OPEN

Defining Objective Measures of Physician Stress in Simulated Critical Communication Encounters

Amy H. J. Wolfe, MD, MEd[1,2]
Pamela S. Hinds, PhD[2,3]
Adre J. du Plessis, MD[4]
Heather Gordish-Dressman, PhD[5]
Robert M. Arnold, MD[6]
Lamia Soghier, MD, MEd[2,7]

OBJECTIVES: This study had three aims: 1) quantify the difference in stress levels between low and high stress roles during simulated critical communication encounters using objective physiologic data (heart rate variability [HRV]) and subjective measures (State-Trait Anxiety Inventory [STAI]), 2) define the relationship between subjective and objective measures of stress, and 3) define the impact of trainee preparedness and reported self-efficacy on stress levels.

DESIGN: Mixed methods simulation-based study.

SETTING: Single center.

PATIENTS: Pediatric critical care fellows and faculty ($n = 12$).

INTERVENTIONS: Subjects participated in six simulated scenarios in both high stress "hot seat" and low stress "observer" roles.

MEASUREMENTS AND MAIN RESULTS: Subjective stress was measured using the STAI at baseline and after each scenario. Objective stress was measured continuously using a wearable biometric device measuring HRV. Previous residency communication training and self-confidence surrounding various communication topics were collected via questionnaire. Significant changes in subjective (STAI) and objective stress (HRV) measurements in the low- versus high-stress roles were observed. STAI scores increased 8 points during low stress and 12 points during high stress role ($p = 0.021$) compared with baseline. Two specific HRV markers, root mean square of successive differences between normal heartbeats, a marker of parasympathetic tone, and the low frequency/high frequency (LF/HF) ratio, a marker of sympathetic activation, were significantly correlated with STAI levels (−0.032, $p = 0.001$; 1.030, $p = 0.002$, respectively). Participants who reported increased confidence in discussing code status had a significant decrease in stress response (measured via LF/HF ratio) during both the observer ($p = 0.033$) and hot seat roles ($p = <0.001$).

CONCLUSIONS: Communicating life-altering news in a simulated environment is a stressful experience. This stress results in physiologic changes that can be measured continuously using HRV. HRV measurement may serve as a novel method in evaluating the effectiveness of communication training programs and measuring future stress-reduction interventions.

KEY WORDS: burnout, professional; communication; critical care; high-fidelity simulation training; stress physiologic; stress, psychologic

Stress and burnout may occur in up to 80% of physicians during their career, with adverse effects on medical systems, patients and their families, and the individual physician (1). Caring for critically ill patients can exacerbate physician symptoms of stress, especially among novice physicians (2–4). Burnout is a result of chronic stress that leads to both emotional and physical exhaustions (5). The COVID-19 pandemic has triggered an increase in

DOI: 10.1097/CCE.0000000000000721

physician stress and burnout, especially among critical care physicians (6, 7).

Stress occurs when a stressor is interpreted as dangerous due to an imbalance between demands and resources (8, 9). Excessive stress results in overactivation of the sympathetic nervous system, eliciting the "fight-or-flight" response, which, in turn, disrupts the ability to empathize, present difficult information, and listen carefully (10–12). Stressed physicians provide decreased quality of care and decreased patient satisfaction (13). Conversely, effective communication can decrease symptoms of stress, anxiety, and depression for family members of critically ill patients and improve patient outcomes (14–16). The escalation of stress in physicians delivering life-altering information may be subtle and go undetected, while eroding effective communication, making identification of an objective and continuous measure of stress of utmost importance in improving communication quality. Heart rate variability (HRV) is a noninvasive objective biomarker of autonomic nervous system (ANS) tone and can serve as a useful continuous biomarker of stress and coping during stressful medical encounters such as communicating life-altering news to families (8, 9).

Stress impacts performance of technical procedures in medicine (17, 18); however, the impact of physiologic stress on communication, the most commonly performed procedure, in pediatrics has not yet been explored (19). Most of the literature surrounding physician stress and discussion of serious news is based on subjective assessment combined with expert opinions. Of the few studies that do not rely solely on subjective assessment, physiologic indicators of stress have been documented, including an anticipatory increase in cortisol and heart rate among physicians discussing bad news with families (20, 21). Important limitations in these few studies include relying on invasive blood draws to measure cortisol and the lack of granularity provided by using heart rate alone as a surrogate marker for stress. A previous exploratory study used a wristwatch to capture HRV and found that communication quality surrounding bad news discussion was influenced by burnout and physicians' experience (22). There are no studies measuring critical care physician stress during simulated life-altering communication encounters.

This study had three aims: 1) quantify the difference in stress levels between low- and high-stress simulated roles using objective physiologic data (HRV) and subjective measures (State-Trait Anxiety Inventory [STAI]), 2) define the relationship between subjective (i.e., perceived) and objective measures of stress, and 3) define the impact of previous communication training during pediatric residency and reported self-efficacy on stress levels during simulated communication encounters.

MATERIALS AND METHODS

This was a mixed-method simulation-based study (Defining Stress in Critical Communication Encounters) approved by the institutional review board at Children's National Hospital, "Pro00015760" on April 10, 2021. Informed consent was obtained, and procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975. Pediatric critical care fellows and faculty from a single institution were invited to participate via e-mail solicitation. Participation was voluntary, and there were no exclusion criteria. Prior to the start of the study, basic demographic and residency communication training information was obtained through a questionnaire.

Measurements

Exposure to life-altering communication encounters is limited for many critical care trainees and junior faculty, making simulated communication skills training an important mechanism for teaching novice physicians' empathetic communication (23, 24). Subjective and objective stress was measured to determine if stress was produced during a 1-day course designed to improve physician communication skills during life-altering encounters with parents of critically ill children.

Subjective stress was measured via the STAI short form, a validated tool used to measure stress (25–27). The trait subscale measures baseline or usual anxiety, and the state subscale measures current anxiety (how the participant feels "right now"). The range of scores is 20–80, with higher scores indicating greater anxiety (28). HRV was used as a surrogate for objective stress and measured via the Hexoskin smart shirt. HRV is defined as the fluctuation in intervals between adjacent heartbeats and serves as a more sensitive marker than heart rate alone in determining the balance between the sympathetic and parasympathetic nervous systems (29). The Hexoskin smart shirt is a noninvasive device that continuously monitors the user's cardiorespiratory function and activity using a variety of embedded sensors, including a 1-lead electrocardiogram (256 Hz). The smart shirt's use has been reported in many peer-reviewed publications and validated to accurately obtain HRV data and its ability to serve as a surrogate marker of stress (17, 18, 30).

Simulation Protocol

Participants completed a baseline subjective STAI survey on the day of the course and were fitted with a Hexoskin biometric device to measure HRV data continuously throughout the 1-day study period. Participants were randomly divided into two cohorts to ensure adequate role-playing opportunity with professional actors. Each cohort participated in a total of six simulated encounters, which were audio- and video-recorded. The simulated cases were previously designed as part of an educational intervention by palliative care, pediatric critical care, and educational experts and have been piloted in prior cohorts of critical care physicians, including both novice and experienced faculty. The three topics were identified based on commonly seen challenging cases in the critical care environment and included progressive malignancy, chronic respiratory failure, and traumatic brain injury with case evolution from the morning to afternoon session (**Fig. 1**). To elevate the level of stress evoked by these cases, the simulated encounters also contained components that were particularly challenging for physicians such as discussing medical error, spirituality, and brain death (31–33). Participants were invited to volunteer for the hot seat (high stress) role of delivering serious news to the simulated parent, a professional actor, whereas the nonhot seat participants or observers (low stress role) took notes of the interaction to debrief afterward. This approach is supported by previous publications where observers have reported lower stress levels than the primary participants performing the simulation (34). After each simulated encounter, participants completed the short form of the STAI. A research assistant noted the time each participant was in the high- and low-stress roles to ensure timing accuracy.

Statistical Analysis

Subjective Stress Outcomes. We compared STAI measures between the high- and low-stress roles using repeated measures analysis models. A mixed-effects regression model was performed with change in STAI from baseline as the dependent variable and role type (low or high stress) as the independent variable. Each model included a random coefficient term for each participant to allow and account for each participant having multiple simulations of each stress role. In addition, robust SE was used in the model to account for potential minor deviations from the Gaussian assumption of the model. This model estimated the % change from baseline during the low- or high-stress roles and whether the % change from baseline was statistically significantly different between the low- and high-stress roles.

Physiologic Data. Five-minute epochs of HRV were analyzed with the Kubios Premium HRV software (Kuopio, Finland) over a 30-minute baseline period as well as during the six simulated encounters. Kubios provides HRV information in three domains: 1) time, 2) frequency, and 3) nonlinear data (**Appendix A**, http://links.lww.com/CCX/B18) that we used to determine the effects of simulated encounters on sympathetic activation. More specifically, time-domain markers quantify the amount of variability in successive heartbeats, and the most commonly used examples include SD of the N-N Intervals (SDNN) and the root mean square of successive differences (RMSSD) between normal heartbeats. SDNN describes a median of the variability and is reflective of sympathetic activation. RMSSD reflects beat-to-beat differences and measures vagally mediated changes, for example, parasympathetic activation. Frequency-domain information was used to determine the distribution of "signal energy" within the component bands (very low frequency [<0.03 Hertz], low frequency [LF: 0.03–0.15 Hz], and high frequency [HF: 0.15–0.4 Hz], with higher frequencies [HF] associated with parasympathetic activation). The ratio of LF/HF is representative of sympathetic/parasympathetic balance, with higher values representative of sympathetic predominance. Nonlinear results allow for quantification of the unpredictability of the time series domain, for example, the complexity of the heart rate pattern. Poincaré plots provide a visual representation of heart rate patterns (Appendix B, http://links.lww.com/CCX/B18). These scatter plots are created by comparing the

Figure 1. Case simulations. Participants completed six case simulations with opportunities for passive participation observing the simulation (low stress role) and active participation (high stress role) directly communicating serious news with the simulated family members. ALL = acute lymphocytic leukemia, PM = post meridiem, TBI = traumatic brain injury.

time between two successive heartbeats (RR_n) versus the interval between the next two heart beats (RR_{n+1}). An ellipse applied to the plot allows for measurements of the plot shape, the short axis is called SD1 (SD of instantaneous beat-to-beat interval variability) and the long-axis SD2 (the continuous long-term R/R interval variability). The ratio of SD2/SD1 is another way to represent sympathetic/parasympathetic balance, with higher values representative of sympathetic activation (35). We selected four commonly used HRV variables to broadly capture all three HRV domains including time (SDNN [ms], RMSDD [ms]), frequency (LF/HF), and nonlinear (SD2/SD1) to compare stress levels throughout the scenarios to baseline measurements. To assess the physiologic data in response to stress roles, we again used repeated measures analysis models.

Comparison of Subjective Versus Physiologic Stress. The relationship between subjective stress measures (i.e., STAI scores) and markers of physiologic stress (i.e., SDNN, RMSDD, LF/HF, and SD1/SD2 ratio) was assessed using mixed-effects regression models with robust standard errors. Simulation role (low vs high stress) was included as a covariate to account for potential different relationships. This model allows each participant to have multiple values for each simulation role, allows for missing data, and tests whether subjective values are linearly related to physiologic measures while accounting for repeated assessments per participant and per simulation type. We also compared physiologic markers of stress to subjective assessments of training preparedness using mixed-effects model to account for multiple situations per participant.

RESULTS

All invited participants agreed to participate in the study. Basic demographic and residency information was obtained. Participants' ages ranged from 29 to 37 years: 58% were male, and the majority were Caucasian (92%). The majority reported regular caffeine use (75%), slept between 6 and 7 hours per night (92%), and exercised regularly (75%). The majority of participants completed residency training at programs containing greater than 20 residents per year (75%). The geographic distribution of training programs varied, with the largest percentage of participants attending programs in the Northeast (42%), followed by Midwest (35%), South (17%), and Mid-Atlantic (17%). The majority of participants were in their first year of fellowship (50%), and 17% were faculty. Participants also reported information regarding the type of communication training previously provided during their residency and whether that training translated into increased comfort/confidence in communicating various topics with families (**Table 1**). Fifty-eight percent of participants reported caring for a substantial number of patients in their last few weeks of life

TABLE 1.
Selected Prior Residency Training Characteristics and Self-Reported Communication Confidence (*n* = 12)

Question	Response	*n* (%)
Experience with caring for patients who were in the last few weeks of life	I seldom cared for patients in their last few weeks of life	5 (42)
	I took care of a substantial number of patients in their last few weeks of life	7 (58)
Did you receive training in discussing various treatment options, including palliative care?	No	8 (67)
	Yes	3 (25)
	Don't remember	1 (8)
Did you receive training in discussing religious or spiritual issues with patients and families?	No	7 (58)
	Yes	5 (42)
Did you receive training in expressing empathy?	No	2 (17)
	Yes	10 (83)
Were you given the opportunity to observe a family meeting where life-altering news was delivered?	No	2 (17)
	Yes	10 (83)
Were you personally given the opportunity to lead a family meeting where life altering news was delivered?	No	8 (67)
	Yes	4 (33)
Was there an opportunity to debrief after the meeting?	No	1 (25)
	Yes	3 (75)

Self-Reported Confidence	Strongly Agree	Agree	Neither Agree/ Disagree	Disagree	Strongly Disagree
I feel well-trained in giving bad news to a family about a loved one's illness	0 (0)	5 (42)	3 (25)	3 (25)	1 (8)
I feel well-trained in leading a family meeting to discuss goals of care	0 (0)	1 (8)	4 (33)	5 (42)	2 (17)
I feel well-trained in discussing various treatment options, including palliative care, with families of critically ill patients	0 (0)	2 (17)	5 (42)	4 (33)	1 (8)
I feel well-trained in discussing code status (do not resuscitate) with a family member	1 (8)	3 (25)	6 (50)	1 (8)	1 (8)
I feel well-trained to discuss religious or spiritual issues with families	0 (0)	2 (17)	6 (50)	3 (25)	1 (8)
I feel well-trained in responding to an emotional parent	2 (17)	4 (33)	2 (17)	3 (25)	1 (8)

during residency. Most participants reported receiving no training in discussing treatment options (67%) and spiritual issues (58%) with families. Sixty-seven percent of participants had not led a family meeting previously, and 58% did not feel confident in leading a family meeting to discuss goals of care.

Subjective and Objective Stress Findings

Subjective stress showed a role-dependent increase in stress, with a significantly greater change from baseline (and % change from baseline) in perceived stress (STAI) when participants were talking to the families (high-stress) versus the low-stress situations. STAI increased 8 points from baseline in the observer role and increased 12 points from baseline in the hot seat role ($p = 0.021$). Objectively, SDNN, SD2/SD1 ratio, and RMSSD parameters all showed a statistically significant percent change from baseline in the observer and hot seat roles (**Table 2**). For SDNN, as expected, there was a significant increase in stress response from baseline during the hot seat versus observer role (hot seat = 71.8, observer = 41.7, $p < 0.001$). The SD2/SD1 ratio, another marker of sympathetic activation, also showed an increase in the hot seat role ($p < 0.001$) compared with baseline. As predicted, RMSSD, parasympathetic activation, was significantly lower during the hot seat role (81.7) compared with observer role (104.9) ($p = 0.007$), indicating more parasympathetic activation in the observer role. No significant differences in percent change from baseline in LF/HF ratio were observed.

Relationship Between Subjective and Objective Stresses

Our secondary aim was to investigate the relationship between subjective stress outcomes (STAI) and HRV outcomes (SDNN, RMSSD, LF/HF ratio, and SD2/SD1 ratio). We found that even after accounting for the different simulation roles, both RMSSD and LF/HF ratio are significantly related to STAI levels (**Table 3**). In the case of RMSSD (reflective of parasympathetic activation), we found that a 1-unit decrease in RMSSD level predicts a 0.032 unit increase in STAI ($p = 0.001$). The LF/HF (reflective of sympathetic activation) ratio has a positive coefficient indicating that as STAI levels increase, so does the LF/HF ratio; and the magnitude of the increase is such that a one unit increase in LF/HF ratio predicts a 1.030 unit increase in STAI ($p = 0.002$). Neither SDNN nor SD2/SD1 ratio showed evidence of a significant relationship with STAI levels.

Impact of Training Preparedness on HRV Outcomes

We found a significant relationship between stress response in the observer (low stress) role and residency programs that provided training on how to communicate with seriously ill patients and exposed residents to patients who were critically ill and dying. More specifically, we found a significant relationship among those participants who had led a family meeting in training and decreased stress response in the observer role

TABLE 2.
Comparison of Group Outcomes Between Observer and Hot Seat Role ($n = 12$)

Outcome	Role Type	Estimated Mean ± SE	*p* Comparing Observer vs Hot Seat
% Change from baseline in SD of the N-N intervals (ms)	Observer	41.7 ± 38.9	**< 0.001**
	Hot seat	71.8 ± 36.5	
% Change from baseline in SD2/SD 1 ratio	Observer	−18.6 ± 7.2	**< 0.001**
	Hot seat	31.0 ± 11.4	
% Change from baseline in root mean square of the successive differences (ms)	Observer	104.9 ± 86.3	**0.007**
	Hot seat	81.7 ± 79.6	
% Change from baseline in low frequency/high frequency ratio	Observer	−25.2 ± 8.5	0.11
	Hot seat	−5.1 ± 15.4	

n = 12 participants, resulting in 69 observations (six for 11 of the participants, and one participant left the course early resulting in only three observations for that participant).
Boldface font indicates statistically significant values.

TABLE 3.
Relationship Between Subjective and Objective Stress Outcomes ($n = 12$)

Subjective Stress Outcome	HRV Outcome	HRV Outcome Coefficient (p)[a]
State-Trait Anxiety Inventory	SD of the N-N intervals (ms)	−0.037 ($p = 0.07$)
	SD2/SD1 ratio	0.174 ($p = 0.86$)
	Root mean square of the successive differences (ms)	−0.032 (**$p = 0.001$**)
	Low frequency/high frequency ratio	1.030 (**$p = 0.002$**)

HRV = heart rate variability, LF/HF, Low frequency/High frequency, RMSSD, root mean square of the successive differences, SDNN = standard deviation of the N-N intervals, SD2/SD1, standard deviation 2/standard deviation 1.
[a]Models were adjusted for simulation role, and simulation role was a significant covariate in each of the models.
$n = 12$ participants, resulting in 69 observations.
Boldface font indicates statistically significant values.

(decreased SD2/1 ratio = −1.08, $p = 0.005$; increased RMSSD = +112.31, $p = 0.033$) compared with those who did not have that experience. Additionally, those who had cared for a substantial number of patients in the last few weeks of life and learned about treatment and palliative options in their training had a decreased stress response in the low-stress role (decrease in SD2/SD1 ratio of −0.9, $p = 0.010$ and $p = 0.041$, respectively) compared with their peers who had not had those opportunities (**Fig. 2**). This decreased stress response was not present in the high-stress role.

We also wanted to define the impact of self-perceived confidence/comfort in communicating various topics with families on stress responses. We found that participants with higher self-reported confidence in discussing code status with families revealed lower stress response in both the observer and hot seat roles (decreased LF/HF ratio). More specifically, we found a statistically significant decrease in stress response during both the observer (−1.016, $p = 0.033$) and hot seat (−2.24, $p < 0.001$) situations as participants reported increased confidence in discussing code status with families (agree and strongly agree) (**Fig. 3**). On the contrary, those that strongly disagreed/disagreed with the statement "I feel well trained to discuss code status" had an increase in stress response during the hot seat role.

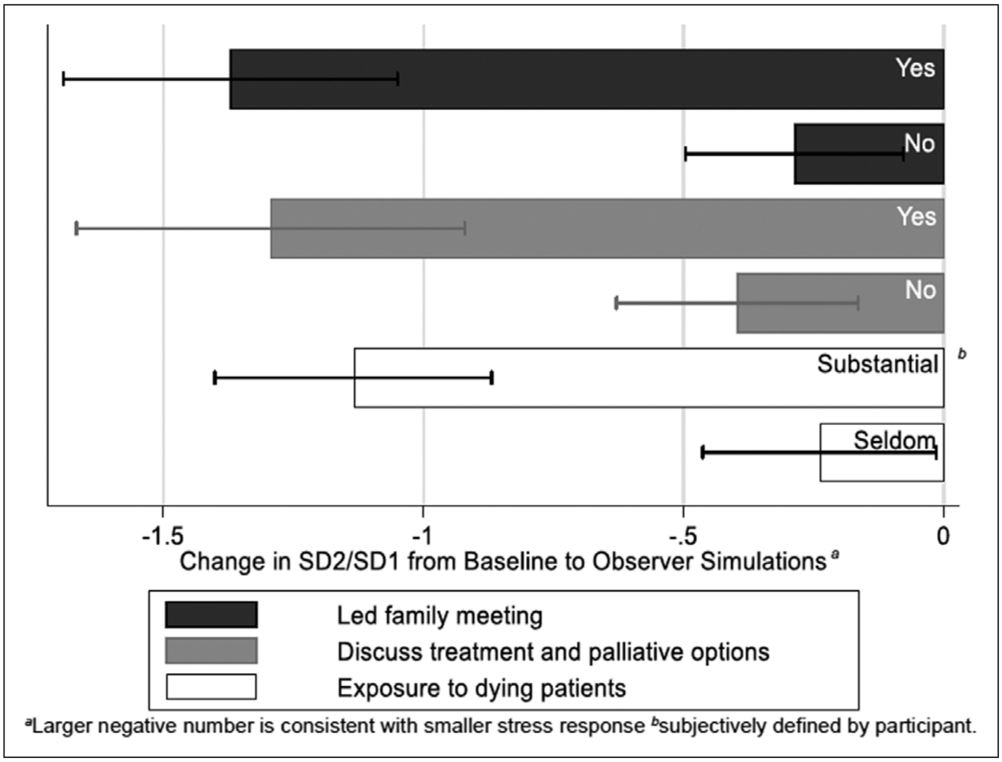

Figure 2. Impact of prior communication training on observer (low stress) simulation role. Decrease in stress response (more negative SD2/SD1) from baseline was observed for participants who had the opportunity to lead a family meeting, received education on discussing treatment options with families, and subjectively reported significant exposure to dying patients during residency training.

DISCUSSION

This study confirms that high fidelity–simulated communication

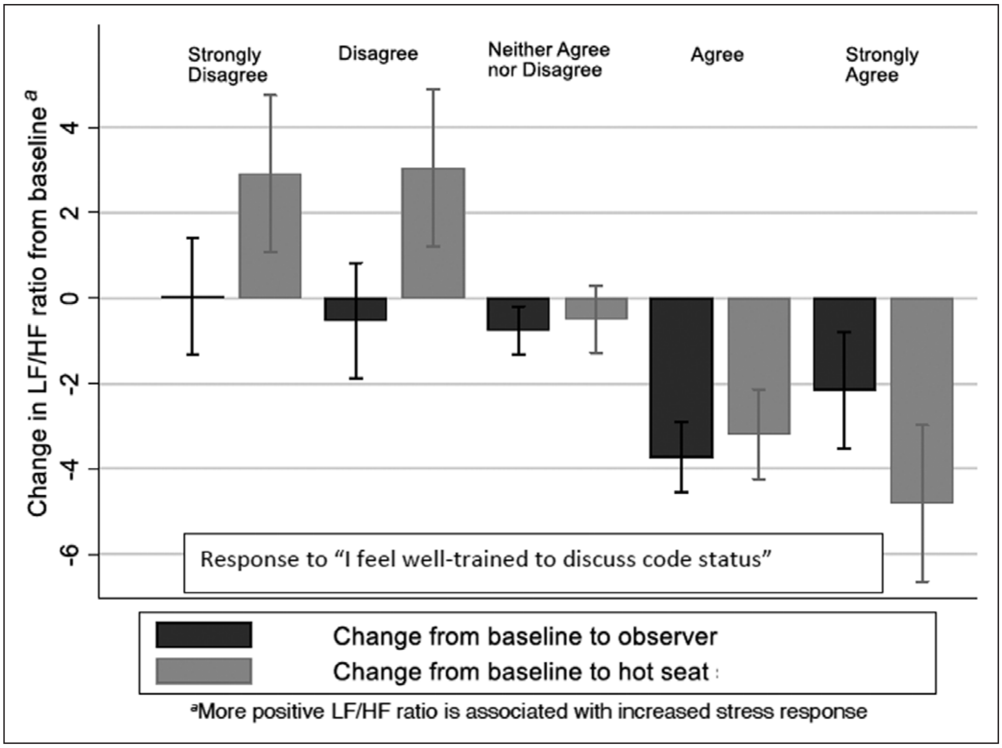

Figure 3. Impact of physician confidence in discussing code status on stress response. Response to the question "I feel well-trained to discuss code status" is demonstrated. Participant stress response decreases as confidence in discussing code status increases, as demonstrated by a decrease in participants low frequency/high frequency (LF/HF) ratio in both observer and hot seat roles compared with baseline for participants who agreed/strongly agreed with the above statement.

encounters induce subjective and objective stresses among critical care physicians. More specifically, we demonstrated four key findings: 1) simulated communication encounters evoke physician subjective stress (STAI), which varies according to simulation role type, 2) HRV can be used as an objective measure of physiologic stress in simulated communication encounters, 3) physicians may not be aware of subtle changes in their body's physiologic stress response, and 4) previous communication training received during residency impacts physician stress response.

Subjectively, participants reported an increase in perceived stress (STAI) during the observer role and a further increase in stress in the hot seat role compared with baseline. Physician self-awareness of stress is important because identifying potential sources of stress is the first step in modulating stress responses. Objectively, three of the four (SDNN, RMSSD, and SD2/SD1) HRV domains we investigated produced a quantifiable difference in physician objective stress in the observer and hot seat roles compared with baseline. Identification of which HRV parameters are most sensitive to detect physiologic stress in simulated communication encounters is essential to measure subtle alterations in stress responses that may impair communication quality as well as impact physician health and well-being. We also found two HRV parameters (LF/HF and RMSSD) correlated with physician self-reporting of stress, with increases in LF/HF (sympathetic activation) associated with an increase in subjective stress and increases in RMSSD (parasympathetic activation) associated with a decrease in subjective stress as predicted. This highlights that although physicians are broadly aware of increases in stress based on specific activities (observer vs hot seat), there may be more subtle experiences that increase physiologic stress that physicians are not aware of, potentially impacting task performance and health.

Additionally, we found previous communication training and self-reported confidence in some communication domains impacted objective stress measures. Trainees who had confidence in discussing code status showed decreased stress response in both low- and high-stress roles. In the other domains ("leading a family meeting, discussing religious/spiritual issues, responding to emotional parents"), participants who felt well trained had decreased stress levels during the low-stress roles but still reported significant levels of stress in the high-stress roles. These findings highlight two key points: 1) discussion of code status seems to be a focus of previous residency training and 2) code status may be viewed by novice learners as a binary decision (limitations of life-sustaining therapy vs full code) rather than appreciating the full range of limitations that may exist and, thus, may translate to increased confidence. Furthermore, despite many participants feeling well trained in the other communication domains, there was not a decreased stress response in the high stress role, bringing to question the relationship between confidence in discussing end-of life care and ability to perform this task independently without additional advanced communication skills training. It is also possible that preparation and confidence may not be sufficient to reduce the stress response beyond a certain level given the intensity of certain critical communication encounters, and some level of stress may be beneficial.

We also found that simply caring for many patients who were dying did not result in a decreased stress response when having these high stress-simulated encounters. These findings highlight the importance of not only targeted and specific communication skills training with active experimentation and role play but, more importantly, opportunities for learners to lead family meetings where life-altering decisions are occurring coupled with real-time feedback provided to the learners afterward.

The ability to quantify subtle changes in physician stress levels during critical encounters is a necessary first step in providing physicians with the ability to recognize and reduce stress in real time. Future interventions, such as mindfulness-based stress reduction, biofeedback, and other emotion-focused coping techniques, will be used to target these potentially maladaptive stress responses of the ANS in life-altering communication encounters. Additionally, although improving physician stress and coping is of paramount importance, it is also necessary to quantify the impact of stress on empathetic communication quality. Future studies that define the role of physician stress during critical communication encounters will be essential to improving the communication quality provided to families.

Although we demonstrated several significant and meaningful relationships in the study, there are several limitations worth highlighting. This study used a small sample size of 12 participants, with limited ethnic diversity, and although each participant had 70–81 five-minute data segments, the results of these findings need to be replicated on a larger scale. The baseline measurement obtained on the same day as the communication course may not be representative of participants true "baseline" given anticipatory stress may be present, and we did not account for differences in circadian rhythms due to sampling at various time points throughout the day. In addition, this was performed as part of a communication course, the number of times participants were in the low- versus high-stress roles is variable, and this design lacked granularity to determine if any one of the six scenarios resulted in higher levels of stress independent of observer versus hot seat role. Although we found statistical significance in three of the four HRV domains, we did not find a statistically significant difference in LF/HF ratio between baseline, observer, and hot seat scenarios. The reason for this is likely multifactorial including how the baseline HRV information was obtained, the small sample size, and the fact that the LF/HF is a ratio and can be variable from second to second based on the slightest changes in sympathovagal balance (36). Last, the relationship between the subjective and objective stresses as measured via RMSSD although statistically significant may not have a clinically meaningful relationship and, thus, requires expansion of this study in a larger cohort in situ in the PICU.

CONCLUSIONS

Subjective and objective stresses can be induced in simulated critical communication encounters. We found HRV to be a reliable, objective, and continuous marker of stress that can be deployed unobtrusively during high-stake communication encounters. This novel approach will transform our ability to design meaningful, valid, and reproducible interventions. The importance of quantifying stress in critical care physicians is paramount not only because of the widespread toll physiologic stress wreaks on the body and mind but also to ensure the design of adequately challenging learning environments for communication competency training. Harnessing this technology will open the door for timely and impactful changes in the way physicians communicate with critically ill families and ensure the highest quality of care is provided to all.

ACKNOWLEDGMENTS

We thank Sarah Allen and Austin Yoders for their assistance in ensuring accurate timing of the data collection.

1 *Department of Critical Care Medicine, Children's National Hospital, Washington, DC.*

2 Department of Pediatrics, The George Washington University School of Medicine and Health Sciences, Washington, DC.

3 Department of Nursing Science, Professional Practice, & Quality, Children's National Hospital, Washington, DC.

4 Division of Prenatal and Transitional Medicine, Prenatal Pediatrics Institute, Children's National Hospital, Washington, DC.

5 Department of Pediatrics, Center for Translational Research, The George Washington University School of Medicine and Health Sciences, Washington, DC.

6 Department of Medicine, Section of Palliative care and Medical Ethics, Department of Medicine, Palliative Research Center, University of Pittsburgh School of Medicine, Pittsburgh, PA.

7 Department of Neonatology Children's National Hospital, Washington, DC.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/ccejournal).

Supported, in part, by an institutional pilot award mechanism.

The authors have disclosed that they do not have any potential conflicts of interest.

This work was performed at Children's National Hospital, Washington, DC.

For information regarding this article, E-mail: ajones3@childrensnational.org

REFERENCES

1. West CP, Dyrbye LN, Erwin PJ, et al: Interventions to prevent and reduce physician burnout: A systematic review and meta-analysis. *Lancet* 2016; 388:2272–2281
2. Sansone RA, Sansone LA: Physician grief with patient death. *Innov Clin Neurosci* 2012; 9:22–26
3. Redinbaugh EM, Sullivan AM, Block SD, et al: Doctors' emotional reactions to recent death of a patient: Cross sectional study of hospital doctors. *BMJ* 2003; 327:185
4. Jackson VA, Sullivan AM, Gadmer NM, et al: "It was haunting.": Physicians' descriptions of emotionally powerful patient deaths. *Acad Med* 2005; 80:648–656
5. Freudenberger HJ: The staff burn-out syndrome in alternative institutions. *Psychotherapy: Theory, Research & Practice* 1975; 12:73–82
6. Kok N, van Gurp J, Teerenstra S, et al: Coronavirus disease 2019 immediately increases burnout symptoms in ICU professionals: A longitudinal cohort study. *Crit Care Med* 2021; 49:419–427
7. Kane L: Medscape National Physician Burnout & Suicide Report 2021: "Death by 1000 Cuts". 2021. Medscape. Available at: https://www.staging.medscape.com/slideshow/2021-lifestyle-burnout-6013456. Accessed December 15, 2021
8. Porges SW: The Polyvagal Theory: Neurophysiological Foundations of Emotions, Attachment, Communication, and Self-Regulation. 18th Edition. New York, NY, W. W. Norton, 2011
9. Lazarus R, Folkman S: Stress, Appraisal, and Coping. New York, NY, Springer Publishing Company, 1974, pp 22–52
10. LeBlanc VR: The effects of acute stress on performance: Implications for health professions education. *Acad Med* 2009; 84:S25–S33
11. Riess H: Empathy in medicine–a neurobiological perspective. *JAMA* 2010; 304:1604–1605
12. Hart JL, Turnbull AE, Oppenheim IM, et al: Family-centered care during the COVID-19 era. *J Pain Symptom Manage* 2020; 60:e93–e97
13. Moss M, Good VS, Gozal D, et al: An official critical care societies collaborative statement: Burnout syndrome in critical care health care professionals: A call for action. *Am J Crit Care* 2016; 25:368–376
14. Lautrette A, Darmon M, Megarbane B, et al: A communication strategy and brochure for relatives of patients dying in the ICU. *N Engl J Med* 2007; 356:469–478
15. King A, Hoppe RB: "Best practice" for patient-centered communication: A narrative review. *J Grad Med Educ* 2013; 5:385–393
16. Hojat M, Louis DZ, Maio V, et al: Editorial: Empathy and health care quality. *Am J Med Qual* 2013; 28:6–7
17. Redmond B, Joseph M, Ray J, et al: Stress as tool or toxin: Physiologic markers and subjective report in neonatal simulation. *Pediatr Res* 2020; 88:784–791
18. Slamon NB, Penfil SH, Nadkarni VM, et al: A prospective pilot study of the biometrics of critical care practitioners during live patient care using a wearable "smart shirt". *J Intens Crit Care* 2018; 04
19. Harvey A, Bandiera G, Nathens AB, et al: Impact of stress on resident performance in simulated trauma scenarios. *J Trauma Acute Care Surg* 2012; 72:497–503
20. van Dulmen S, Tromp F, Grosfeld F, et al: The impact of assessing simulated bad news consultations on medical students' stress response and communication performance. *Psychoneuroendocrinology* 2007; 32:943–950
21. Cohen L, Baile WF, Henninger E, et al: Physiological and psychological effects of delivering medical news using a simulated physician-patient scenario. *J Behav Med* 2003; 26:459–471
22. Brown R, Dunn S, Byrnes K, et al: Doctors' stress responses and poor communication performance in simulated bad-news consultations. *Acad Med* 2009; 84:1595–1602
23. Johnson EM, Hamilton MF, Watson RS, et al: An intensive, simulation-based communication course for pediatric critical care medicine fellows. *Pediatr Crit Care Med* 2017; 18:e348–e355
24. Markin A, Cabrera-Fernandez DF, Bajoka RM, et al: Impact of a simulation-based communication workshop on resident preparedness for end-of-life communication in the intensive care unit. *Crit Care Res Pract* 2015; 2015:534879
25. Wong ML, Anderson J, Knorr T, et al: Grit, anxiety, and stress in emergency physicians. *Am J Emerg Med* 2018; 36:1036–1039
26. Voultsos P, Koungali M, Psaroulis K, et al: Burnout syndrome and its association with anxiety and fear of medical errors among intensive care unit physicians: A cross-sectional study. *Anaesth Intensive Care* 2020; 48:134–142
27. Eskander J, Rajaguru PP, Greenberg PB: Evaluating wellness interventions for resident physicians: A systematic review. *J Grad Med Educ* 2021; 13:58–69

28. Marteau TM, Bekker H: The development of a six-item short-form of the state scale of the Spielberger State—Trait Anxiety Inventory (STAI). *Br J Clin Psychol* 1992; 31:301–306
29. Thayer JF, Ahs F, Fredrikson M, et al: A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neurosci Biobehav Rev* 2012; 36:747–756
30. Cherif NH, Mezghani N, Gaudreault N, et al: Physiological data validation of the Hexoskin smart textile. In: BIODEVICES 2018 - 11th International Conference on Biomedical Electronics and Devices, Proceedings; Part of 11th International Joint Conference on Biomedical Engineering Systems and Technologies, BIOSTEC 2018. 2018
31. Mazor KM, Simon SR, Gurwitz JH: Communicating with patients about medical errors: A review of the literature. *Arch Intern Med* 2004; 164:1690–1697
32. Morris NA, Zimmerman EE, Pozner CN, et al: Brain death determination: An interprofessional simulation to determine brain death and communicate with families focused on neurology residents. *MedEdPORTAL* 2020; 16:10978
33. Gradick K, October T, Pascoe D, et al: 'I'm praying for a miracle': Characteristics of spiritual statements in paediatric intensive care unit care conferences. *BMJ Support Palliat Care* 2020 Aug 27. [online ahead of print]
34. Bong CL, Lee S, Ng ASB, et al: The effects of active (hot-seat) versus observer roles during simulation-based training on stress levels and non-technical performance: A randomized trial. *Adv Simul (Lond)* 2017; 2:7
35. Shaffer F, Ginsberg JP: An overview of heart rate variability metrics and norms. *Front Public Health* 2017; 5:258
36. Billman GE: The LF/HF ratio does not accurately measure cardiac sympatho-vagal balance. *Front Physiol* 2013; 4:26