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Pupil by Dietlein ratio: introducing a simple objective measure using two low-cost method for measuring early sympathetic and parasympathetic response of pupillary change in the ICU

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The box method for estimation of PLD ratios measures limbal diameter (A, blue diameter) and pupil diameter (B, red diameter) pupillary sizes at parallel axes and not always the same axes. The separation between the two diameters is proportional to the pupillary eccentricity

The PLD ratio of different subjects taken from the different angles and at different para-horizontal axial diameters (see methods section) were very similar with a low S.E.M (max S.E.M was 0.0008), indicating that these measures were reliable. For a 11.5 mm limbus diameter, pupillary measures between 0.1 and1mm translate to a PLD ratio in the range between 0.009 and 0.087, this range is substantially greater than the S.E.Ms obtained by PLD measurements from digital photographs. Thus, pupillary images can be captured easily at the bedside by different caregivers virtually eliminating inaccuracies in diagnosis of anisocoria that may arise from examiner bias and perspective. The PLD ratios measured at different para-horizontal diameters for each image gave very similar ratios.

For all images taken at each ambient light levels using the cameras spot-metering capability, we found that the digital camera gave identical F-stop, ISO speed and exposure times. We also found that the brightness values registered by the camera for calculating exposure had very little variation and ensured the exact exposure setting for all images taken under each conditions of background illumination. These brightness values can be used for cross-reference on the ambient lighting conditions helping in documentation.

Microsoft Powerpoint was used for image analysis because this was readily available. Any graphing software including the graphing tools that are provided by most electronic medical records system (once images are uploaded) can be used for the *two-box method* of estimating PLD ratios. Because the contrast between the cornea versus sclera and iris versus pupil is relatively high, this *two-box method* can be easily automated to estimate PLD ratios. Pupil to limbal area instead of pupil to limbal diameter can give the same PLD ratio, but will not be able to give a value for relative eccentricity of the pupil if that is additionally required.

One limitation of our study was that we did not image the pupils for illuminance below 1 lux. The image resolution for conditions below 1 lux was fuzzy. The lowest illumination tested, at which anisocoria was found in the patient [Figure 1c and d] was in the mesopic range at which both rods and cones are active in the retina.[27,28] Additionally, we did not measure dynamics of pupillary changes. Alternative image capture paradigms in the dark such as use of flash photography or IR illumination with an IR capable camera were also not employed by this study. The presence of significant hippus can confound static pupillary measurements. In the presence of significant pupillary or corneal asymmetries PLD ratio measurements will have limited utility in the detection of anisocoria but can be used for plotting the time course of pupillary changes.

In summary, the PLD ratios are an objective measure for rapidly and accurately quantifying anisocoria and following the time course of change of the pupil in the ICU. PLD ratios can be reliably estimated using the *two-box method* from digital photographs that can be taken from a readily available cellphone camera that has spot-metering capability at no additional cost. Evaluation of pupillary size via PLD ratios should include imaging under conditions of darkness and bright light to addresses involvement of the parasympathetic or sympathetic control centers in acute brain lesions. Keeping the camera angle not too far from the optical axis, using spot-metering and avoiding superior views gives well-defined limbal and pupillary edges for measuring the PLD ratios. The patient's eyes should be fixed at a target, if the patient is conscious, to eliminate the effects of accommodation and vergence on the pupillary size. Future studies should focus on development and testing of portable hand-held methodologies to rapidly measure PLD ratios for a range of illuminations as well as measure PLD ratios dynamically.

Footnotes

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