Resident Stress Level during Steps of Cataract Surgery

Aditya Rali, MD[1,2] Jerry Fontus, BS[3] Laura Ward, MSPH[1] Maria Aaron, MD[1,2] Jeremy Jones, MD[1,2] Elliot Moore, PhD[3] Yousuf M. Khalifa, MD[1,2]

[1] Department of Ophthalmology, Emory University School of Medicine, Atlanta, Georgia
[2] Department of Ophthalmology, Grady Memorial Hospital, Atlanta, Georgia
[3] School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia

Address for correspondence Yousuf M. Khalifa, MD, Grady Eye Clinic, 80 Jesse Hill Jr Drive SE, Atlanta, GA 30303 (e-mail: yousuf.khalifa@emoryhealthcare.org).

J Acad Ophthalmol 2018;10:e179–e184.

Abstract

Purpose To investigate intraoperative stress levels using heart rate monitoring during each step of cataract surgery.

Setting Single tertiary hospital.

Design Observational study recording resident heart rate as a measure of acute stress level during cataract surgeries.

Methods Emory ophthalmology postgraduate year (PGY) 3 and PGY-4 residents operating at Grady Memorial Hospital during the time period of the study were eligible to participate. Chest-strapped Bluetooth devices recorded heart rate during the surgeries. The mean, maximum, and minimum heart rates were then analyzed individually for the following steps of surgery: incisions, continuous curvilinear capsulorhexis, hydrodissection, nucleus disassembly, quadrant removal, cortical cleanup, intraocular lens insertion, and closure. Data collection started in April 2017 and ended in February 2018.

Results Out of the 549 surgeries recorded, 427 yielded viable data. Across that dataset, quadrant removal had the highest adjusted mean heart rate value (90.3; 95% confidence interval [CI]: 82.9–97.7; $p < 0.0001$), highest adjusted maximum heart rate value (97.3; 95% CI: 89.5–105.3; $p < 0.0001$), and highest adjusted minimum heart rate value (82.1; 95% CI: 75.2–89; $p < 0.0001$). Nuclear disassembly and incisions were second and third highest, respectively.

Conclusions Quadrant removal, nucleus disassembly, and incisions are the three most stressful steps for resident surgeons. This knowledge should be applied to enhance the resident experience by emphasizing these steps during surgical preparation and training. Future studies using intraoperative heart rate monitoring may be warranted to better understand the resident and attending experience and ultimately improve surgical outcomes.

Keywords
- cataract
- training
- residents
- residency
- stress
- heart rate
- steps

Stress level monitoring, while only sparingly used within surgical training, has previously been used in other professions such as aviation, military, and athletics that also require high-intensity training.[1–7] While a certain degree of stress can assist in task performance, psychological evidence from professionals working within a variety of high-stress fields such as aviation and military suggests that excessive levels can have a detrimental effect on performance.[8,9] Stress has been shown to potentially impair technical skills, vigilance, memory, and other cognitive processes.[8,10] These effects are of great significance

received
September 3, 2018
accepted after revision
October 12, 2018

DOI https://doi.org/10.1055/s-0038-1676043.
ISSN 2475-4757.

when considering how they may negatively affect surgeon performance and thereby have an effect on patient safety.

Stress during surgical training can result from learning new techniques and mastering the nuances of surgery, conducting complex procedures, and working under a time crunch.[11,12] While the degree of participation of a resident surgeon may not always be well-defined, cataract surgery is one area where the resident must frequently have a significant lead role as required by the Accreditation Council for Graduate Medical Education (ACGME). The ACGME requires each resident to perform a minimum of 86 cataract surgeries as the primary surgeon, with many programs performing a higher number.[13–17] When performing cataract surgery as the primary surgeon, the resident sits at the main scope, while the attending sits at the side scope. This positioning ensures that the resident performs the surgery with limited, if any, direct surgical input from the attending. The attending provides guidance and usually provides surgical intervention only when deemed necessary.

Although managing stress has a clear role in optimizing surgical outcomes, few studies have closely evaluated intraoperative stress in relation to events in the surgery itself.[1–3] Cataract surgery offers a unique and exciting opportunity to study intraoperative stress for several reasons: these surgeries are typically of shorter duration, can be divided into fixed steps of surgery, are more frequently recorded given the standard use of microscopes, and have a high minimum number required to meet ACGME requirements.[17,18] As such, it is feasible to monitor events during the surgery and simultaneously track their effects on the trainee stress levels over many cases. It is important to make note that stress may not always have a detrimental effect on surgical performances. Certain studies have shown that moderate levels of stress could lead to improvements in performance and selective attention.[19,20] While the delineation between productive stress levels and detrimental stress levels requires further study, stress certainly plays a role in the operating room, and a better understanding of the resident experience could be useful in improving surgical training. For instance, measuring stress levels over the course of training may provide insight on the minimum number of cases necessary before a resident begins to feel comfortable with each step of cataract surgery and may even help determine the delineation between productive and detrimental levels of stress. Since surgical complications during cataract surgery often occur without advance notice, monitoring stress levels could provide cues for intraoperative intervention by the attending physician. Improving the resident experience would not only facilitate better teaching but could also pave the way for improved surgical outcomes in resident-performed cataract surgeries.

This study sought to monitor resident stress levels during surgery in relation to different steps of the cataract surgery: incisions, continuous curvilinear capsulorrhexis, hydrodissection, nucleus disassembly, quadrant removal, cortical cleanup, intraocular lens (IOL) insertion, and closure. Stress levels were quantified using heart rate (HR), which has been previously used as a reliable marker for stress.[1,2]

Design and Methods

The resident HR is measured through a Beets BLU chest-strapped Bluetooth device (►**Fig. 1**). The Bluetooth device is linked to an iPod application specifically designed for this study to simultaneously collect HR and audio during surgery. The iPod application creates timestamps for the audio and HR recordings so that they can be properly aligned with various steps during surgery. A SHURE MV88 iOS digital stereo condenser microphone was placed below the microscope oculars for audio recording and connected through a USB cable to an Apple iPod Touch placed on the arm of the machine, as shown in ►**Fig. 1**. The USB cable is kept firmly against the body of the microscope using adhesive tape. Furthermore, video recording is obtained for each procedure. The audio and video components are synchronized using the audiovisual cue of "incision" as the paracentesis incision is made, which is synchronized with the video of the paracentesis incision. The video is then divided down into the stages of cataracts as follows: incisions,

Fig. 1 Beets BLU chest-strapped Bluetooth devices (left) and the setup showing placement of microphone and Ipod device on the microscope (right).

continuous curvilinear capsulorhexis, hydrodissection, nucleus disassembly, quadrant removal, cortical cleanup, IOL insertion, and closure. Each step then has its corresponding audio, video, and HR data available for analysis.

Emory ophthalmology residents who operated at Grady Memorial Hospital during the course of the study from April 2017 to February 2018 were eligible to participate in the study. All participants provided written informed consent after being informed of the purpose of the study and the associated risks and benefits. No personal health information was collected from the patients. The research protocol and informed consent were approved by the Emory University Institutional Review Board.

Statistical Methods

HR data were collected continuously during the surgery. For each surgery, the minimum, maximum, and mean HRs were calculated for each stage. For each of these measures, a repeated measure analysis of the outcome was performed with a means model, calculating the adjusted means and confidence intervals at each stage of surgery, over the course of the entire surgery. A compound–symmetric variance–covariance form was assumed and used to control for the correlation that inherently exists in the data since the HR measures were taken on the same resident, both over time in a single surgery and across time in multiple surgeries. All missing data were assumed to be missing at random, and *t*-tests were used to compare differences over time. The mean HR data were considered the primary model for analysis. The minimum and maximum HRs were also examined as secondary outcomes, each in a separate mixed means model. For all three outcomes, unadjusted means and confidence intervals were also calculated for comparison purposes. These unadjusted measures did not control for the correlation across time or within each resident. An α of 0.05 was used for all statistical tests, and SAS 9.4 (SAS Institute Inc.) was used to complete the analyses.

Results

Thirteen residents, seven postgraduate year (PGY) 3 and six PGY-4, were enrolled in the study. A total of 549 surgeries were recorded over a 10-month period starting on April 4, 2017, and ending on February 28, 2018, during which all cataract surgeries performed at Grady Memorial Hospital were recorded. Out of the 549 surgeries recorded, 427 (77.8% of the total surgeries) yielded viable data. Reasons for data dropout included forgetting to press record on the audio or video recording devices, improperly placed HR chest straps, physical movement such as standing up or walking, and malfunctioning of iPod application software.

The mean, minimum, and maximum HR values were analyzed for each step of surgery described earlier. There was a statistically significant difference between the mean HRs for the stages ($p < 0.0001$). Quadrant removal had the highest adjusted mean HR of 90.3 (95% confidence interval [CI]: 82.9, 97.7) beats per minute followed by nucleus disassembly at 89.1 (82, 97.7) beats per minute and incisions at 88.5 (80.7, 96.2) beats per minute (►**Fig. 2**). The average maximum HR showed a similar trend with quadrant removal yielding the highest value at 97.3 (89.5, 105.3) beats per minute followed by incisions at 97 (88.4, 105.5) beats per minute and nucleus disassembly at 96.8 (89.2–104.5) beats per minute (►**Fig. 3**). The average minimum HR data still has quadrant removal highest at 82.1 (75.2, 89) beats per minute, whereas nucleus disassembly at 81.4 (74, 88.8) beats per minute and hydrodissection at 81 (74.1, 88) followed (►**Fig. 4**). ►**Table 1** demonstrates the comprehensive findings for all the steps.

Discussion

Measuring a resident's stress is difficult. Real-time questionnaires, which are often used to assess stress perception, are not feasible during surgical procedures.[12,16] Cortisol monitoring, which is another method of measuring acute stress,

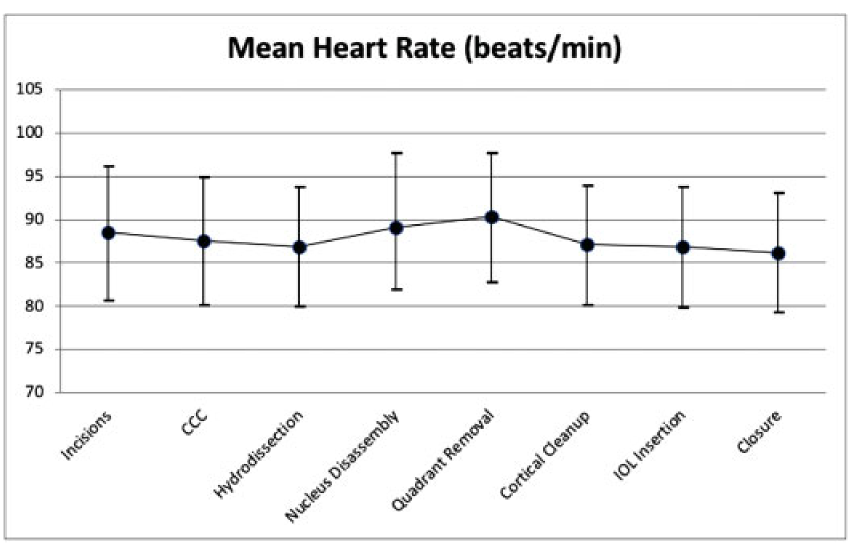

Fig. 2 Average values for mean heart rate during each step of cataract surgery. CCC, continuous curvilinear capsulorhexis; IOL, intraocular lens.

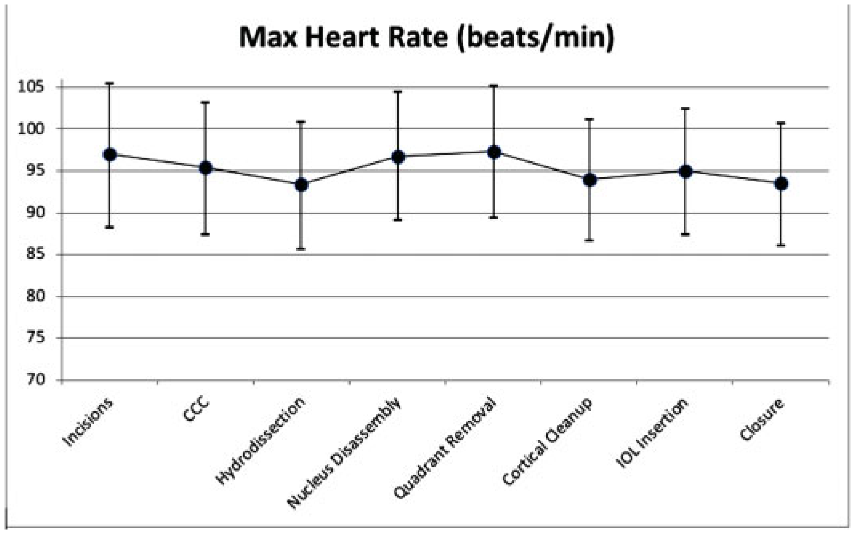

Fig. 3 Average values for minimum heart rate during each step of cataract surgery. CCC, continuous curvilinear capsulorhexis; IOL, intraocular lens.

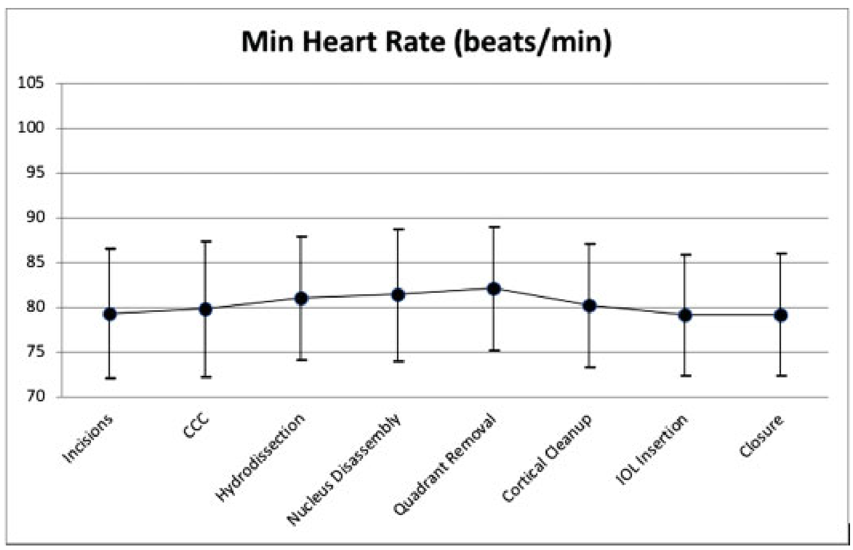

Fig. 4 Average values for maximum heart rate during each step of cataract surgery. CCC, continuous curvilinear capsulorhexis; IOL, intraocular lens.

is also not practical given the need to monitor stress continuously throughout the procedures.[3] What is more practical, however, is measuring the resident's HR during a procedure. There is little doubt that acute stress leads to physiological effects on the cardiovascular system. Among the numerous cardiovascular parameters investigated, HR increases have been consistently reproducible in response to acutely stressful events.[21–23] While the degree of HR reactivity may depend on several factors unique to each individual, the presence of this reactivity has been uniform across several studies.[21–23] Since HR increases are related to increased stress, HR measurements are an excellent surrogate in assessing the resident's stress.[1–3,24] While HRs have been used previously to study stress during surgeries, as done by Becker et al and Arora et al for general, orthopaedic, and cardiac surgeries, previous studies have not measured stress continuously in real time as a function of actual events during the operation, as we have done here.[1,3]

The primary criticism for using HR as a measure for stress levels has been that physical exertion or movement also can affect HR.[3] In this study, however, that effect is minimal considering that cataract surgery is performed while in a stable, seated position. Any significant movement by the resident, such as standing, was noted and accounted for by omission in the final analysis. A limitation of the study was that while 13 PGY-3 and PGY-4 residents took part in the study, the six PGY-4 residents, who operated most frequently, make up a large portion of the dataset. Statistically, this was controlled for with mixed means models to ensure that the data were not inappropriately skewed by the large proportion of the total surgeries performed by certain residents. Furthermore, we did not note consumption of stimulants such as caffeine and cardiovascular modulators such as β-blockers, which could potentially have had an effect on intraoperative HR. While it is possible that these agents may have affected all the steps of surgery evenly, it is also quite possible that depending on the

Table 1 Adjusted and unadjusted means for mean, maximum, and minimum HRs along with the corresponding CIs

	Adjusted mean for mean HR (95% CI)	Adjusted mean for max HR (95% CI)	Adjusted mean for min HR (95% CI)	Unadjusted mean for mean HR (95% CI)	Unadjusted mean for max HR (95% CI)	Unadjusted mean for min HR (95% CI)
Incisions	88.5 (80.7, 96.2)	97 (88.4, 105.5)	79.3 (72.1, 86.6)	94.6 (93, 96.1)	102.6 (100.9, 104.4)	86.4 (85, 87.8)
CCC	87.6 (80.2, 95)	95.4 (87.5, 103.3)	79.9 (72.3, 87.4)	93.7 (92.2, 95.3)	101.1 (99.3, 102.8)	86.9 (85.4, 88.4)
Hydrodissection	86.9 (80.1, 93.8)	93.4 (85.8, 100.9)	81 (74.1, 88)	93 (91.6, 94.5)	99 (97.4, 100.6)	88.1 (86.6, 89.5)
Nucleus disassembly	89.1 (82, 97.7)	96.8 (89.2, 104.5)	81.4 (74, 88.8)	95.2 (93.8, 96.7)	102.5 (100.8, 104.1)	88.4 (86.9, 89.9)
Quadrant removal	90.3 (82.9, 97.7)	97.3 (89.5, 105.3)	82.1 (75.2, 89)	96.4 (94.9, 97.9)	103 (101.4, 104.6)	89.2 (87.7, 90.6)
Cortical cleanup	87.1 (80.2, 94)	94 (86.8, 101.2)	80.3 (73.3, 87.2)	93.2 (91.8, 94.6)	99.6 (98.1, 101.1)	87.3 (86, 88.6)
IOL insertion	86.9 (79.9, 93.8)	95 (87.5, 102.6)	79.2 (72.4, 85.9)	93 (91.6, 94.4)	100.7 (99.2, 102.2)	86.3 (85, 87.5)
Closure	86.2 (79.4, 93.1)	93.5 (86.1, 100.8)	79.2 (72.4, 86)	92.3 (91, 93.6)	99.1 (97.6, 100.5)	86.2 (85, 87.5)

Abbreviations: CCC, continuous curvilinear capsulorhexis; CI, confidence interval; HR, heart rate; IOL, intraocular lens.

particular agent and time of administration, they may have affected the different steps unevenly. As such, data collection in future studies should record use of stimulants and cardiovascular modulators. Another limitation is that the study did not have a control group such as a group of experienced attendings operating with minimal stress. Having such a group in future studies would provide context and help more thoroughly interpret resident stress levels.

Based on our results, quadrant removal, nucleus disassembly, and incisions represent, in that order, the three most stressful steps of cataract surgery for the resident surgeon. Our results were not surprising as these particular steps are often when surgical complications such as posterior capsular rupture may occur (quadrant removal and nucleus disassembly) or, in the case of incisions, when the resident may be experiencing the most nervousness before settling into the surgery. With this knowledge, it follows that these particular steps may require increased attention as the resident surgeon prepares for the challenges of cataract surgery. This preparation may come in the form of supplementary effort in a controlled environment such as the wet laboratory or additional attending guidance during the cataract surgery itself.

Additionally, this study paves the way for further research using intraoperative HR monitoring to improve resident training and surgical outcomes. While the cataract surgeries performed during this period did not result in enough complications to draw conclusions regarding the effect of HR fluctuations on complication rate, a more longitudinal examination may shed light on this relationship. Multiple studies have commented on the resident surgeon cataract learning curve using measures such as phacoemulsification times, complication rates, postoperative visual acuity, and completion rate.[13,25] The method of intraoperative HR monitoring we describe here could provide another objective way to track the resident learning curve. Such a study could help us better understand the number of cases required for residents to feel more comfortable and confident performing cataract surgery. In turn, this knowledge could contribute to the important discussion of determining the ideal number of resident-performed cataract surgeries during training and ultimately establishing the minimum number of cases to demonstrate competence in phacoemulsification.

In addition to the resident learning curve, intraoperative HR monitoring could also be a useful aid in better understanding the attending learning curve. Puri et al found significant differences between a novice and an experienced attending's complication rates when they did a retrospective analysis of resident-performed cataract surgeries.[26] Since the complication rates were higher with the novice attending, they concluded that surgical programs should aim to reinforce areas for improvement to create top surgical educators.[26] Intraoperative stress monitoring could provide an objective manner in which to identify areas where more junior attendings may feel less confident. Perhaps, these areas are not true weaknesses in the attending's technical skills but rather a reflection of the resident's anxiety affecting the attending surgeon's confidence in surgical decision-making. Simultaneous intraoperative HR monitoring of both the attending and resident during surgery could help elucidate the relationship between attending and resident stress levels.

Conclusion

Overall, our data suggest that certain steps of cataract surgery are significantly more stressful for resident surgeons. Surgical training programs should devote additional time and resources in preparing residents for these steps. Whether it requires additional practice in the wet laboratory or more attending guidance in the operating room, an emphasis on these steps of cataract surgery will improve the resident experience, surgical training, and ultimately patient outcomes. Looking toward the future, the scope of intraoperative monitoring can be widely expanded to shed further light on the longitudinal stress levels of residents throughout the training program as well as the resident and attending experience and interaction during resident-performed cataract surgery.

Note
This paper was presented at the Association of University Professors of Ophthalmology's Educating the Educators meeting in Austin, Texas, in January 2018.

Conflict of Interest
None.

References

1 Becker WG, Ellis H, Goldsmith R, Kaye AM. Heart rates of surgeons in theatre. Ergonomics 1983;26(08):803–807
2 Payne RL, Rick JT. Heart rate as an indicator of stress in surgeons and anaesthetists. J Psychosom Res 1986;30(04):411–420
3 Arora S, Tierney T, Sevdalis N, et al. The Imperial Stress Assessment Tool (ISAT): a feasible, reliable and valid approach to measuring stress in the operating room. World J Surg 2010;34 (08):1756–1763
4 Sexton JB, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. BMJ 2000;320 (7237)745–749
5 Hammermeister J, Burton D. Stress, appraisal, and coping revisited: examining the antecedents of competitive state anxiety with endurance athletes. Sport Psychol 2001;15:66–90
6 Driskell JE, Salas E. Overcoming the effects of stress on military performance: human factors, training, and selection strategies. In: Gal R, Mangelsdorff A, eds. Handbook of Military Psychology. Oxford: John Wiley & Sons; 1991:183–193
7 Crocker PR, Alderman RB, Smith FM. Cognitive-affective stress management training with high performance youth volleyball players: effects on affect, cognition, and performance. J Sport Exerc Psychol 1988;10:448–460
8 Hassan I, Weyers P, Maschuw K, et al. Negative stress-coping strategies among novices in surgery correlate with poor virtual laparoscopic performance. Br J Surg 2006;93(12):1554–1559
9 Flin R, O'Connor P, Crichton M. Safety at the Sharp End: A Guide to Non-Technical Skills. Aldershot: Ashgate; 2008
10 Klein G. The effects of acute stress on decision making. In: Driskell JE, Salas E, eds. Stress and Human Performance. Mahwah, NJ: Erlbaum; 1996
11 Arora S, Sevdalis N, Nestel D, Tierney T, Woloshynowych M, Kneebone R. Managing intraoperative stress: what do surgeons want from a crisis training program? Am J Surg 2009;197(04):537–543
12 Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. Am J Surg 2006;191(01):5–10
13 Randleman JB, Wolfe JD, Woodward M, Lynn MJ, Cherwek DH, Srivastava SK. The resident surgeon phacoemulsification learning curve. Arch Ophthalmol 2007;125(09):1215–1219
14 Rutar T, Porco TC, Naseri A. Risk factors for intraoperative complications in resident-performed phacoemulsification surgery. Ophthalmology 2009;116(03):431–436
15 Quillen DA, Phipps SJ. Visual outcomes and incidence of vitreous loss for residents performing phacoemulsification without prior planned extracapsular cataract extraction experience. Am J Ophthalmol 2003;135(05):732–733
16 Prakash G, Jhanji V, Sharma N, Gupta K, Titiyal JS, Vajpayee RB. Assessment of perceived difficulties by residents in performing routine steps in phacoemulsification surgery and in managing complications. Can J Ophthalmol 2009;44(03):284–287
17 Review Committee for Ophthalmology. ACGME (2013). Required Minimum Number of Procedures for Graduate Residents in Ophthalmology. Available at: www.acgme.org/Portals/0/PFAssets/ProgramResources/240_Oph_Minimum_Numbers.pdf. Accessed July 14, 2018
18 Stephenson M. Advancements in Surgical Microscopes. Review of Ophthalmology [Published May 5, 2015]. Available at: https://www.reviewofophthalmology.com/article/advancements-in-surgical-microscopes. Accessed July 20, 2018
19 LeBlanc V, Woodrow SI, Sidhu R, Dubrowski A. Examination stress leads to improvements on fundamental technical skills for surgery. Am J Surg 2008;196(01):114–119
20 Chajut E, Algom D. Selective attention improves under stress: implications for theories of social cognition. J Pers Soc Psychol 2003;85(02):231–248
21 de Geus EJ, van Doornen LJ, de Visser DC, Orlebeke JF. Existing and training induced differences in aerobic fitness: their relationship to physiological response patterns during different types of stress. Psychophysiology 1990;27(04):457–478
22 Boutcher SH, Stocker D. Cardiovascular response of young and older males to mental challenge. J Gerontol B Psychol Sci Soc Sci 1996;51(05):261–267
23 Uchino BN, Birmingham W, Berg CA. Are older adults less or more physiologically reactive? A meta-analysis of age-related differences in cardiovascular reactivity to laboratory tasks. J Gerontol B Psychol Sci Soc Sci 2010;65B(02):154–162
24 Huang CJ, Webb HE, Zourdos MC, Acevedo EO. Cardiovascular reactivity, stress, and physical activity. Front Physiol 2013;4:314
25 Lee JS, Hou CH, Yang ML, Kuo JZ, Lin KK. A different approach to assess resident phacoemulsification learning curve: analysis of both completion and complication rates. Eye (Lond) 2009;23(03):683–687
26 Puri S, Kiely AE, Wang J, Woodfield AS, Ramanathan S, Sikder S. Comparing resident cataract surgery outcomes under novice versus experienced attending supervision. Clin Ophthalmol 2015;9:1675–1681