Psychophysiologic responses of invasive cardiologists in an academic catheterization laboratory

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Background This study examined the psychophysiologic responses of invasive cardiologists during cardiac catheterizations. Because occupations are most stressful when one is not in control, the effect of a teaching versus an autonomous role on the psychophysiologic response of invasive cardiologists was investigated.

Methods The subjects were 9 invasive cardiologists. Psychophysiologic variables such as state anxiety and salivary cortisol levels were measured before and after each invasive cardiologist performed 7 cardiac catheterizations. Heart rate was measured before, during, and after procedures. Three procedures were studied while invasive cardiologists were in the primary operator (autonomous) role with full responsibility and control, whereas 4 were studied while the subjects were in the secondary assistant (teaching) role with full responsibility and no control.

Results There were no significant differences in physiologic arousal (heart rate and salivary cortisol levels) between catheterizations performed in the autonomous role versus those in the teaching role. However, the perceived anxiety scores were higher when in the teaching role versus when in the autonomous role. There were significant differences in psychophysiologic measurements of stress between less experienced cardiologists (out of training <5 years) and more experienced cardiologists (out of training >5 years). Less experienced invasive cardiologists had significantly higher trait anxiety (38.4 vs 31.7, $P = .001$), baseline salivary cortisol levels (0.51 vs 0.33, $P = .01$), and heart rate change (50.1 vs 27.4 beats/min, $P = .001$) during procedures compared with more experienced cardiologists.

Conclusions Although there were no overall differences in the physiologic response to the autonomous and teaching roles, there was a higher perceived state of anxiety when in the teaching role. Less experienced invasive cardiologists had higher psychophysiologic measurements of stress during invasive procedures than did more experienced cardiologists. (Am Heart J 2006;151:522-8.)

Levels of stress[1-3] and anxiety in physicians' lives are increasing, given the changing demands of the practice[4-6] and the influence of multiple external environmental factors that affect physicians.[7] Continued and prolonged exposure to stressful situations may have detrimental effects on performance as well as harmful long-term psychological and physical consequences.[8-11] Both surgeons and invasive cardiologists are in occupations of high stress because they are exposed to a constant mental strain as well as a fast tempo of thought process and action.

In addition to increasing occupational stress, it is the responsibility of academic cardiologists to train young physicians. Procedures training is an integral part of all cardiovascular training programs. Attending physicians are expected to train young physicians in various hands-on techniques but are also directly responsible for the care and safety of patients. One of the most stressful occupational environments is one in which demands are high and the ability to control the situation is low.[12,13] Therefore, the training of inexperienced invasive cardiologists may cause significant physiologic and psychological stress on academic staff cardiologists. Although prior studies have delineated the relationship between physiologic arousal and specific situations encountered by health care providers,[10,14] minimal research have examined the physiologic response to stress that health care providers experience in situations of criticality, especially when there is loss of control such as that which occurs in the teaching situation.

The purpose of this study was to examine the psychophysiologic responses of invasive cardiologists during the performance of cardiac catheterizations to determine if there are differences in the physiologic and psychological responses during procedures performed in the autonomous role (full control) versus those performed in the teaching role (loss of control).

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Methods

Study participants

After obtaining institutional review board approval, the cardiac catheterization laboratory director invited invasive cardiologists to participate in the study. He also identified experienced (last 2 weeks of training) and inexperienced (first 2 weeks of training) cardiac fellows as prospective trainee participants. Nine male invasive cardiologists (N = 9) volunteered. None of the cardiologists were taking medications.

Tests and measures

Psychological measures

Speilberger state/trait anxiety inventory. The trait version of this questionnaire was administered at the outset of the study to the invasive cardiologists to measure their predisposition to view life events as threatening or anxiety provoking. The state version of this questionnaire indicates the subjects' specific state of anxiety at the time the survey was completed. The state version of anxiety was administered within 5 minutes before entering the procedure room and within 5 minutes after completing the procedure. Both trait and state measures have high validity and reliability. Total possible scores range from 20 to 80, with higher scores indicating more severe anxiety. The average state anxiety score for men is 35.7 $\pm$ 10.4 and the average trait anxiety score is 34.9 $\pm$ 9.2.[15]

Evaluation of difficulty of procedure. Attending cardiologists rated their perceptions of the technical difficulty of the procedures and the patients' conditions on a 5-point Likert scale. The subjects rated technical difficulty between 1 (least difficult) and 5 (most difficult) using their past experience of the least and most difficult diagnostic angiogram cases that they had encountered in their career as a staff consultant. A patient's condition was rated between 1 (stable) and 5 (most critical) using a similar rating scale based on the subjects' past experience. These ratings were made by each cardiologist immediately after the procedure.

Physiologic measures

1. Blood pressure, pulse rate, and respirations were recorded before and after procedures.
2. Electrocardiogram (ECG) monitoring. Invasive cardiologists wore a 3-electrode telemetry system (strapped at the waist and positioned at back) to obtain a continuous lead II ECG heart rate (HR) signal (Figure 1).
3. Salivary cortisol levels. These levels were taken within 5 minutes of entering the procedure room and within 5 minutes of completing the procedure. Invasive cardiologists provided 5 mL of saliva per sample, obtained by chewing on a cotton salivette. Gloved research assistants placed the saliva in a syringe before squeezing it into a sterile tube. Samples were cooled, frozen, and sent to a laboratory for radioimmunoassay. Results are expressed in micrograms per deciliter and salivary cortisol level scores >2.5 times baseline are considered to indicate a meaningful stimulation of the hypothalamus-pituitary adrenal axis.[16-20]

Other measures. A continuous video and audio recording of the procedure was performed for purposes of analyzing offline the technical difficulty of the procedure and the potential complications encountered during the procedure. There was a video camera that recorded the movements of the invasive cardiologist as well as a portable microphone that was worn by each cardiologist throughout the procedure.

Cardiac catheterization protocols

Catheterization procedures are performed under 2 different protocols in the Mayo Clinic cardiac catheterization laboratory.

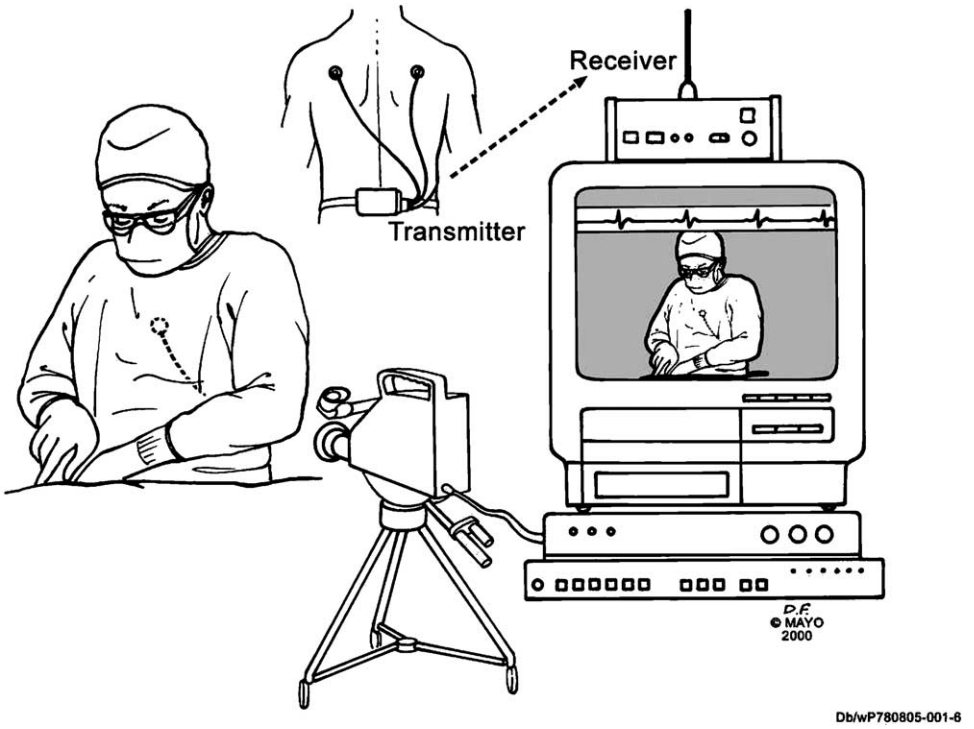
1. The standard protocol is a teaching approach in which a cardiovascular fellow (trainee) is the primary operator. The primary operator obtains vascular access, manipulates the catheter to engage the coronary arteries, and moves the patient under the x-ray machine to obtain diagnostic pictures. The attending invasive cardiologist serves as secondary assistant to assist with catheter changes and to inject contrast through the catheter into the coronary artery. Attending cardiologists assume the role of a mentor and supervisor to optimize the fellow's technique. During the execution of this protocol, the attending cardiologist is responsible for patient safety and ensures that all diagnostic information is obtained.
2. In the second protocol, the attending cardiologist is the primary operator and a skilled technician assists. The attending invasive cardiologist has no teaching responsibilities and is both in full control and responsible for the outcome.

Procedure

Elective diagnostic coronary angiographic procedures were selected for this study. If an intervention was performed after a diagnostic procedure, the study was ended at the termination of the diagnostic procedure. A signed consent was obtained from cardiologists before starting the study and verbal consent was obtained from patients when cardiologists explained the procedure. No individual datum was collected on patients, who remained anonymous to investigators. Patients were advised that data would be obtained from their attending invasive cardiologist during their procedure. Cardiologists were studied on 3 occasions when performing cardiac catheterization in the primary operator (autonomous) role (period 1), on 2 occasions in the secondary assistant (teacher) role with an experienced cardiac trainee (period 2), and on 2 occasions in the secondary assistant teacher role with an inexperienced trainee (period 3). Heart rate telemetry monitors were placed on cardiologists before they scrubbed and ECG, video, and audio signals were recorded during all procedures.

A baseline trait anxiety score was obtained from all cardiologists before initiation of the study. State anxiety, HR, respiratory rate, blood pressure, and salivary cortisol levels were obtained within 5 minutes before entering the procedure room and within 5 minutes of completing the procedure. Invasive cardiologists rated each procedure in terms of difficulty and patient criticality immediately after the case.

Figure 1



This figure depicts an interventional cardiologist performing a cardiac catheterization. The cardiologist is wearing a 3-electrode ECG telemetry unit. The transmitted signal of a lead II EGG tracing is detected by the receiver and the tracing is integrated with the videotape-recorded procedure.

Statistical analysis

Data were analyzed using descriptive statistics. Data are presented as the mean ± SD. Grouped differences in vital signs, salivary cortisol levels, and state anxiety before and after procedures were analyzed using a paired *t* test for those with a gaussian distribution and a signed-rank test for those with a non–gaussian distribution. When determining differences between periods 1, 2, and 3, using a paired *t* test, the threshold of statistical significance was set at $\alpha = .05$ and all tests were 2 sided. A Bonferroni adjustment was made for both 3 and 2 comparisons (comparing period 1 vs either period 2 or period 3). Differences in parameters comparing those obtained in the autonomous role versus those in the teaching role were made using a non–paired *t* test.

Results

Baseline data

The 9 male attending cardiologists had a mean age of 42 years (34-54 years) and an average of 11 years (2-25 years) of experience. All cardiologists were board certified and had a major commitment to the catheterization laboratory, as all performed more than 300 diagnostic procedures each year. The mean trait anxiety score was 37. The mean baseline cortisol level was 1.1 ± 1.2 μg/dL with a wide range (0.23-4.10 μg/dL).

Overall effect of the procedure

The mean difficulty score for the procedure as assessed by each interventional cardiologist was 2.3 ± 1.1 (1 = least difficult, 5 = most difficult). The mean criticality score of the patients was 1.8 ± 0.6 (1 = most stable, 5 = most critical). There were no significant changes in the cardiologists' vital signs of HR, blood pressure, or respiratory rate before versus after the procedure. There was no significant difference in the parameters of salivary cortisol levels or state anxiety comparing those before versus those after the procedure (Table I). A significant increase in salivary cortisol level (2.5× the baseline) occurred in only 7% of all cases.

Teaching role (loss of control) versus autonomous role (full control)

To determine if loss of control during the teaching role affected the psychophysiologic responses of attending cardiologists, the parameters were analyzed during the 3 periods (period 1 = autonomous function, period 2 =

Table I. Overall changes in psychophysiologic parameters of stress before and after a cardiac catheterization procedure

Parameter	Before	After	*P*
HR (beats/min)	73 ± 12	76 ± 15	NS
Salivary cortisol (μg/dL)	0.41 ± 0.27	0.45 ± 0.45	NS
State anxiety	34 ± 8.7	34 ± 9.2	NS

Table II. Changes in HR comparing period 1 (autonomous), period 2 (teaching experienced fellows), and period 3 (teaching inexperienced fellows)

Subject	Period 1	Period 2	Period 3
1	26.6	24.0	19.5
2	29.7	26.5	31.5
3	20.7	41.0	31.5
4	31.0	29.0	20.5
5	24.3	24.0	24.0
6	38.0	24.5	33.5
7	43.6	41.5	45.5
8	48.3	60.0	48.5
9	47.0	59.5	62.5
N	9	9	9
Mean ± SD	34.4 ± 10.2	36.7 ± 14.7	35.2 ± 14.3

Table III. State anxiety score and procedure duration comparing the autonomous role versus the teaching role during invasive procedures

	Autonomous role	Teaching role	*P*
State anxiety score	31.8 ± 6.8	35.7 ± 9.7	.05
Procedure duration (min)	17.2 ± 11.7 (6-55)	32.5 ± 33.0 (8-192)	.03

Table IV. Mean scores on the psychophysiologic parameters of less experienced cardiologists versus those of more experienced cardiologists

	Less experienced cardiologists	More experienced cardiologists	*P*
Trait anxiety score	38.4	34.7	<.01
Salivary cortisol (μg/dL)	0.51	0.33	<.01
Change in HR during procedure (beats/min)	50.1	27.4	<.01

teaching role with experienced trainee, and period 3 = teaching role with inexperienced trainee). There were no significant differences in the change in vital signs, state anxiety, or salivary cortisol before and after procedures during the 3 periods. There were no significant differences in the cardiologists' rating of the technical difficulty of the procedures or of the patients' conditions between the 3 periods, although there was a trend toward more technically difficult procedures (period 1 = 2.6 ± 1.0, period 2 = 2.3 ± 1.1, period 3 = 2.2 ± .6) and more critically ill patients (period 1 = 2.1 ± 1.1, period 2 = 1.8 ± 1.0, period 3 = 1.5 ± .7) in the autonomous mode (period 1).

The maximum change in HR during procedures is shown for the 3 periods (Table II). There was no significant overall difference in the change in HR when examining all subjects during the 3 periods. The difference in the change in HR was −2.3 ± 10.3 beats/min (comparing period 1 with period 2), −0.9 ± 8.2 beats/min (comparing period 1 with period 3), and 1.4 ± 7.3 beats/min (comparing period 2 with period 3); none of these differences were statistically significant. The heart rhythm was sinus rhythm throughout all the procedures for all subjects. There were no episodes of ventricular tachycardia, supraventricular tachycardia, or frequent premature beats (defined as 6 beats/min).

The baseline state anxiety score was significantly higher when in the teaching role versus when in the autonomous role (35.7 ± 9.7 vs 31.8 ± 6.8, $P = .05$). This was associated with a longer procedure time when in the teaching role versus when in the autonomous role (32.5 ± 33 minutes vs 17.2 ± 11.7 minutes, $P = .03$) (Table III).

Effect of experience of the interventional cardiologist

There were 6 cardiologists who had been attending invasive cardiologists for >5 years. The other 3 invasive cardiologists had completed their training <5 years before the study. When comparing the more experienced cardiologists with the less experienced cardiologists, there were baseline differences in trait anxiety scores and salivary cortisol levels (Table IV). The less experienced cardiologists had a significantly higher trait anxiety score (38.4 vs 31.7, $P = .001$) and a higher baseline salivary cortisol level (0.51 vs 0.33, $P = .01$) compared with the more experienced cardiologists. There was a higher change in HR during a procedure in less experienced cardiologists compared with the more experienced cardiologists (50.1 vs 27.4 beats/min, $P < .001$).

Discussion

Invasive cardiologists are in a profession where they are exposed to a high degree of stress for long periods.[1-11] The hours in a typical catheterization laboratory are unpredictable because emergency procedures occur at any time of the day or night. Most laboratories are high volume and, even with elective cases, the hours spent directly in procedures or combined with clinical practice are frequently more

than would be expected in other medical specialties. Although routine procedural protocols usually result in a good outcome, major life-threatening complications may occur unexpectedly and without warning. There is the constant expectation of skillful execution of complex psychomotor skills combined with an astute decision-making thought process.[7,12,21-23]

A prolonged state of high arousal is common to both invasive cardiologists and surgeons. High levels of serum cortisol have been documented in some surgeons during procedures, providing objective evidence of a high arousal state,[2-10] which may have long-term detrimental effects. For example, Swedish surgeons have a 2:1 greater risk of dying from ischemic heart disease than general practitioners.[8] These surgeons experienced greater mental strain, worked more hours at a faster tempo, and were less able to relax than general practitioners.[8] Prior studies of the HR response of invasive cardiologists during catheterization have shown significant individual variation in mean HR[11] and have suggested that some invasive cardiologists may be at risk for the negative effects of prolonged arousal, which accumulate as a consequence of daily exposure.[10,11,14] It is thus important to determine the factors that influence the degree of stress that invasive cardiologists may experience in their practice. Because stress is defined as a substantial imbalance between environmental demand and response capability,[12] a stressful occupational environment (when demands are high and the ability to control the situation is low)[2,10,13] may occur when teaching cardiac trainees to perform invasive procedures. Trainees must have a hands-on experience while learning to perform a procedure, but the attending cardiologist is still responsible for patient safety. This loss of control may be particularly difficult for invasive cardiologists, who are sometimes described as having a surgical personality (competitive, independent, dominant, and with a need for power).[1,2,5,6,8-11]

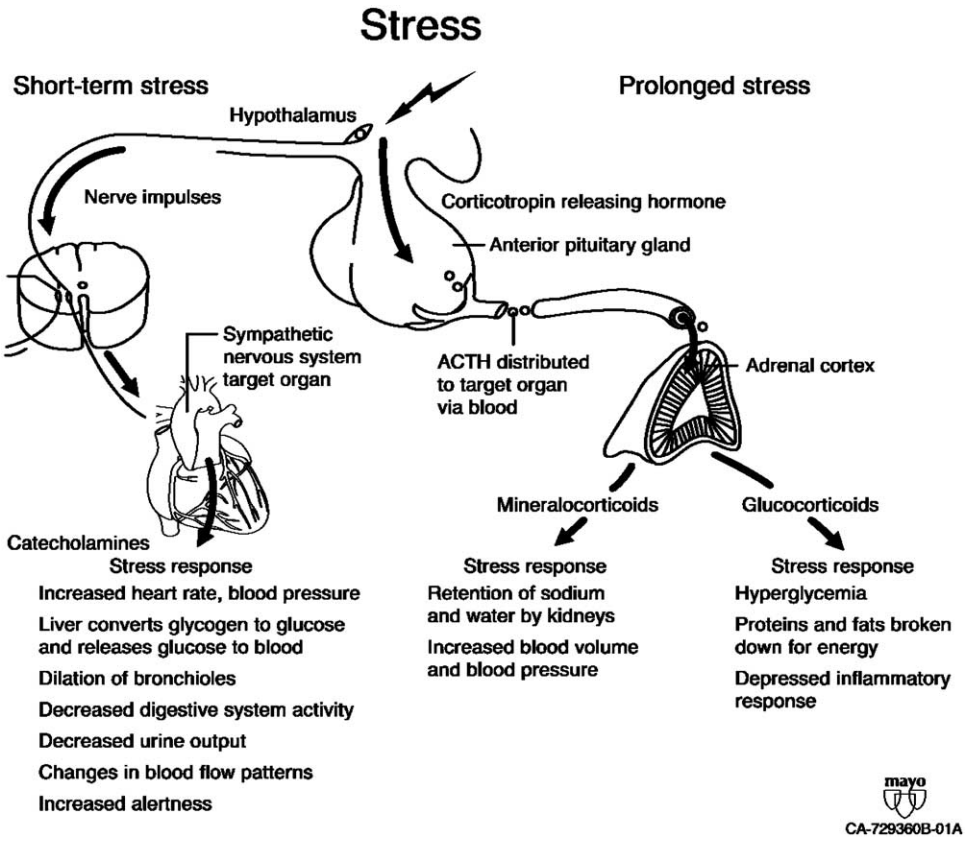
The results of this study did not show an overall difference in the measured parameters of physiologic arousal to stress between the periods when there was full control (autonomous role) and when there was no control (teaching role). The physiologic response to stress was measured by recording HR (the response to epinephrine secreted via the sympathoadrenal medullary axis) and cortisol levels (a response of stimulation of the hypothalamus-pituitary adrenal cortical axis) (Figure 2). There was no significant difference in the HR, blood pressure, or salivary cortisol levels before and after procedures comparing the periods in the autonomous role and in the teaching role. However, despite the trend toward a perception of a more technically difficult procedure while in the autonomous role, there was a higher state anxiety level when in the teaching role versus when in the autonomous role, indicating a subjective feeling of increased stress for the invasive cardiologists. There was also a significantly longer procedure time when cardiologists were in the teaching role versus when in the autonomous role, which may further have increased the perception of being in a stressful situation.

The lack of objective physiologic findings overall, as a measure of stress, could be related to the level of complexity and difficulty of the procedures studied. In this current investigation, to limit the confounding effect of procedure difficulty, only diagnostic coronary angiographic procedures were studied, which may account for the lack of overall difference in measured parameters between the autonomous and loss of control situations. The cardiologists assigned a low score for both the technical difficulty of these procedures as well as the criticality of these patients. More significant differences in the measured parameters between these 2 situations might have emerged if difficult interventional procedures were studied with more critically ill patients.

In this study, there were significant differences in the baseline measures of stress in the less experienced attending cardiologists (out of training <5 years) compared with the more experienced cardiologists (out of training >5 years). Less experienced cardiologists tended to have higher baseline cortisol levels, anxiety scores, and HRs. Dienstbier,[24,25] after reviewing stress and physiologic response in animals and human beings, concluded that an organism's response to repeated stress can be adaptation. Whether less experienced cardiologists adapt when exposed to continually high levels of stress as a function of experience is unclear from the current study.

Another unanswered question is whether day-to-day exposure to stress is good or bad. Stress (depicted as a noun, an adjective, and/or a verb) is complex and has positive (eustress) and negative (distress) effects.[12,14,21,26-32] It is not clear whether high arousal negatively or positively affects performance in the cardiac catheterization laboratory. For example, high state anxiety predicted a poorer endotracheal suctioning performance in critical care nurses compared with the performance of less anxious colleagues.[14] Conversely, studies on ice hockey goalies showed that, in some goalies, fast HR was associated with an optimal performance.[14,26] Heightened awareness may be necessary to address the need for intermittent urgent intervention with complex psychomotor skills that have life or death consequences.[14,12,26] However, high levels of prolonged arousal have been shown to negatively affect visual spatial organizing ability or other characteristics predictive of surgical proficiency.[23,30] It will be important to study the relationship between indices of high arousal and adaptation or the acquired resiliency[24,25] that may accompany repeated performance of both the autonomous and the teaching protocols used in catheterization procedures.

Figure 2



This figure depicts the stress stimulus and its effect on both the sympathoadrenomedullary axis and the hypothalamus-pituitary adrenal cortical axis.

A major limitation in this study is the small number of cardiologists (N = 9) studied. The sample size was determined by the number of invasive cardiologists available to participate from any single academic catheterization laboratory. In such a small sample, a type II statistical error may occur in which a true difference is not identified. The stratification of groups by years of experience was a retrospective analysis and thus the results of increased psychophysiologic stress in younger cardiologists will need to be confirmed in larger prospective studies. The lower rating for technical difficulty of diagnostic angiography, especially in stable patients, may have masked hypothesized differences between the effect of an autonomous mode versus that of a teaching mode. This lack of differences precluded analysis of the effect of underlying psychological profiles on the ability to adapt to stressful situations. The assessment of the difficulty of the procedure was subjective and the Likert scale used was not previously validated. There was no objective documentation of the difficulty of the procedure, such as the number of catheter changes or specific analysis of the tortuosity of the great vessels or anatomic variations of the coronary ostia. The effect of video recording the procedure itself was not analyzed because it was done on all procedures, but this recording may have enhanced the stress response of the cardiologists and should be an area for future study.

This study is the first to examine the psychological and physiologic responses of interventional cardiologists in an autonomous and a teaching role. There were no differences overall in the objective biologic stress response in the control and lack of control roles. However, the most perceived stressful situations occurred when cardiologists were supervising trainees. This preliminary study also showed that invasive cardiologists, recently out of training, may be under more stress than more experienced invasive cardiologists. The emphasis of most clinical research has been on the effect of invasive procedures on patients, not on health

care providers. Nevertheless, we believe that it is also important to identify the psychophysiologic cost to those performing invasive procedures, such as interventional cardiologists.[7] Understanding the factors that contribute to prolonged stressful environments will lead to identification of interventions that will decrease the degree of stress and anxiety. This line of inquiry is important not only to the health of cardiologists performing procedures but also to the patients on whom the procedures are being performed.

References

1. Green A, Duthie HL, Young HL, et al. Stress in surgeons. Br J Surg 1990;77:1154-8.
2. Payne RL, Rick JT, Smith GH, et al. Multiple indicators of stress in an 'active' job—cardiothoracic surgery. J Occup Med 1984;26: 805-8.
3. Payne RL, Rick JT. Heart rate as an indicator of stress in surgeons and anesthetists. J Psychosom Res 1986;30:411-20.
4. Bunch WH, Dvonch VM, Storr CL, et al. The stresses of the surgical residency. J Surg Res 1992;53:268-71.
5. Ramirez AJ, Graham J, Richards MA, et al. Mental health of hospital consultants: the effects of stress and satisfaction at work. Lancet 1996;347:724-8.
6. Schwartz RW, Barclay JR, Harrell PL, et al. Defining the surgical personality: a preliminary study. Surgery 1994;115:62-8.
7. Beller GA. Presidents' page: cardiologist under stress: the response of the American College of Cardiology. J Am Coll Cardiol 2001;37:1155-7.
8. Arnetz BB, Andreasson S, Strandberg M, et al. Comparison between surgeons and general practitioners with respect to cardiovascular and psychosocial risk factors among physicians. Scand J Work Environ Health 1988;20:118-24.
9. Johnson JT, Wagner RL, Rueger RM, et al. Professional burnout among head and neck surgeons: results of a survey. Head Neck 1993;15:557-60.
10. Robert G, Hockey J, Payne RL, et al. Intra-individual patterns of hormonal and affective adaptation to work demands: an n = 2 study of junior doctors. Biol Psychol 1996;42:393-411.
11. Peters R, Chadda KD. Changes in cardiac rate and rhythm in physicians performing cardiac catheterization. Catheter Cardio Diagn 1983;9:533-5.
12. Gould D. Intensive sport participation and the prepubescent athlete: competitive stress and burnout. In: Cahill BR, Pearl AJ, editors. Intensive participation in children's sports: American Orthopedic Society for Sports Medicine. Champagne (Ill): Human Kinetics; 1993. p. 19-38.
13. Theorell T. Fighting for and losing or gaining control of life. Acta Physiol 1997;640:107-11.
14. Smith AM, Ortiguera SA, Laskowski ER, et al. A preliminary analysis of psychophysiological variables and nursing performance in situations of increasing criticality. Mayo Clin Proc 2001;76: 275-84.
15. Speilberger CD, Gorush RL, Lushene RE, et al. Manual for the State-Anxiety Inventory STAI (Form Y). Palo Alto (Calif): Consulting Psychological Press; 1983.
16. Kakimoto Y, Nakamura A, Tauri H, et al. Crew workload in JASDFC-1 transport flights: change in heart rate and salivary cortisol. Aviat Space Environ Med 1988;59:511-6.
17. Kirschbaum C, Klauer T, Filipp SH, et al. Sex-specific effects of social support on cortisol and subjective responses to acute psychological stress. Psychosom Med 1994;57:23-31.
18. Kirschbaum C, Schommer N, Federenko I, et al. Short term estradiol treatment enhances pituitary-adrenal axis and sympathetic responses to psychosocial stress in healthy young men. J Clin Endocrinol Metab 1996;81:3639-43.
19. O'Connor PH, Morgan WP, Raglin JS, et al. Mood state and salivary cortisol levels following over-training in female swimmers. Psychoneuroendocrinology 1989;14:303-10.
20. Forsham PH, Melmon KL. The adrenal: Part I. The adrenal cortex. In: Williams RH, editor. Textbook of endocrinology. Philadelphia (Pa): WB Saunders Co; 1968. p. 294-309.
21. Landers DM, Arent SM. Arousal-performance relationships. Appl Sport Psychol 14:206-28.
22. Gould D, Krane V. The arousal athletic performance relationship: current status and future directions. In: Horn TS, editor. Advances in sport psychology. Champaign (Ill): Human Kinetics Publishers; 1992. p. 119-41.
23. Schueneman AL, Pickleman J, Hesslein R, et al. Neuropsychologic predictors of operative skill among general surgery residents. Surgery 1984;96:288-95.
24. Dienstbier RA. Arousal and physiological toughness: implications for mental and physical health. Psychol Rev 1989;96:84-100.
25. Dienstbier RA. Behavioral correlates of sympathoadrenal reactivity: the toughness model. Med Sci Sport Exerc 1991;23:846-52.
26. Smith AM, Sim FH, Smith HC, et al. Psychologic, situational and physiologic variables and on-ice performance of youth hockey goalkeepers. Mayo Clin Proc 1998;73:17-27.
27. Smith AM, Stuart MJ, Fish KN. Psychological, physiological and performance variables in goalies during hockey games. In: Ashare AB, editor. Safety in ice hockey. West Conshohocken (Pa): American Society Testing Materials; 2000. p. 220-35.
28. Smith AM, Finnie SB, Stuart MJ, et al. Psychophysiologic factors and performance in ice hockey goalies during competition. In: Pearsall D, Ashare AB, editors. Safety in ice hockey, vol. 4. STP 1446 West Conshohocken (Pa): American Society Testing Materials; 2004. p. 244-64.
29. Colgan DB, Smith AM, Hartman AD, et al. A psychophysiological view of figure skating: the mind-body connection. Prof Fig Skat Mag 2000;34-7.
30. Issenberg SB, McGaghie WC, Hart LR, et al. Simulation technology for health care professional skills training and assessment. JAMA 1999;282:861-6.
31. Smith AM, Adler CH, Crews D, et al. The "yips" in golf: a continuum between a focal dystonia and choking. Sports Med 2003;13-31.
32. Detling NJ, Smith AM, Heil J, et al. A psychophysiological view of fencing: the mind-body connection. American Fencing 1999;17-8.