

Evaluation of Static Pupil Size Using Digital Web Camera through Image Analysis

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Abstract

Introduction: Pupillometry is the measurement of pupil area or diameter which is a key parameter of routine clinical examination in wide variety of diseases. Pupillometer is a self-contained camera that objectively measures pupil diameter. Measurement of pupil area/ diameter is known as pupillometry. Manual assessment can be done using pen torch which is subjective and qualitative measure. So the present study was aimed to measure the pupil size by infrared based web camera which is more accurate, repeatable and cost effective.

Materials and Method: A simple web camera was used where the infrared light filter was removed from the optics so as to get image under infrared light. This camera was mounted on a stand in front of the eye at a distance of 5 cm. The recordings were done in twenty normal subjects in the age group of 18 – 30 years. The captured pictures were analyzed for minimum and maximum diameter of the pupil by using the ImageJ software. One time calibration for spatial measure was done prior to measurements. This was achieved by using an image of the ruler scale kept at 5 cm.

Results: Mean dilated pupil diameter was $7.17 \text{ mm} \pm 1.38$, Constricted mean diameter was $3.34 \text{ mm} \pm 0.56$.

Conclusion: We have developed technique to measure the pupil diameter which is cost effective. By capturing the static pictures with help of modified web camera, it can be used to identify various clinical abnormalities reflected in pupils.

Keywords: Pupillometry, Infrared videography, ANS activity, Image analysis

Introduction

Pupil is the central aperture of iris which allows the light rays in to the inner retinal part of eye ball⁽¹⁾. Pupil is surrounded by two muscles that controls diameter of

pupil and intensity of light rays. Sphincter pupillae is the inner circular muscle supplied by III cranial nerve (Parasympathetic stimulation) leads to constriction of pupil. Dilator pupillae is outer radial muscle innervated by sympathetic fibers from cervical ganglion causes pupillary dilation⁽²⁾. Thus pupillary response is involuntary and it is influenced by multiple factors like illumination, accommodation of eye, stress and cognitive load⁽³⁻⁵⁾. The intensity and reactivity of Pupil response alters in various clinical conditions and it act as early predictor of neuronal derangement⁽⁶⁾. The traditional method of determining pupil response is swinging flash light test where light is thrown in to eye to find out the pupil response. It is a qualitative measurement which does

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not provide much information about pupil⁽⁷⁾. Therefore Dynamic Pupillometry is the quantitative measurement of pupil diameter and reactivity that act as a surrogate method for various diseases and psychological status of an individual⁽⁸⁾.

The pupillometer is the self-contained camera that measures static and dynamic responses of pupil⁽⁹⁾. It records the pupil response in total darkness followed by a flash of white light. The pupil dilation cannot be captured under darkness. To achieve this the eye exposed to Infrared light with wavelength of $>700\text{nm}$ above the visual spectrum which does not elicit a pupillary light reflex. Thus Infrared illumination helps to acquire the dilated responses of pupil⁽¹⁰⁾. This measurement of pupil size in relation to time can be a vital index to know the status of Autonomic derangement, neuronal integrity in head injuries and brain tumors. It can also be used for the control of retinal illumination in visual field, electroretinography and to control pupil size under low illumination in cataract and refractive surgery^(11,12). Though Infrared light digital videography is highly advanced, still it is least used in the field of medicine as it is too expensive⁽¹³⁾. Therefore the present study was focused to capture static pupil diameter with the help of image analysis using Infrared video.

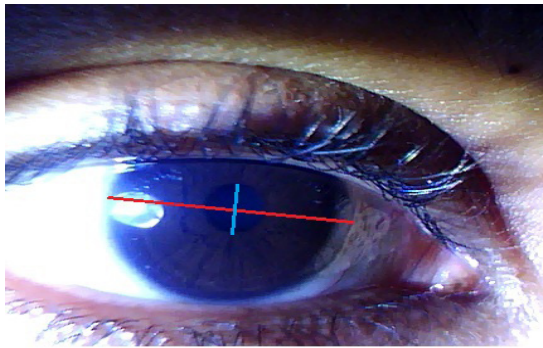
Material and Method

Design of Pupillometer: The Infrared based web camera was used in which Infrared filter removed from optics to get images under Infrared illumination. This camera was mounted to a stand. The subjects chin was rested on a chin rest which had the facility to change the height as per the individual subjects need. It was fixed with a micro controller based electronic circuitry to control standard intensity of Infrared and white light. The system was calibrated by fixing a normal centimeter scale at fixed distance. Later these images were taken to confirm the accuracy and reliability of the system for the measurements. Then it is proceeded with real time pupil capture and analysis⁽¹⁴⁾.



Fig. 1 shows the position of camera and the subject

Study design: A cross sectional study was undertaken in which 20 healthy volunteer subjects in the age group of 18-30 years were recruited. Institutional Ethical clearance was obtained for this study from Narayana Medical College, Nellore. Entire pupillometry procedure was explained to the each subject and informed written consent was taken as per the declaration of Helsinki. All the subjects were instructed to maintain their normal sleep pattern, not to ingest beverages with caffeine or alcohol, and not to perform physical exercise before the evaluations. This test was conducted in morning after 2 hours of light breakfast. Subjects were encouraged to void urine before commence of recording. In all the procedures were done in a dark room after adapting for 5 minutes with a controlled breathing. In this method static images were taken in total darkness under infrared illumination which provides maximum dilated pupil followed by a flash of white light for 2 seconds which leads to maximum constriction of pupil. These pictures were taken by modified web camera which could capture 30 frames/sec with a resolution of 33.3 msec. / frame. These frames were subjected to Image analysis software (ImageJ ver.1.43u National Institute of Health, USA). The result was given as maximum diameter, and minimum diameter of the pupil. It is a Java-based image processing software developed at the National Institutes of Health (NIH). ImageJ was designed with an open architecture that provides extensibility via Java plugins and recordable macros. Custom acquisition, analysis and processing plugins can be developed using a built-in editor and a Java compiler. Image J built-in development environment has made it a popular platform for processing of images. The authors of current paper were established the analysis of pupil for diameter using image analysis⁽¹⁵⁾.



Blue line is pupil diameter --?
Red line is size of iris - 12mm

Fig. 2 shows the captured picture of pupil (Blue line) with in the iris (Red line)

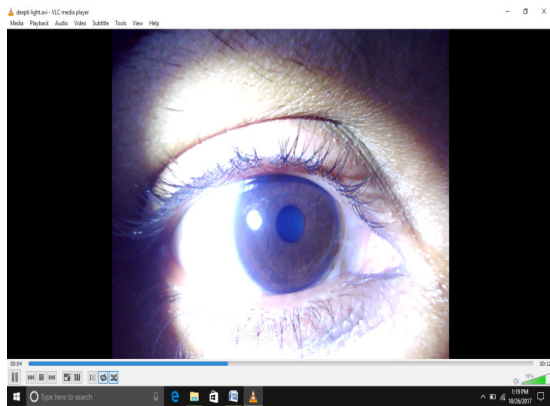


Fig. 3 shows minimum pupil diameter captured under bright light illumination



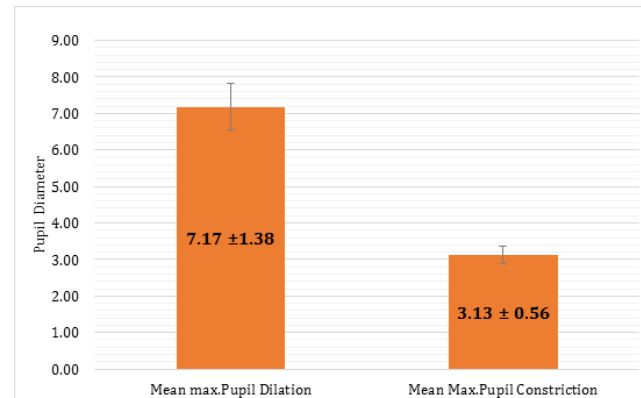
Fig. 4 shows maximum pupil diameter captured under infrared light illumination

Statistical analysis: Statistical analysis was done by SPSS 17.0 software. All data were reported as mean \pm standard deviation (SD).

Results

The data obtained from the protocol were analyzed and described as maximum and minimum pupil diameter. Values are expressed as mean \pm SD in the tables. The mean max. pupil diameter is 7.17 ± 1.38 mm and mean

min. pupil diameter is 3.13 ± 0.56 mm. However we did not measure dynamic responses (velocities) of the pupil for constriction and dilation in different illuminations.



Graph -1 shows mean max. and min. pupil diameters

Discussion

The current study was aimed to develop a novel technique to quantify the pupil dimensions using a simple web camera. The images were captured with the help of modified web camera in different illuminations. The maximum dilated pupil was seen and captured under infrared illumination and minimum pupil was taken when the eye is exposed to flash light. These values of pupil in both types of illuminations were measured by processing the images through Image J software. The obtained results are promising and favorable to improve the quantitative pupil measurements using digital image analysis.

Pupillary examination varies with the skill of the examiner and can result in errors. Determination of pupil diameter is the vital diagnostic tool, especially in brain injuries⁽¹⁶⁾. Litvan et.al had administered an objective scale that gives inter-rater variability of pupil measurement⁽¹⁷⁾. This method is useful only in the visible light which is difficult to find out especially when the illumination is minimal. The complete dilated pupil can be captured under infrared illumination, which increases accuracy of pupil determination and does not initiate pupillary light reflex. Quantitative infrared based pupillometry can produce reliable, accurate pupil size values which provides more information than pupillary measures obtained through the direct clinical examination by the physician⁽¹⁸⁾. The relative weakness of the dilator muscle in patients with a Horner is expected to cause 'dark miosis', i.e. the pupil should remain small in complete darkness and this can be measured straightforwardly

using infra-red techniques for pupillometry. However there are a number of confounding influences that limit the usefulness of this measure as a test of sympathetic integrity⁽¹⁹⁾. Kostas N. Fountas et.al and Rose Du et.al introduced the automated pupillometer (NeuroOptics, Inc., Irvine, CA) which is a hand-held, portable device with liquid crystal display screen and has an option of video recording for pupillary measurements. The accuracy and precision of the device are much higher compared to the manual examination⁽²⁰⁻²²⁾. Elizabeth L. Johnson et.al also used a camera that automatically captures the pupil at 7 cms. distance, with a temporal resolution of 120Hz, to evaluate task-evoked pupil dilation among children who were subjected to short term memory tasks⁽²³⁾. However, these automated pupillometers are highly expensive. Pupillometry is a low-cost, noninvasive technique that may be useful for monitoring cholinergic deficits which generally lead to memory and cognitive disorders. Pupillometry demonstrates potential as an adjunct (possibly together with blood or other biomarkers) for accurate diagnosis of Alzheimer's Disease and monitoring of disease progress and response to therapy and for low-cost and noninvasive detection of preclinical, recruitment into preclinical Alzheimer's Disease therapeutic trials and also monitoring response in these trials⁽²⁴⁾.

It's a newer approach to quantify the pupil dimensions which has a modified web camera and can capture the images of pupil in different illuminations. The captured images were analyzed using Image J software which provides static dimensions of pupil accurately. We have done preliminary study to prove the concept of quantitative pupil determination which will be preceded with measurement of various parameters of pupillary light reflex.

Limitations: The interpretation of the obtained measurements requires a thorough knowledge of all the limiting factors, which could potentially alter these measurements. The time related parameters could not be analyzed at this point of time, which can be more useful in the clinical setups.

Conclusion: We have developed technique to measure the pupil diameter which is cost effective. It can be used to identify various clinical abnormalities reflected in pupils. It is also possible to get dynamic changes of pupillary responses by analyzing individual frames. In future we are planning to measure the time

characteristics of pupillary responses.

Conflict of Interest: On behalf of all authors, the corresponding author states that, there is no conflict of interest.

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