent report showing the distinct and incremental increase in crisis resource management scoring brought about by the introduction of a medium fidelity, technical surgical task into an operating room simulation scenario.[24]

Limitations of this study are significant and conclusions should be considered hypothesis generating and as a starting point for further investigation. In the first place, the nature of the technical skills rubrics means that assessment of improvement in technical performance over time is nearly impossible. Because there can be only one first place in any category, and because scores are generated based on ordinal rank of teams, it is impossible for all teams to achieve the highest possible score. Second, the sample size is limited to only one year of data. Given the steep and consistently positive linear fit of the nontechnical skills data it is tempting to consider that one or two more years of data may produce more broad and consistent statistical significance but this is only conjecture at this time. Finally, any changes seen in a group of trainees over time must have a great deal to do with factors outside the curriculum being analyzed. Time bias means that trainees will inevitably be gaining skill and experience during the conduct of their clinical duties and uncontrolled differences in exposure to trauma resuscitations in particular could affect the data.

By demonstrating the feasibility of a complex and ambitious simulation program, inclusive of novel elements such as the use of performance report cards and annotated video feedback, this paper should impact any readers currently designing simulation curricula to "up the ante" in terms of the quality of the planned feedback. Although signals for improved resuscitative skills are still elusive from this early data it is fascinating to observe the growing correlation between the nontechnical and technical skills of trauma resuscitation. Future research should begin to deeply analyze this signal as modern surgical training program may need to emphasize the fact that mastery of the scalpel and mastery of the crisis go hand in hand for trauma resuscitation (Tables A.1 and B.2).

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APPENDIX A. SAMPLE TECHNICAL EFFICIENCY RUBRIC

APPENDIX B. SAMPLE REPORT CARD

Simulation details

This table provides data regarding when the session occurred and the general topic of the simulation. *Example*:

Scenario details

Date		2017/xxx/xx
Cycle	-	Simulation 3
Scenario theme	-	Penetrating zone 2 neck trauma

Behind the curtain

This section provides space to describe the scenario to participants and reiterate the learning objectives. Any specific interesting features are also included here.

Example: This was a 27 year old male presenting after a single stab wound to the neck. The patient was bleeding profusely beneath a cervical collar and cursing loudly on presentation.

The objectives of this scenario were for participants to:

1. Understand and manage penetrating neck trauma
2. Consider the potential for a difficult airway
3. Prepare for and perform a surgical airway
4. Transition care from ER to OR

Critical behaviors

This table outlines the exact actions and behaviours that were necessary during the simulation. It also shows participants their times, scores and ranks for each behaviour.

Example:

Feedback video

Video of each simulation was taken and stored on a server so that participants were able to review their own footage.

Example:

A narrated video of your performance is available here (link to video). Please keep this video confidential and use it to reflect on your group's performance and deepen your learning.

Overall assessment

This section provides space for an overall summary of the performance of the team during the simulation, along with other tips and comments as desired.

Example:

Team Girotti... you guys were SO CLOSE to another gold medal finish on this sim. In fact, your bronze medal really comes down to one simple but important trap that cost you marks early and prevented you from seizing the gold medal in spite of your near flawless airway performance... that C collar! You guys were fooled the longest by the cervical spine collar and took nearly two and a half minutes to expose the bleeding carotid that was killing this kid. Now that you know collars are not to be used in penetrating trauma you won't make that mistake again!

As for the airway issues what can we say... This was perfect teamwork and a brilliantly executed performance. Everyone who watched the video agreed on a global rating score of 5 for the performance. Well done.

Overall rank

3

TABLE A1. Technical Efficiency Rubric for a Specific Trauma Simulation Scenario

Critical Behavior - Timed	**Specifics**	**Elapsed Time**	**Rank**
Primary survey complete			
	Assess pupils/GCS		
Secondary survey complete			
	Completion of log roll		
Recognize tension pneumothorax			
	Time to decompression		
FAST complete			
Recognition of blown pupil			
	Called out or repeated by leader		
Blood product administration			
	When blood begins flowing		
Book OR for trauma laparotomy			
	OR charge nurse given booking		
Call neurosurgery			
Transition to CT/OR			
Critical behavior - Untimed	Specifics	**Score**	**Rank**
Manage raised intracranial pressure	Administer hyperosmolar agent (1 point) Selection of 3% NaCl (1 point) Raise head of bead to 30° (1 point) Target PCO2 32-36 mmHg (1 point) Target sBP > 90 mmHg (1 point)		
Decision to CT scan	Pan scan (0 points) No CT, to OR (0 points) CT head only (2 points)		

TABLE B1. Technical Efficiency Rubric for a Specific Trauma Simulation Scenario

Critical Behavior - Timed	Elapsed Time	Rank
Primary Survey complete	11:00	1
Secondary Survey complete	10:00	4
Initiate bleeding control (pressure)	2:25	5
State need for surgical exploration	2:50	5
State initial preference for airway management in OR	3:40	3
Duration of cricothyrotomy	0:41	1
Total time until airway secured	7:50	3
Critical Behavior - Untimed	**Score**	**Rank**
Correct technique chosen for airway		
Chose open cric tray		
Chose RSI with paralytic agents		
Divided team into laryngoscopy and cric	4	1
Prepared for surgical airway prior to first laryngoscopy attempt		