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Title:

Use of non-technical skills can predict medical student performance in acute care simulated scenarios

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Abstract

Background: Though the importance of physician non-technical (NT) skills for safe patient care is recognized, NT skills of medical students, our future physicians, has received little attention. This study aims to investigate the relationship of medical student NT skills and clinical performance during acute care team simulation (ACTS).

Methods: Forty-one medical students participated in ACTS. A nurse confederate facilitated and evaluated clinical performance. Two raters assessed participants' NT skills using an adapted NT assessment tool and overall NT skills score was calculated. Regressions predicting clinical performance using NT constructs were conducted.

Results: Overall NT skills score significantly predicted students' clinical performance (r^2=0.178, p=0.006). Individual NT constructs also significantly predicted performance: communication (r^2=0.120, p=0.027), situation awareness (r^2=0.323, p<0.001), leadership (r^2=0.133, p=0.019), and decision making (r^2=0.163, p=0.009).

Conclusions: Medical student NT skills can predict clinical performance during ACTS. NT skills assessments can be used for targeted education for better feedback to students.

Keywords

Medical students training; general surgery clerkship; acute care team simulation; team performance

Introduction

Surgeons' non-technical (NT) skills, which are centered around social, behavioral, and cognitive skills that facilitate safe and effective patient care, have been identified as critical for surgical team performance and patient safety in the operating room.[1,2] Literature in the surgical domain have distilled these skills into constructs such as communication, teamwork, decision making, and situation awareness, and studied their relationship to surgical outcomes.[3–6] Previous research found that communication was the casual factor of 43% of errors during surgical incidents during all phases of surgical care and errors of NT skills are more frequent than technical skill errors in trauma situations.[3,7,8] Recent literature reviews found 21 articles showing failures in NT skills were associated with rate of technical errors.[3,4,9,10] Three out of thirteen reviewed studies of simulation-based trauma team training found significantly increased clinical team performance after NT training. Given the importance of NT skills in the operating room and trauma care, several tools have been proposed to facilitate training and assessments.

Various assessment tools have been developed to assess varying team roles and surgical specialty. For example, the Non-Technical Skills for Surgeons (NOTSS) measure has been designed to assess surgeons and the Oxford Non-Technical Skills (NOTECHS) and Observational Teamwork Assessment for Surgery (OTAS) have been commonly used to assess surgical teams and sub-teams.[4,11–13] These tools have been used to link NT skills and surgical outcomes and evaluate teamwork behavior of surgical team members.[3,13,14] Other investigators have adapted these tools for specific surgical specialties. T-NOTECHS has been developed for evaluation of NT skills for trauma resuscitation teams while the Interpersonal and Cognitive Assessment for Robotic Surgery (ICARS) evaluates NT skills during robotic surgery.[15,16] A systematic review by Wood et al.[17] has shown that the interrater reliability of these assessment tools vary between specialty and tool. While these evaluations focus on surgical teams, limited tools focused on NT assessments during early medical education.

Current literature on medical students NT skills have been limited and focused on few constructs. Brunckhorst et al.[18] emphasized the need for NT skills training and evaluated the feasibility of a simulation-based curriculum to assess technical and NT skills simultaneously. It was found that there was a strong correlation between these skills and joint assessment of these skills are needed in medical student training curricula. Yedidia et al.[19] evaluated a communications training program for medical students and observed significantly improved NT skills, e.g., communications competence and decision-making. Finally, the Self-Assessment Teamwork Tool was designed for self-assessment of practicing physicians and used medical student for validating the tool.[20] Though these studies have medical student participants, there is a need to develop an objective, observer-based assessment for medical student NT skills during early medical education.

Though the importance of physician NT skills for safe patient care is increasingly recognized,[17] assessment of NT skills of medical students, our future physicians, has received little attention. The objectives of this study were: (1) to develop a tool to assess medical student NT skills in acute care team scenarios (ACTS); (2) to investigate relationship between NT skills and simulated clinical performance score; and (3) to evaluate interrater reliability of the tool.

Methods

Study design

Institutional review board approval (IRB#1611105172A009) was obtained at Indiana University School of Medicine. Third year medical students voluntarily participated in this study. After obtaining written informed consent, participants completed one of six simulated ACTS, randomly assigned, for their general surgery clerkship rotation evaluation at the Indiana University Simulation Center. Students were given 10 minutes to complete each a scenario. Within this time, they assumed the role of the primary surgical resident responsible for patient care and completed patient assessments, determined differential

diagnoses, and formed a definitive treatment plan. The scenarios described situations from pre- to post-operative day 5 and are summarized in Table 1. The scenarios were facilitated by a nurse confederate who evaluated student clinical performance on an expert-developed assessment tool (Figure 1), which was collaboratively created with the surgery clerkship director, nurse educator, and surgical education researcher. The nurse confederate was a very experienced medical educator and was consistent for all participants. A patient manikin (SimMan 3G, Laerdal Medical, NY) was used to represent the patient, and the actor operating the manikin was also consistent. Each session was video recoded by three cameras capturing the manikin's vitals, an overhead view of the patient bed, and a high-angle view of the simulated room (Figure 2). The students' NT skills were evaluated using an adapted NT skills tool.

NT assessment tool development

A modified NOTECHS tool was adapted from current literature to ACTS by a team of clinicians and human factors engineers (Table 2). A compilation of existing NT skills assessment tools was completed which included tools such as the Oxford NOTECHS, NOTSS, OTAS, and T-NOTECHS. Constructs and subscales (i.e., elements in the NOTSS scale) within each construct were taken and overlapping constructs were consolidated. The constructs of communication, situation awareness and vigilance, cooperation and team skills, leadership, and decision making and problem-solving were included in this tool. The constructs were comprised of subscales that were identified critical to ACTS, which was determined through consensus among human factors engineers and study-team members with knowledge about surgical critical care and the ACTS. Notable changes to the modified assessment tool include the separation of communication aspects between the clinical team and to the patient. Patient communication in ACTS was found to be critical and were evaluated separately, which was not prevalent in previous literature.[3,21] Each construct was comprised of subscales that were individually rated. The construct score was determined by the average of all element scores within the construct. Overall NT skill score was then calculated from the average of all five constructs. The score range was adapted from the OTAS assessment.[12] The specific subscales scores range was 0 – 6, where 0 represented very problematic

behavior which endangered patient safety and team performance and 6 representing model behavior. For example, the rating 0 for the "risk assessment" subscale of the decision making and problem-solving (Table 2) construct would indicate not vocalizing concerns or decision process, while the rating 6 would be given if the trainee identify future problems and remains calms to unexpected events. Non-applicable could be used for subscales that were not observed and this was not used in the overall score. Prior to data analysis, raters completed several training sessions to gain consensus. The human factors team conducted 2 training sessions to train raters. First, an overview of the constructs was given along with discussion of the anchor points and exemplars for each construct. Two examples from pilot data were evaluated individually then reviewed as a group.

Evaluation and statistical analysis

The first 22 cases were evaluated independently with three raters (one clinician and two human factors raters), while the remaining 19 cases were evaluated with two raters (one clinician rater and one human factors rater). Each case was evaluated by at least 2 raters. Each rater scored each subscale and the average of all subscale elements were taken as the construct score. The averages of the construct and overall NT skills scores were calculated. The raters were completely blinded to the clinical performance score. Clinical performance scores were completed by the nurse confederate immediately after the scenario, and overall clinical performance was used as the metric to correlate with NT skills. The overall clinical performance score was scored taking into metrics such as the accuracy of the students' focused assessment and differential diagnosis, appropriateness of the definitive and supportive treatment, and the time to complete the scenario. SPSS (v.24, IBM, Chicago, IL) was used for statistical analysis. One-way analysis of variance (ANOVA) with Tukey-Kramer adjustment was conducted to compare the effect of scenario on NT skills score. Linear regressions predicting clinical performance using NT constructs were completed. Finally, the two-way random intra-class correlation (ICC) was calculated for the for the raters' scores. Following consensus of the field, the ICC scores within the range of 0.21 – 0.40 indicated fair, between 0.41 – 0.60 as moderate, and within 0.61 – 0.80 indicated substantial agreement.[22] Data were

expressed as mean and standard deviation. A *p*-value of less than 0.05 was considered statistically significant.

Results

Forty-one 3rd year medical students participated in the study. All participants completed the one of six scenarios and scored for their NT skills. Six students completed scenario 1, 9 completed scenario 2, and 8 completed scenario 3. Six students completed scenario 4, 8 completed scenario 5, and 4 students completed scenario 6. The scores of each of the NT constructs are summarized in Table 3. Range of NT skills varied widely between participants. The lowest minimum score of a participant was 0 in leadership and highest maximum score was 4.8 in communication. No participants received the maximum score (rating of 6) for any of the constructs. The average scores for each construct ranged from 3.1 to 3.4, within the range where their behavior neither enhanced nor hindered patient safety. The mean and standard deviation clinical performance scores for scenarios 1 – 6 were 69 ± 21, 60 ± 27, 65 ± 18, 67 ± 23, 74 ± 22, and 69 ± 20, respectively. NT skills score of participants completing scenario 6 was significantly higher than all other scenarios ($p < 0.001$). The greatest score difference of 0.73 was seen between scenario 6 and 4, while the smallest score difference of 0.45 with scenario 6 was scenario 1. Scenario 1 score was 0.28 higher than scenario 4 ($p < 0.024$). No other significant differences were found between the scenarios ($p > 0.129$).

Figure 3 shows the relationship between overall NT skill score and clinical performance score. Analysis of the results indicated no violation of regression assumptions of normal distribution, linearity, and homoscedasticity. Overall NT skill scores significantly predicted the student's overall clinical performance in ACTS ($\rho = 0.422$, $r^2 = 0.178$, $p = 0.006$). Four of the five individual constructs also significantly predicted performance: communication ($\rho = 0.346$, $r^2 = 0.120$, $p = 0.027$), situation awareness and vigilance ($\rho = 0.569$, $r^2 = 0.323$, $p < 0.001$), leadership ($\rho = 0.364$, $r^2 = 0.133$, $p = 0.019$), and decision making and problem-solving ($\rho = 0.404$, $r^2 = 0.163$, $p = 0.009$). Cooperation and team skills

scores, however, did not show a significant relationship ($\rho = 0.230$, $r^2 = 0.053$, $p = 0.148$). Analysis with the extreme outlier removed (beyond quartile 1 – 3*interquartile range or quartile 3 + 3*interquartile range) was conducted. The correlation between the overall NT score and clinical performance was no longer statistically significant ($r^2 = 0.014$, $p = 0.219$); however, the situation awareness & vigilance relationship remained statistically significant ($r^2 = 0.143$, $p = 0.009$).

The ICC among the three raters was 0.539 and the Cronbach's alpha based on standardized items was 0.541. The ICC between rater 1 and 3 (both human factors raters) was 0.648 and between rater 1 and 2 (human factors & clinical rater) was 0.489. The ICC agreement for each construct ranged is summarize in Table 4.

Discussion

Our adapted NT assessment tool provides a framework for educators to evaluate medical students' NT skills during ACTS training. The mean score for each construct was between 3 to 4, and the tool was sensitive to the high variability of NT skill scores between participants. Average scores (~3) indicate behaviors that neither enhanced nor hindered team performance patient safety, and no student received a maximum score, which suggest that further emphasis on NT skills training may need to be incorporated in the medical student training curriculum. This may be especially critical as 20% of students received less than 3, which indicate behaviors that slightly to severely compromise team performance and patient care.

NT skills could significantly predict simulated clinical performance during ACTS. Consistent among the significant relationship is that increasing NT skills scores was positively related to increasing clinical performance. Situation awareness and vigilance had the strongest correlation with clinical performance, better explaining clinical performance variations than the other constructs. The situation awareness and vigilance construct focuses on the monitoring, understanding, and anticipating the team and patient. Our findings suggest that these may be especially critical in ACTS. These findings are similar to the findings

of Hull et al.[3] which was that low situation awareness among surgeons are associated with increased incidences of technical errors. In contrast to the situation awareness and vigilance construct, our findings did not show a significant correlation between clinical performance and cooperation and team skills construct; however, this does not necessarily mean that "positive rapport" and "understanding team needs" (examples subscales of this construct) are not critical in ACTS. Specifically, the lack of correlation may be due to the simulation design. The current ACTS scenarios consisted only of 2 team members, and trainees may have not encountered the need to perform actions that were evaluated under this category such as team conflict handling which the raters would then rate N/A.

The proposed NT assessment tool can potentially enhance medical student education and builds on the existing toolkit for NT skills assessment. Constructs identified critical to ACTS mirrored work by Hamilton et al.[23], which included an additional "escalating care" metric, and the Physician-Patient Interaction Global Rating Scale by Hull et al.[24], which is a validated tool that included metrics such as the physician's empathy and amount of organization. The identified domains where students scored lower could be used to provide better personalized feedback to students. Although more evidence for the tool's validity is needed, this information may accelerate students' learning curve by allowing them to target specific NT skills in their training. More importantly, this tool provides educators and students quantitative and predictive data points that show which specific skills significantly impact clinical performance for a given curricula. In the current ACTS scenarios, results showed that the constructs situation awareness and vigilance and leadership can be targeted for education. Furthermore, since there are many brief simulation assessments in today's medical student education, there are many opportunities to apply this NT skills tool. The multiple simulation and NT assessments over time can provide a longitudinal tool to continuously assess NT training in medical education and transfer of NT skills as simulation complexity scales.

Future work is needed to address several limitations in this study. There were a limited number of raters, and scoring may be subjected to their bias and expertise. For example, the clinical rater may have scored students less for respect for the patient with their training of bedside manners than the human factors rater which may have affected ICC. The presence of fair to moderate agreement showed that further improvement of the tool by defining different or more behavioral markers[25] may be needed to reliably assess the subscales and constructs. The higher average student NT skills scores in scenario 6 could be attributed to the nature of the case. In the first five scenarios, the patient was less responsive and students often encountered unexpected events such as the patient screaming. Students' response to unexpected events was evaluated in a subscale within decision making and problem-solving, which a negative reaction may have decreased their NT skills score. In the last scenario, however, students often had conversations with the patient, who was getting ready to be discharged, and may not have felt the sense of urgency as much as those in the pre-operative scenario. Although statistical relationships between clinical performance and NT skills scores were limited, we believe that further refinement of the tool can improve its interrater reliability and its predictability of clinical performance score. In addition, findings from this study can be further supported if a physician rater completely removed from the ACTS simulation, not the nurse confederate, evaluates the clinical performance score. Future work will include adding additional raters, and applying the tool in non-simulated settings, and gathering additional evidence of the tool's validity.[26]

Conclusion

An assessment tool of NT skills for medical students completing ACTS was developed. The study showed that NT skills is correlated with simulated clinical performance. NT assessments provide deeper insight to how NT skills constructs influence performance and can be used to focus training and provide specific feedback to trainees.

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Table 1. Description of ACTS scenarios

Scenario	Description
1: Motor vehicle crash (MVC) shock	Patient has been brought to the emergency room after an MVC and has damaged left lower extremity with bleeding controlled by tourniquet
2: Pneumothorax due to central venous line	Patient is 6 hours out from surgery and complains of chest pain
3: Disturbance of consciousness due to hyponatremia	Post-operative day 2 and patient is very combative, confused, and refusing physical therapy. Water bottles are hidden beneath limbs.
4: Left leg compartment syndrome	Post-operative day 3 and patient's external fixator was bumped, and patient is under serious pain
5: Pulmonary Embolus	Post-operative day 4 and patient is complaining of some leg pain
6: Heparin Induced Thrombocytopenia	Post-operative day 5 and patient has rash on feet and heparin injection site

Table 2. Sample of subscales of assessment tool

Subscale	Description	Score
COMMUNICATION		
Instructions/Questions to team members distinct	Spoke loud and clear; provided concise instructions and/or descriptions; unambiguous; uses names	
Instructions/Questions to patient distinct		
Responses/Dialogue distinct	Responded verbally to questions; did not mumble to self; spoke clearly when sharing relevant information	
Respect for team	Faces team while speaking	
Respect for patient	Empathize with patient; proper tone of voice; respectful posture; appropriate touching	
SITUATION AWARENESS/VIGILANCE		
Notice/Monitor	Observes team members & patient; asks for information; aware of available resources; request reports/updates/progress	
Understand/Share/Think ahead/Anticipate	Observes and discusses own and team's capabilities and constraints; identifies possible future problem	
COOPERATION/TEAM SKILLS		
Maintains positive rapport/ream building	Relaxed; supportive; does not compete/antagonize team or patient	
Open to opinions/understands team needs	Listens to others; recognizes ability of team	
LEADERSHIP		
Leadership	Accessible; reflects on suggestions; persistent; appropriate assertiveness	
DECISION MAKING/PROBLEM-SOLVING		
Prompt identification of problem	Uses all resources; analytical decision-making; reviews problem elements with team	
Response to unexpected events	Say relaxed and keeps calmed in unexpected events	
Risk assessment	Estimates and vocalizes risks; considers risk in terms of own and team capabilities; estimates patient outcome	

Table 3. Descriptive statistics of NT skills scores of all scenarios

Construct	Score (mean ± SD)	Minimum Score	Maximum Score
Communication	3.3 ± 0.6	1.4	4.8
Situation Awareness/Vigilance	3.1 ± 0.7	0.5	4.2
Cooperation/Team Skills	3.4 ± 0.5	1.9	4.5
Leadership	3.1 ± 0.9	0.0	4.3
Decision Making/Problem-Solving	3.2 ± 0.7	0.9	4.4
Overall	3.2 ± 0.6	0.9	4.3

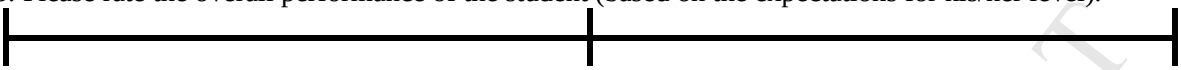
Score of 0 represents problematic performance and 6 represents model behavior.

Table 4. ICC results for each construct

Construct	3 raters		rater 1 & 2	
	ICC	**Agreement Level**	**ICC**	**Agreement Level**
Communication	0.493	Moderate	0.348	Fair
Cooperation	0.529	Moderate	0.414	Moderate
Decision Making	0.548	Moderate	0.574	Moderate
Leadership	0.652	Substantial	0.691	Substantial
Situation Awareness	0.601	Moderate	0.651	Substantial
Overall	0.539	Moderate	0.489	Moderate

Figure 1. Sample questions from clinical performance assessment tool

1. How appropriate was the supportive treatment the student selected?
2. How accurate was the student's focused assessment?
3. How accurate was the student's differential diagnosis?
4. How appropriate was the definitive treatment the student selected?
5. Please rate the overall performance of the student (based on the expectations for his/her level).



0	50	100
Not appropriate/accurate Unacceptable for level	Average	Very appropriate/accurate Outstanding for level

Figure 2. Simulation-based ACTS with patient manikin and participant that was used by NT skills raters

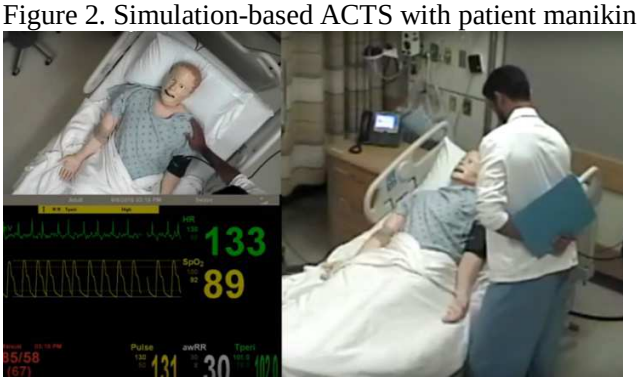
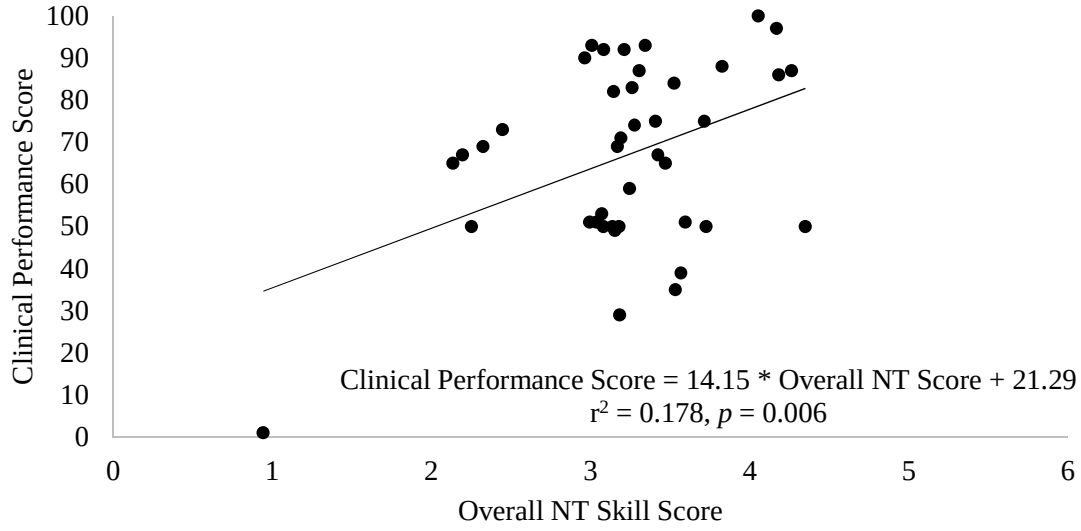


Figure 3. Relationship of overall NT skill score and clinical performance score



Highlights

- Developed an assessment tool of medical student non-technical skills (NTS)
- Found correlation between simulated clinical performance and NTS scores
- Established fair to moderate intra-class correlation of tool between raters