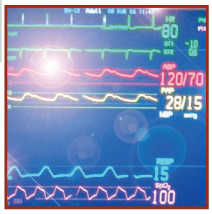

Describing Anisocoria in Neurocritically Ill Patients

By Ciji Saju, MSN, RN, CCRN, CNRN, Arianna Barnes, DNP, RN, ACCNS-AG, CCRN, PHN, Joji B. Kuramatsu, MD, Jade L. Marshall, BS, Hirofumi Obinata, MD, PhD, Ava M. Puccio, PhD, RN, Shoji Yokobori, MD, PhD, DaiWai M. Olson, PhD, RN; for the END-PANIC Investigators

Background Anisocoria (unequal pupil size) has been defined using cut points ranging from greater than 0.3 mm to greater than 2.0 mm for absolute difference in pupil size. This study explored different pupil diameter cut points for assessing anisocoria as measured by quantitative pupillometry before and after light stimulus.
Methods An exploratory descriptive study of international registry data was performed. The first observations in patients with paired left and right quantitative pupillometry measurements were included. Measurements of pupil size before and after stimulus with a fixed light source were used to calculate anisocoria.
Results The sample included 5769 patients (mean [SD] age, 57.5 [17.6] years; female sex, 2558 patients [51.5%]; White race, 3669 patients [75.5%]). Anisocoria defined as pupil size difference of greater than 0.5 mm was present in 1624 patients (28.2%) before light stimulus; 645 of these patients (39.7%) also had anisocoria after light stimulus ($P<.001$). Anisocoria defined as pupil size difference of greater than 2.0 mm was present in 79 patients (1.4%) before light stimulus; 42 of these patients (53.2%) also had anisocoria after light stimulus ($P<.001$).
Discussion The finding of anisocoria significantly differed before and after light stimulus and according to the cut point used. At most cut points, fewer than half of the patients who had anisocoria before light stimulus also had anisocoria after light stimulus.
Conclusion The profound difference in the number of patients adjudicated as having anisocoria using different cut points reinforces the need to develop a universal definition for anisocoria. (*American Journal of Critical Care.* 2023;32:402-409)

CE 1.0 Hour

This article has been designated for CE contact hour(s). See more CE information at the end of this article.

doi:https://doi.org/10.4037/ajcc2023558

Evaluation of the pupillary light reflex (PLR) is part of the standard neurologic assessment for patients with known or suspected intracranial pathology.[1] Quantitative pupillometry (QP) is expanding clinical science research on PLR beyond the assessment of neurocritically ill patients.[2-4] Anisocoria, the absolute difference in left and right pupil diameter (pupil size), has been suggested as an important clinical biomarker.[5,6] However, the definition of anisocoria is imprecise. Little evidence describes how QP can help define anisocoria and assess neurologically ill patients for anisocoria. Nurses, more than members of other professions, are tasked with frequent assessment of patients with neurologic injury.[7,8]

Anisocoria is a disorder characterized by unequal pupil size. The term *anisocoria* is a combination of Greek and Latin. The prefix *an-* ("without" or "not"), combined with *iso* ("equal"), *kore* ("doll" or "pupil"), and the Latin suffix *-ia*, forms the word *anisocoria* to indicate an abnormal condition.[9] Both historically and in current practice, clinicians have used differing definitions for anisocoria, with absolute difference in pupil size classified by cut points ranging from greater than 0.3 mm to greater than 2.0 mm.[5,10-13] Because anisocoria is pivotal to the diagnosis of specific neurologic conditions and has been linked to neurologic worsening and pharmacologic effects, providing clinicians with a deeper understanding of this clinical finding is vital.[14-18] Missing from the literature is a summary of absolute differences in pupil size in a large cohort of neurologically injured patients before and after pupillary light exposure.

The low reliability inherent in human estimation of pupil size and reactivity is not present with QP.[19,20] Whereas different light intensities may produce false-positive results,[21] QP provides a consistent light source and an objective measure of PLR components, including pupil size before and after light stimulus.[22] Using QP to measure pupil size increases the accuracy and consistency of pupil measurements between clinicians and may also increase the reliability of detecting anisocoria.[19,23] Differences in PLR between the right and left eye, particularly differences detectable only with QP, have significant clinical implications.[24,25]

Identifying PLR changes, including the presence of anisocoria, may aid in diagnosis and treatment of neurologic injury.[26] One study showed that nurses did not identify anisocoria in 50% of cases in which it was identified using QP.[26] Another study showed that anisocoria was more prevalent in patients under varied lighting conditions.[21] The nursing profession has increasingly adopted evidence-based practices.[27] Finding evidence often requires long-standing, traditional practices to be explored with a fresh perspective.[28-30] The primary aim of this study was to assess the frequency of anisocoria as measured by QP using different cut points for absolute difference in pupil size before and after exposure to a light stimulus. This information will aid in the development of future evidence-based guidelines.

Clinicians use different definitions for anisocoria.

Methods

This descriptive analysis used data from the Establishing Normative Data for Pupillometer Measurements in a Neuro-Intensive Care Unit (END-PANIC) registry.[19,31] The END-PANIC registry is ongoing and approved by the institutional review board at each site. The registry has enrolled more than 6000 patients admitted to neuroscience intensive care units at 1 hospital in Japan, 1 hospital in Germany, and 4 hospitals in the United States. To reduce repeated-measures bias, a separate analysis data set limited to the first observed PLR values for each patient was extracted from the END-PANIC registry. Inclusion criteria required that paired left and right QP values were obtained less than 5 minutes apart. Patients with a history of eye disease, such as cataract and glaucoma, were not excluded because these conditions do not influence Neurological Pupil index (NPi) values.[32,33]

About the Authors
Ciji Saju is an assistant nurse manager, University of Texas Southwestern Medical Center, Dallas, Texas. **Arianna Barnes** is a clinical nurse specialist at Barnes-Jewish Hospital, St Louis, Missouri. **Joji B. Kuramatsu** is a professor at University of Erlangen-Nuremberg, Erlangen, Germany. **Jade L. Marshall** is a clinical research associate, University of Texas Southwestern Medical Center. **Hirofumi Obinata** is a research associate at Nippon Medical School, Tokyo, Japan. **Ava M. Puccio** is an associate professor at University of Pittsburgh, Pennsylvania. **Shoji Yokobori** is a professor at Nippon Medical School. **DaiWai M. Olson** is a professor at University of Texas Southwestern Medical Center. A complete list of the **END-PANIC Investigators** appears in the Acknowledgments.

Corresponding author: DaiWai M. Olson, University of Texas Southwestern Medical Center, 5323 Harry Hines Blvd, CS05.106, Dallas, TX 75390-8855 (email: DaiWai.Olson@UTSouthwestern.edu).

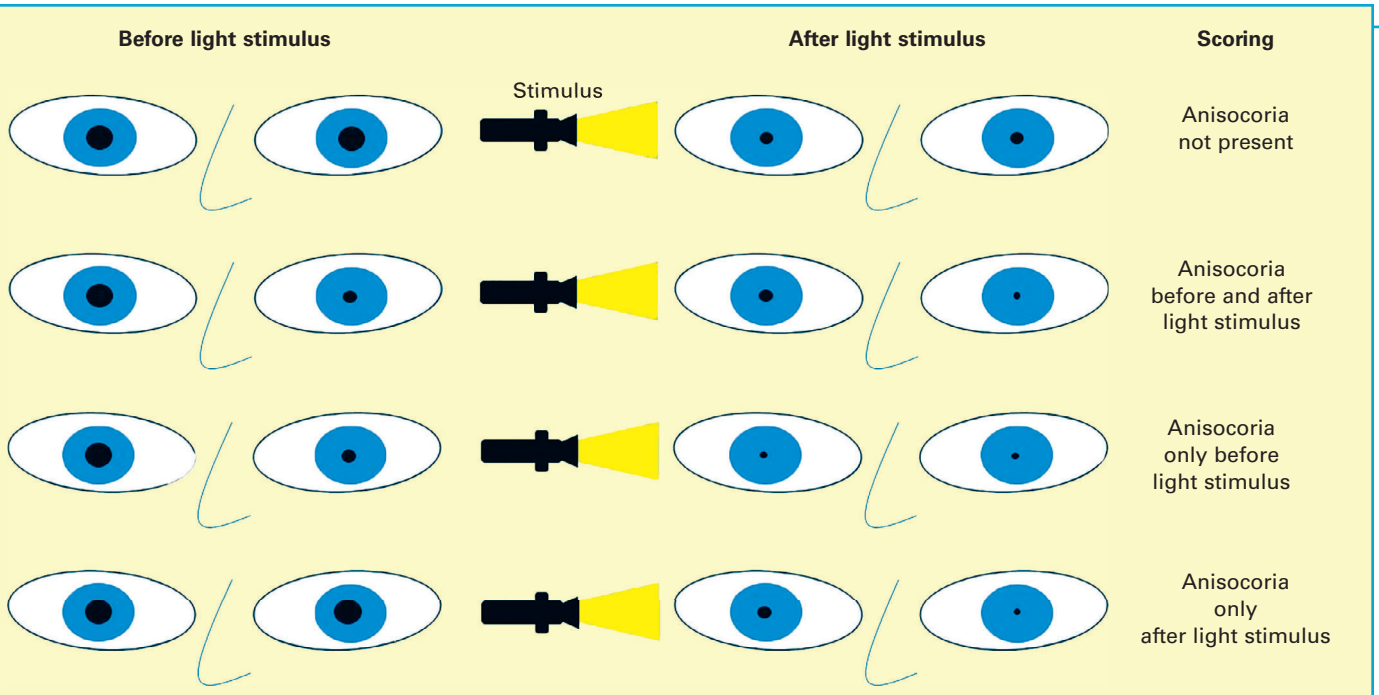

Figure Four possible observations of anisocoria.

The QP devices used in this registry were the NPi-200 and NPi-300 (NeurOptics Inc). The NPi-100, NPi-200, and NPi-300 have high interdevice reliability.[34,35] These QP devices use a digital camera with a built-in infrared light source to brighten the patient's eye and record images at 30 frames per second. The NPi-300 emits the following intensities of light (in radiometric units): 0 µW, 1 µW, 10 µW, 50 µW, 121 µW, and 180 µW. The duration of the measurement is 3 to 41 seconds. The results are immediately displayed for the clinician and stored on a microchip implanted in the device. Data are then available for upload into the electronic health record.[36]

Anisocoria before light stimulus was defined as the absolute difference between the left and right pupil diameters (in millimeters) before exposure to a light stimulus. This measurement is labeled "size" on the NPi-300. The formula $|\text{size}_{\text{left eye}} - \text{size}_{\text{right eye}}|$ was used to derive anisocoria before light stimulus for all QP measurements. Anisocoria after light stimulus was defined as the absolute difference between the left and right pupil diameters (in millimeters) after exposure to a light stimulus. This measurement is labeled "min" on the NPi-300. The formula $|\text{min}_{\text{left eye}} - \text{min}_{\text{right eye}}|$ was used to derive anisocoria after light stimulus for all QP measurements. The presence of anisocoria before and after light stimulus was then evaluated using the following cut points for absolute difference in pupil diameter: greater than 0.5 mm, greater than 0.7 mm, greater than 1.0 mm, greater than 1.5 mm, and greater than 2.0 mm.

The first pupillometry measurement for each patient was analyzed.

Statistical analyses were completed using SAS statistical software for Windows, version 9.4 (SAS Institute). Values were reported as mean (SD) or frequency (percentage) unless otherwise noted. *P* values of less than .05 were considered significant. Demographic data and values for anisocoria before and after light stimulus were analyzed using descriptive statistics. The McNemar test was used to model the paired binomial distributions (anisocoria present vs absent) at each cut point. An omnibus test using generalized linear models was used to examine frequencies of combinations of anisocoria before and after light stimulus: (1) neither before nor after light stimulus, (2) both before and after light stimulus, (3) only before light stimulus, and (4) only after light stimulus (see Figure). To be maximally conservative, we also included anisocoria either before or after light stimulus as a possible observation.

Results

A total of 5769 patients met the inclusion criteria of paired (left and right) pupil measurements. Patients had a mean age of 57.5 (17.6) years. The largest demographic sectors in the sample were 2558 patients (51.5%) who identified as female, 3669 (75.5%) who identified as White, and 4369 (89.2%) who identified as non-Hispanic (Table 1). Hospital stays ranged from 0 to 242 days (median [IQR], 6 [3-14] days). Intensive care

unit stays ranged from 0 to 177 days (median [IQR], 3 [1-8] days).

The presence of anisocoria before and after light stimulus for the 5 different cut points of anisocoria is shown in Table 2. Anisocoria before light stimulus was most common when defined as an absolute difference in pupil size of greater than 0.5 mm (1624 patients [28.2%] and least common when defined as an absolute difference in pupil size of greater than 2.0 mm (79 patients [1.4%]). Anisocoria after light stimulus was most common when defined as an absolute difference in pupil size of greater than 0.5 mm (885 patients [15.3%] and least common when defined as an absolute difference in pupil size of greater than 2.0 mm (74 patients [1.3%]). For the cut point of greater than 0.5 mm, 645 of the 1624 patients (39.7%) who had anisocoria before light stimulus also had anisocoria after light stimulus ($P<.001$). For the cut point of greater than 2.0 mm, 42 of the 79 patients (53.2%) who had anisocoria before light stimulus also had anisocoria after light stimulus ($P=.55$).

Table 3 shows observations of anisocoria using the 5 different cut points for the 5 possible combinations of anisocoria in each patient: (1) neither before nor after light stimulus, (2) either before or after light stimulus, (3) only before light stimulus, (4) only after light stimulus, and (5) both before and after light stimulus. Frequencies of patients with anisocoria ranged from 32 patients (0.6%) to 1864 patients (32.3%). The least frequent observation was 32 patients (0.6%) who had anisocoria only after light stimulus, based on the anisocoria cut point of greater than 2.0 mm. Among patients with anisocoria, the most frequent observation was 1864 patients (32.3%) who had anisocoria either before or after light stimulus, based on the anisocoria cut point of greater than 0.5 mm.

Table 1
Patient demographics and baseline variables (N=5769)

Variable	No. (%) of patients[a]
Age, mean (SD), y (n=5753)	57.5 (17.6)
Admission NIHSS score, mean (SD)	12.1 (10.4)
ICU length of stay, mean (SD), d	6.0 (8.2)
Hospital length of stay, mean (SD), d	10.3 (12.3)
Sex	
Female	2558 (51.5)
Male	2398 (48.3)
Not given	11 (0.2)
Race	
Black	647 (13.3)
Asian	217 (4.5)
White	3669 (75.5)
American Indian/Alaska native	9 (0.2)
Pacific Islander	3 (0.1)
Other	313 (6.4)
Ethnicity	
Not Hispanic	4369 (89.2)
Hispanic	480 (9.8)
Not given	47 (1.0)
Hunt and Hess score	
1	54 (21.5)
2	50 (19.9)
3	56 (22.3)
4	53 (21.1)
5	38 (15.1)
Intracerebral hemorrhage score	
0	60 (17.5)
1	77 (22.4)
2	70 (20.4)
3	75 (21.9)
4	47 (13.7)
5	13 (3.8)
6	1 (0.3)
Diagnosis	
Acute ischemic stroke	811 (16.7)
Subarachnoid hemorrhage	556 (11.4)
Intracerebral hemorrhage	488 (10.0)
Tumor	1142 (23.5)
Spinal injury	238 (4.9)
Trauma	327 (6.7)
Other	988 (20.3)
Seizure	319 (6.6)
History of eye disease	
No	5005 (86.8)
Yes	764 (13.2)

Abbreviations: ICU, intensive care unit; NIHSS, National Institutes of Health Stroke Scale.

[a] Unless otherwise indicated. Percentages are calculated from the total number of patients with data available in each category.

Discussion

This study included the largest available sample of in-hospital pupil size measurements using QP. We found that the incidence of anisocoria ranges widely according to the cut point used. Anisocoria is present more often when a smaller difference in pupil sizes is required. A smaller difference is more easily detected by QP than by human observation. Human observations of anisocoria before and after light stimulus also lack consistency. Our results provide new insight into the use of QP to improve the reliability of PLR examinations and also build a foundation for biomarker discovery research regarding PLR components as indicators of neurologic function.[4,13,15,37-39] Agreement upon the definition of anisocoria (including cut points) before and after light exposure is an important next step in research.

Our finding that anisocoria is present in 0.6% to 32.3% of patients, depending on the cut point used, extends previous reports in the literature.[13,21,40]

Table 2
Presence of anisocoria before and after light stimulus at different cut points

Cut point: absolute difference in left and right pupil size, mm	No. (%) of patients with anisocoria present (N=5769)			P[b]
	Before light stimulus	After light stimulus	Both before and after light stimulus[a]	
>0.5				<.001
Yes	1624 (28.2)	885 (15.3)	645 (11.2)	
No	4145 (71.8)	4884 (84.7)	5124 (88.8)	
>0.7				<.001
Yes	978 (17.0)	500 (8.7)	346 (6.0)	
No	4791 (83.0)	5269 (91.3)	5423 (94.0)	
>1.0				<.001
Yes	460 (8.0)	275 (4.8)	189 (3.3)	
No	5309 (92.0)	5494 (95.2)	5580 (96.7)	
>1.5				<.001
Yes	178 (3.1)	136 (2.4)	86 (1.5)	
No	5591 (96.9)	5633 (97.6)	5683 (98.5)	
>2.0				.55
Yes	79 (1.4)	74 (1.3)	42 (0.7)	
No	5690 (98.6)	5695 (98.7)	5727 (99.3)	

[a] Percentages for yes values in this column are calculated from the total number of yes values before light stimulus for that cut point.
[b] McNemar test of binomial response (presence of anisocoria) in paired observations before and after light stimulus.

Table 3
Observations of anisocoria at different cut points

Cut point: absolute difference in left and right pupil size, mm	No. (%) of patients with anisocoria observed (N=5769)[a]				
	Neither before nor after light stimulus	Either before or after light stimulus	Only before light stimulus	Only after light stimulus	Both before and after light stimulus
>0.5	3905 (67.7)	1864 (32.3)	979 (17.0)	240 (4.2)	645 (11.2)
>0.7	4637 (80.4)	1132 (19.6)	632 (11.0)	154 (2.7)	346 (6.0)
>1.0	5223 (90.5)	546 (9.5)	271 (4.7)	86 (1.5)	189 (3.3)
>1.5	5541 (96.0)	228 (4.0)	92 (1.6)	50 (0.9)	86 (1.5)
>2.0	5658 (98.1)	111 (1.9)	37 (0.6)	32 (0.6)	42 (0.7)

[a] All *P* values <.001.

The use of a nonuniversal cut point limits comparison with findings of published reports that used a different cut point. The broad range of findings for the prevalence of anisocoria (3.1%-17.4%,[40] 12.8%,[14] 13%,[5] 20%,[41] 41%,[11] 63%,[12] and 73%[21]), which are based on various definitions of anisocoria and various conditions, reduces clinicians' ability to accurately detect anisocoria. This inconsistency also confounds the ability of clinician scientists to examine this phenomenon. Not surprisingly, anisocoria is more frequently detected by QP when the cut point is smaller (eg, at least a 0.5-mm absolute difference in pupil size) than when a larger cut point is required (eg, at least a 2.0-mm absolute difference). Correctly identifying pupil size by subjective assessment is difficult; without QP, it would be harder for clinicians to identify anisocoria in small pupils than in large pupils.[19,20] Our finding of the high rate of anisocoria using a cut point of greater than 0.5 mm likely reflects the advantage of QP accuracy. Very few studies have reported anisocoria using QP, and to our knowledge, this is the first study to examine anisocoria after light stimulus.[5]

About a third (32.3%) of patients had anisocoria either before or after light stimulus.

Although the amount and duration of light stimulus were preset by the manufacturer of the QP devices, real-world sampling did not control for light conditions during pupil assessment.[42] In addition to the

many different cut points used to define anisocoria, descriptions of best practices vary in regards to the lighting conditions under which the pupil should be examined. Published criteria include complete darkness, ambient light, both darkness and light, and varied suggestions for the duration of each light condition before assessment.[18,21,43] Although a large portion of the population has anisocoria in low light, one cannot assume that those with anisocoria in ambient light will also have anisocoria detected in low light.[21] Pupil accommodation occurs when a person focuses vision on objects at different distances, so unilateral visual acuity may influence anisocoria. Measurements of QP are made by varied clinical teams with different levels of experience.[42,44-46] Our decision to use real-world data enhances the external validity of our findings. Moreover, in intensive care units, recommendations for near-total darkness can rarely be followed.[47]

Our results confirm the presence of anisocoria after light stimulus. This measure was first reported in 2021 by Nyancho et al,[14] who found that anisocoria after light stimulus was associated with higher morbidity than was anisocoria in ambient light.In our study, a relatively small proportion of patients met the definition of anisocoria both before and after light stimulus at any given cut point. Anisocoria has no agreed-upon definition, and QP provides a more precise measure of pupil size difference than was previously available.[34,35] This study was designed not to explore outcomes but rather to explore the existence of this phenomenon. Future research should examine persistent anisocoria using various cut points.

Limitations

One limitation of our study is the inability to determine if patients had anisocoria before admission or if they had new-onset anisocoria. Another limitation is that the END-PANIC study data came primarily from sites in the United States. However, the sample was large and included data from Asian and European sites. The exploration of anisocoria after light stimulus is novel and not well studied. It is possible that analyzing percentage change in size, rather than absolute size difference, would produce different results. However, we found that some patients without anisocoria before light stimulus had anisocoria after light stimulus, which suggests that using an absolute cut point value is not a limiting factor in finding anisocoria. The data were not linked to changes in hemodynamic status or medication use because this information was not available in the registry. Future prospective studies examining PLR and anisocoria may benefit from including hemodynamic status as a predictor variable.

Conclusion

Using different anisocoria cut points (>0.5 mm, >0.7 mm, >1.0 mm, >1.5 mm, and >2.0 mm) results in anisocoria being identified in significantly different numbers of patients. The presence of anisocoria before light stimulus does not predict the presence of anisocoria after light stimulus. In health care, documenting physiologic responses under different conditions (eg, blood pressure measured while sitting and standing or heart rate measured before and after activity) is often valuable. Our results suggest that reporting pupil size both before and after light stimulus is beneficial. Our results also suggest the potential for new research into anisocoria as a biomarker of injury.

> Using different cut points to define anisocoria limits generalizability.

ACKNOWLEDGMENTS

The END-PANIC Investigators are Sonja Stutzman, Nathan Schneider, Venkatesh Aiyagari, Morgan McCreary, Julia Koehn, Michelle Hill, Jessica Dewitt, Allison Argone, Daniel Martinez, Misha Monfort-Mills, Dawit Measho, and Maria Denbow.

FINANCIAL DISCLOSURES

This research received partial funding from NeurOptics Inc.

SEE ALSO

For more about pupillometry, visit the *AACN Advanced Critical Care* website, **www.aacnacconline.org**, and read the article by Scarboro and McQuillan, "Traumatic Brain Injury Update" (Spring 2021).

REFERENCES

1. Olson DM, Fishel M. The use of automated pupillometry in critical care. *Crit Care Nurs Clin North Am.* 2016;28(1):101-107. doi:10.1016/j.cnc.2015.09.003
2. Campos YA, Rana P, Reyes RG, et al. Relationship between automated pupillometry measurements and ventricular volume in patients with aneurysmal subarachnoid hemorrhage. *J Neurosci Nurs.* 2022;54(4):166-170. doi:10.1097/jnn.0000000000000657
3. Obinata H, Yokobori S, Shibata Y, et al. Early automated infrared pupillometry is superior to auditory brainstem response in predicting neurological outcome after cardiac arrest. *Resuscitation.* 2020;154:77-84. doi:10.1016/j.resuscitation.2020.06.002
4. Morelli P, Oddo M, Ben-Hamouda N. Role of automated pupillometry in critically ill patients. *Minerva Anestesiol.* 2019;85(9):995-1002. doi:10.23736/s0375-9393.19.13437-2
5. George AS, Abraham AP, Nair S, Joseph M. The prevalence of physiological anisocoria and its clinical significance—a neurosurgical perspective. *Neurol India.* 2019;67(6):1500-1503. doi:10.4103/0028-3886.273623
6. Prescott BR, Saglam H, Duskin JA, et al. Anisocoria and poor pupil reactivity by quantitative pupillometry in patients with intracranial pathology. *Crit Care Med.* 2022;50(2):e143-e153. doi:10.1097/CCM.0000000000005272
7. Alexandrov AW. The sky's the limit: expanding nursing's contribution to acute stroke science. *Am J Crit Care.* 2022;31(4):266-274. doi:10.4037/ajcc2022109

8. Banzon PC, Vashisht A, Euckert M, et al. Original research: practice variations in documenting neurologic examinations in non-neuroscience ICUs. *Am J Nurs.* 2023;123(1):24-30. doi:10.1097/01.NAJ.0000905564.83124.2d
9. Payne WN, Blair K, Barrett MJ. Anisocoria. In: StatPearls [Internet]. StatPearls Publishing; 2023. Updated December 26, 2022. Accessed September 9, 2022. https://www.ncbi.nlm.nih.gov/books/NBK470384
10. Loewenfeld IE. "Simple central" anisocoria: a common condition, seldom recognized. *Trans Sect Ophthalmol Am Acad Ophthalmol Otolaryngol.* 1977;83(5):832-839.
11. Lam BL, Thompson HS, Corbett JJ. The prevalence of simple anisocoria. *Am J Ophthalmol.* 1987;104(1):69-73. doi:10.1016/0002-9394(87)90296-0
12. Prescott BR, Saglam H, Duskin JA, et al. Anisocoria and poor pupil reactivity by quantitative pupillometry in patients with intracranial pathology. *Crit Care Med.* 2022;50(2):e143-e153. doi:10.1097/ccm.0000000000005272
13. Heath Jeffery RC, Young B, Swann PG, Lueck CJ. Unequal pupils: understanding the eye's aperture. *Aust J Gen Pract.* 2019;48(1-2):39-42. doi:10.31128/ajgp-07-18-4641
14. Nyancho D, Atem FD, Venkatachalam AM, et al. Anisocoria correlates with injury severity and outcomes after blunt traumatic brain injury. *J Neurosci Nurs.* 2021;53(6):251-255. doi:10.1097/jnn.0000000000000613
15. El Ahmadieh TY, Bedros N, Stutzman SE, et al. Automated pupillometry as a triage and assessment tool in patients with traumatic brain injury. *World Neurosurg.* 2021;145:e163-e169. doi:10.1016/j.wneu.2020.09.152
16. Falardeau J. Anisocoria. *Int Ophthalmol Clin.* 2019;59(3):125-139. doi:10.1097/iio.0000000000000276
17. LaRoche MJ. Anisocoria and an array of neurologic symptoms in an adult with Ewing sarcoma. *J Adv Pract Oncol.* 2017;8(1):18-23. doi:10.6004/jadpro.2017.8.1.2
18. Martin TJ. Horner syndrome: a clinical review. *ACS Chem Neurosci.* 2018;9(2):177-186. doi:10.1021/acschemneuro.7b00405
19. Olson DM, Stutzman S, Saju C, Wilson M, Zhao W, Aiyagari V. Interrater reliability of pupillary assessments. *Neurocrit Care.* 2016;24(2):251-257. doi:10.1007/s12028-015-0182-1
20. Couret D, Boumaza D, Grisotto C, et al. Reliability of standard pupillometry practice in neurocritical care: an observational, double-blinded study. *Crit Care.* 2016;20:99. doi:10.1186/s13054-016-1239-z
21. Steck RP, Kong M, McCray KL, Quan V, Davey PG. Physiologic anisocoria under various lighting conditions. *Clin Ophthalmol.* 2018;12:85-89. doi:10.2147/opth.S147019
22. Olson DM, Stutzman SE, Atem F, et al. Establishing normative data for pupillometer assessment in neuroscience intensive care: the "END-PANIC" registry. *J Neurosci Nurs.* 2017;49(4):251-254. doi:10.1097/jnn.0000000000000296
23. Meeker M, Du R, Bacchetti P, et al. Pupil examination: validity and clinical utility of an automated pupillometer. *J Neurosci Nurs.* 2005;37(1):34-40.
24. Privitera CM, Neerukonda SV, Aiyagari V, et al; END PANIC Investigators. A differential of the left eye and right eye neurological pupil index is associated with discharge modified Rankin scores in neurologically injured patients. *BMC Neurol.* 2022;22(1):273. doi:10.1186/s12883-022-02801-3
25. Traylor JI, El Ahmadieh TY, Bedros NM, et al. Quantitative pupillometry in patients with traumatic brain injury and loss of consciousness: a prospective pilot study. *J Clin Neurosci.* 2021;91:88-92. doi:10.1016/j.jocn.2021.06.044
26. Kerr RG, Bacon AM, Baker LL, et al. Underestimation of pupil size by critical care and neurosurgical nurses. *Am J Crit Care.* 2016;25(3):213-219. doi:10.4037/ajcc2016554
27. Rhudy LM, Johnson MR, Krecke CA, et al. Standardized change-of-shift handoff: nurses' perspectives and implications for evidence-based practice. *Am J Crit Care.* 2022;31(3):181-188. doi:10.4037/ajcc2022629
28. Perera AC, Joseph S, Marshall JL, Olson DM. Exploring plan of care communication with a multidisciplinary rounding plan to nursing care plans. *J Neurosci Nurs.* 2023;55(2):49-53. doi:10.1097/jnn.0000000000000690
29. Halm MA. On low-value nursing care: part 2, de-implementing practices in your unit. *Am J Crit Care.* 2022;31(6):508-513. doi:10.4037/ajcc2022835
30. Halm MA. On low-value nursing care: part 1, why de-implementation matters for quality care. *Am J Crit Care.* 2022;31(4):338-342. doi:10.4037/ajcc2022857
31. Lussier BL, Stutzman SE, Atem F, et al. Distributions and reference ranges for automated pupillometer values in neurocritical care patients. *J Neurosci Nurs.* 2019;51(6):335-340. doi:10.1097/jnn.0000000000000478
32. Stutzman S, Olson D, Venkatachalam A, Barnes A, Atem F. The presence of cataract does not influence assessment of the pupillary light reflex using automated pupillometry. *J Health Caring Sci.* 2021;3(2):85-95. doi:10.37719/jhcs.2021.v3i2.oa001
33. Al-Obaidi S, Atem F, Stutzman SE, Aiyagari V, Olson DM. Investigating the association between eye colour and the Neurological Pupil index. *Aust Crit Care.* 2020;33(5):436-440. doi:10.1016/j.aucc.2019.10.001
34. Stutzman S, Iype P, Marshall J, et al. Inter-device reliability of the NPi-200 and NPi-300 pupillometers. *J Clin Neurosci.* 2022;100:180-183. doi:10.1016/j.jocn.2022.04.023
35. Zhao W, Stutzman S, DaiWai O, Saju C, Wilson M, Aiyagari V. Inter-device reliability of the NPi-100 pupillometer. *J Clin Neurosci.* 2016;33:79-82. doi:10.1016/j.jocn.2016.01.039
36. Zafar SF, Suarez JI. Automated pupillometer for monitoring the critically ill patient: a critical appraisal. *J Crit Care.* 2014;29(4):599-603. doi:10.1016/j.jcrc.2014.01.012
37. Aoun SG, Welch BG, Cortes M, et al. Objective pupillometry as an adjunct to prediction and assessment for oculomotor nerve injury and recovery: potential for practical applications. *World Neurosurg.* 2019;121:e475-e480. doi:10.1016/j.wneu. 2018.09.140
38. Kamal A, Ahmed KM, Venkatachalam AM, et al. Pilot study of Neurologic Pupil index as a predictor of external ventricular drain clamp trial failure after subarachnoid hemorrhage. *World Neurosurg.* 2022;164:2-7. doi:10.1016/j.wneu.2022.04.123
39. Jahns FP, Miroz JP, Messerer M, et al. Quantitative pupillometry for the monitoring of intracranial hypertension in patients with severe traumatic brain injury. *Crit Care.* 2019;23(1):155. doi:10.1186/s13054-019-2436-3
40. Kılınç Hekimsoy H, Şekeroğlu MA, Yeşilyaprak N, Doğuizi S, Yılmazbaş P. The pupillary dynamics of patients with physiological anisocoria. *Eye (Lond).* 2022;36(8):1578-1582. doi:10.1038/s41433-021-01696-7
41. Kotani J, Nakao H, Yamada I, Miyawaki A, Mambo N, Ono Y. A novel method for measuring the pupil diameter and pupillary light reflex of healthy volunteers and patients with intracranial lesions using a newly developed pupilometer. *Front Med (Lausanne).* 2021;8:598791. doi:10.3389/fmed.2021.598791
42. Lussier BL, Stutzman SE, Atem F, et al. Distributions and reference ranges for automated pupillometer values in neurocritical care patients. *J Neurosci Nurs.* 2019;51(6):335-340. doi:10.1097/jnn.0000000000000478
43. Weerakoon SM, Stutzman SE, Atem FD, Kuchenbecker KS, Olson DM, Aiyagari V. Investigation of pupillary changes after carotid endarterectomy and carotid stent placement using automated pupillometry. *J Stroke Cerebrovasc Dis.* 2020;29(5):104693. doi:10.1016/j.jstrokecerebrovasdis.2020.104693
44. Stout D, Dullaway J, McMahan H, Daniel BA, Olson DM. Reflections on patient care technicians obtaining pupillometer readings in a neuroscience intensive care unit. *J Neurosci Nurs.* 2022;54(6):245-246. doi:10.1097/jnn.0000000000000676
45. Giamarino K, Blessing R, Boelter C, Thompson JA, Reynolds SS. Exploring the relationship between objective pupillometry metrics and midline shift. *J Neurosci Nurs.* 2021;53(6):233-237. doi:10.1097/jnn.0000000000000614
46. Martineau-Lessard C, Arbour C, Germélus NÉ, Williamson D, De Beaumont L, Bernard F. Pupil light reflex for the assessment of analgesia in critically ill sedated patients with traumatic brain injury: a preliminary study. *J Neurosci Nurs.* 2022;54(1):6-12. doi:10.1097/jnn.0000000000000627
47. Olson DM, Borel CO, Laskowitz DT, Moore DT, McConnell ES. Quiet time: a nursing intervention to promote sleep in neurocritical care units. *Am J Crit Care.* 2001;10(2):74-78.

CE 1.0 Hour Category A

Notice to CE enrollees:

This article has been designated for CE contact hour(s). The evaluation demonstrates your knowledge of the following objectives:

1. Describe the advantages and disadvantages of using quantitative pupillometers to evaluate the pupillary light reflex.
2. List the various pupil size difference cut points used to define anisocoria.
3. Discuss the implications of after-light-stimulus anisocoria as a novel biomarker of brain injury.

To complete the evaluation for CE contact hour(s) for activity A2361, visit https://aacnjournals.org/ajcconline/ce-articles. No CE fee for AACN members. See CE activity page for expiration date.

The American Association of Critical-Care Nurses is accredited as a provider of nursing continuing professional development by the American Nurses Credentialing Center's Commission on Accreditation, ANCC Provider Number 0012. AACN has been approved as a provider of continuing education in nursing by the California Board of Registered Nursing (CA BRN), CA Provider Number CEP1036, for 1.0 contact hour.