· Clinical Research ·

Real time video-based gaze tracking for detecting subtle deviation angle change in abducens nerve palsy

Natalia Christina Angsana, Amelia Devy Indriasari, Indra Tri Mahayana

Department of Ophthalmology, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Jl. Farmako, Sekip Utara, Yogyakarta 55248, Indonesia

Correspondence to: Indra Tri Mahayana. Department of Ophthalmology, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Jl. Farmako, Sekip Utara, Yogyakarta 55248, Indonesia. indra.tri.m@mail.ugm.ac.id

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Abstract

● **AIM:** To measure abducens nerve palsy patients' visual angle using real time video-based gaze tracking system.

● **METHODS:** This research was a cross-sectional study. The subjects were taken by convenience sampling technique in the Neuro-ophthalmology department at Sardjito General Hospital Yogyakarta, Indonesia, and had met the inclusion and exclusion criteria. The visual angle measurements were performed using an eye tracker with a computer webcam (GENICULA system/Gaze Tracking Artificial Intelligence for Ocular Motor Palsy). The analytical method used was the Mann-Whitney test to compare the visual angle between the abducens nerve palsy group and the healthy eye group. The Wilcoxon test was used to see the significance of differences in visual angle improvement in abducens nerve palsy patients.

● **RESULTS:** A total of 39 subjects participated, with a mean age of 46.54±15.67y; 17 were male and 22 were female. The visual angle was 20.88±3.76 in the abducens nerve palsy group (n=39 eyes) and 23.10±2.91 in the normal group (n=39 eyes, P=0.011). The visual angle improvement of abducens nerve palsy before and after cured was statistically significant (P=0.039).

● **CONCLUSION:** The real time video-based gaze tracking system is easy to use, efficient, and accurate. A slight decrease in visual angle measurement can be detected using this GENICULA system and therefore it is important for diagnosis slight deviation in abducens nerve palsy.

● **KEYWORDS:** abducens nerve palsy; eye tracker; ocular motor nerve palsy; neuro-ophthalmology; visual angle

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INTRODUCTION

The abducens nerve (cranial nerve VI) is one of the cranial nerves involved in the motor functions of the extraocular muscles, alongside the oculomotor nerve (cranial nerve III) and the trochlear nerve (cranial nerve IV). The abducens nerve is purely a motor nerve, lacking sensory function, and innervates the lateral rectus muscle, facilitating ipsilateral eye abduction[1-3]. Abducens nerve palsy, hereafter referred to as abducens palsy, is the most common ocular motor palsy in adults, with an incidence of 11.3 per 100 000 individuals. In children, it is the second most common type, following trochlear nerve palsy, with an incidence of 2.5 cases per 100 000[1]. In a total cohort study, 209 patients (0.32%) were found to have ophthalmoplegia, of which 111 patients (53.11%) had abducens nerve palsy, 76 patients (36.36%) had oculomotor nerve palsy, and 6 patients (2.8%) had trochlear nerve palsy[4]. From 2018 to 2022, a total of 373 patients with abducens nerve palsy were treated at Sardjito General Hospital. Microvascular ischemia is the most frequent cause of abducens nerve palsy in adults, although other potential causes include trauma, neoplasms, and idiopathic origins[1,5-6].

The clinical diagnosis of strabismus involves inspection of misalignment, ptosis, pupil abnormalities, duction, vergence, saccadic and pursuit movements, oculocerebral maneuvers, and qualitative and quantitative measurements of ocular misalignment, including cover-uncover tests, alternate cover tests, Maddox rod, Krimsky, or Hirschberg tests, performed manually by the physician[7-10]. Initially, it is crucial to determine whether the neurological deficit is limited to the abducens nerve or involves other cranial nerves innervating the extraocular muscles. The diagnosis of abducens nerve palsy is established based on clinical examination, revealing incomitant esotropia due to the antagonistic action of the medial rectus muscle, with an inability to perform abduction[11-13]. Traditional diagnostic methods tend to be more expensive and yield more subjective results. Consequently, Chen *et al*[9] conducted a study on automated strabismus examination using an eye-tracking device, resulting in objective outcomes.

An eye tracker is a method for recording eye movements and the position of gaze. This device measures where and how a patient's gaze shifts when presented with specific tasks. Eye-tracking technology is employed across various fields, including healthcare, neuroscience, mathematics and computer science, education and social sciences, engineering and technology, biology and agriculture, physics and chemistry, business and law, and environmental science. With advancements in technology, several techniques have been widely used to track eye movements, including electro-oculography (EOG), infrared reflection devices (IRD), the scleral search coil method, and video-oculography (VOG)[14-16].

Eye movement trackers currently used in the medical field predominantly rely on VOG technology. This technique employs a video camera to capture images, which are then processed by a computer. VOG automatically detects eye markers such as the pupil, corneal limbus, iris, and episcleral blood vessels. The measurement of two-dimensional gaze direction in VOG is based on corneal reflections and pupil localization, necessitating a stable head position[17-18]. Eye-tracking technology has advanced significantly, with modern systems now capable of using webcams, making it more user-friendly for both participants and researchers[7,19-21].

The present study was aimed to investigate the ability of real time video-based gaze tracking system in detecting and diagnosis of cranial nerve palsy affecting extraocular muscles, making it easier, more cost-effective, and more objective. With this gaze tracking system, it is anticipated that even mild abducens nerve palsy can be detected.

PARTICIPANTS AND METHODS

Ethical Approval This study was approved by the Medical and Health Research Ethics Committee, Faculty of Medicine, Public Health and Nursing, Gadjah Mada University KE/FK/0191/EC/2023 on 8 February 2023. Informed consent forms were provided to all subjects prior to the start of the examination.

Study Design This is a cross-sectional observational analytical study design. The primary outcome was comparing the visual angles between the abducens nerve palsy eye group and the healthy eye group using the gaze tracking system. The secondary outcome was comparing the visual angles between the pre-treatment group and the post-treatment group.

Settings and Participants The population of this study was the patients of the Neuro-Ophthalmology Clinic at Sardjito General Hospital, Yogyakarta, Indonesia, who have been diagnosed with abducens nerve palsy based on clinical examination from January to December 2023. The total subjects were 39 and taken by using convenience sampling

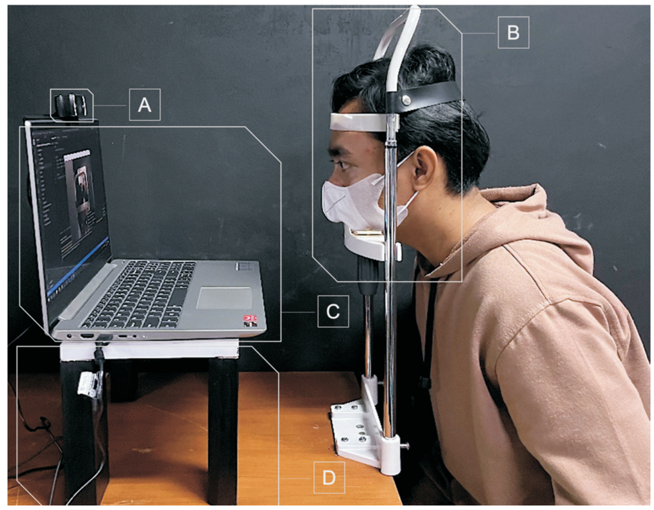


Figure 1 Apparatus set-up A: Webcam camera; B: Head mounting for head fixation and height adjustment; C: Laptop computer; D: Laptop stand.

techniques. The inclusion criteria for the subjects were patients who were diagnosed with unilateral abducens nerve palsy by the neuro-ophthalmologist, aged above 17y and want to participate in this study. The exclusion criteria were patients with another ocular disease such as comitant strabismus, congenital strabismus, and extraocular muscle entrapment; patients with poor visual acuity 20/200 or less; and not cooperative.

Apparatus and Data Measurement The GENICULA system (Gaze Tracking Artificial Intelligence for Ocular Motor Palsy) is a real time video-based gaze tracking program written in phyton code using visual studio application. It has been copyrighted from the Ministry of Law and Human Rights of Indonesia (Copyright number: EC00202299023, December 2022). The system using a laptop with minimal resolution of 1366×768 and a frame rate of 120 Hz with additional Logitech C922 Webcam Pro was used as the eye tracker. The subject was using the head rest and positioned 40 centimeter in front of the laptop (Figure 1).

The steps in the GENICULA application include calibration, configuration, eye tracker/gazer menu, stimulus presentation. At the beginning of the examination, system calibration was performed by asking the subject to look at four green points (up, down, right, and left), followed by pressing the corresponding button according to the direction of their gaze. The basic requirements for running GENICULA application are: opencv-python==4.6.0.66; mediapipe==0.8.10.1; protobuf==3.20.1; tk==0.1.0; tkcalendar==1.6.1; pandas==1.4.3; PyYAML==6.0. The trials started with a green dot at the center of the monitor, then a red circle was our gaze tracker (Figure 2). The green dot will appear in 9 positions alternately and the patient was asked to glance at the green dot (Figure 3). The visual angle will be calculated using the formula that was installed in the program

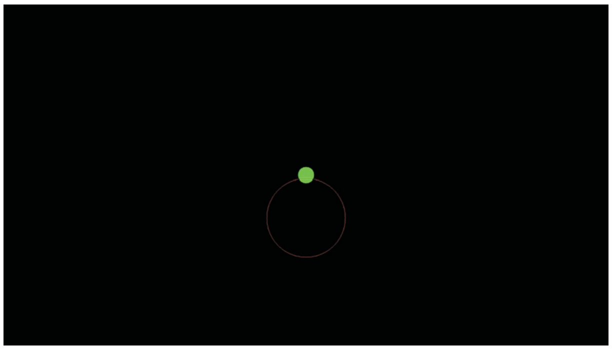


Figure 2 The green dot with a red circle (red circle indicates the real time eye movement).

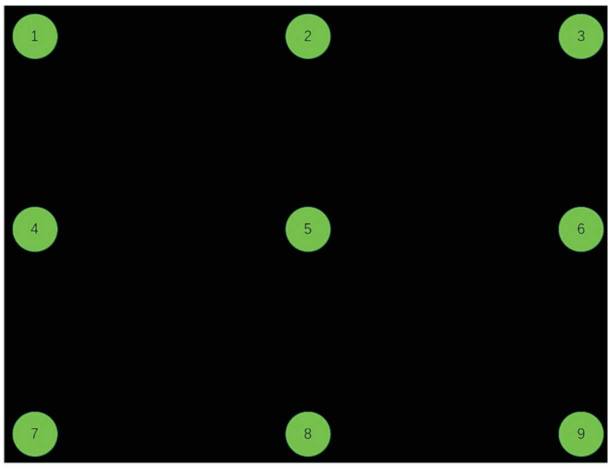


Figure 3 Total 9 positions of gaze.

(Figure 4). For the right eye, the visual angle of lateral gaze was number 6, and for the left eye was number 4 (Figure 3)[22].

Data Analysis The results of the visual angle will be shown in the GENICULA© application *via* Microsoft Excel. The results were then analyzed using Microsoft Excel and IBM SPSS Statistics 25 applications. The analytical method used was the Mann-Whitney test to see the difference in visual angles between the abducens nerve palsy eye group and the healthy eye group. To see the comparison of the visual angles between the pre-treatment group and the post-treatment group, the Wilcoxon signed rank test was used.

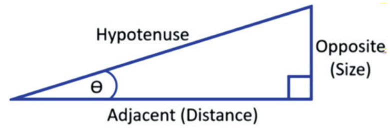
RESULTS

Characteristics of Study Subjects The subjects' characteristics of the abducens nerve palsy patients are shown in Table 1.

Comparison the Visual Angle Between the Abducens Palsy Group and the Healthy Eye Group The comparison of the mean visual angle between the abducens palsy group and the healthy eye group can be seen in Figure 5.

Comparison the Visual Angle Between the Abducens Palsy Group Before and After Treatment The comparison of the mean visual angle between the abducens palsy group before and after treatment can be seen in Figure 6.

Cut-off Analysis Based on Sensitivity and Specificity Test The cut-off value for visual angle based on sensitivity and specificity test was 23.435 degree of visual angle (cut-off sensitivity: 59% and specificity: 61.5%). Values below this threshold indicate abducens nerve palsy, while values above it is considered within the normal range (Figures 7 and 8).



$$\theta = \tan\frac{opposite\ (size)}{adjacent\ (distance)}$$

Figure 4 Formula of visual angle (θ is the calculated visual angle).

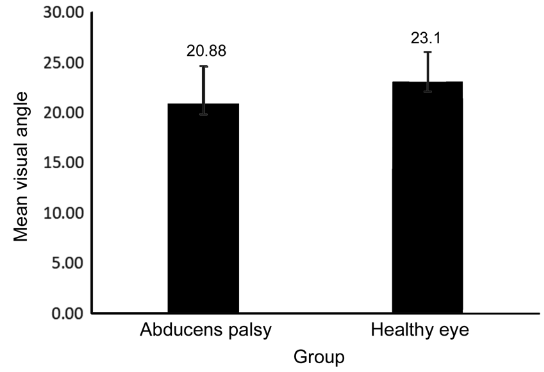


Figure 5 The Visual angle comparison of abducens palsy (n=39 eyes) and healthy eye (n=39 eyes; P=0.011).

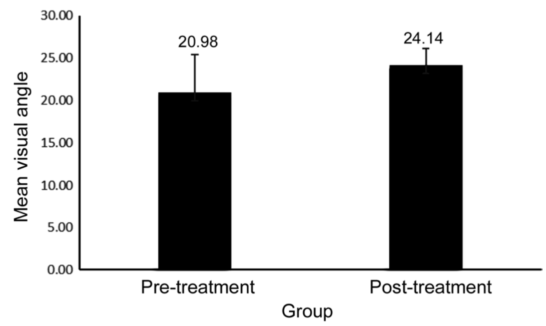


Figure 6 The visual angle comparison of abducens pre-treatment group (n=13) and post-treatment (n=13) group (P=0.039).

Table 1 Subject characteristics n=39 (%)

Variable	Total
Age, mean±SD	46.54±15.67
<40y	12 (30.77)
≥40y	27 (69.23)
Sex	
Male	17 (43.59)
Female	22 (56.41)
Etiology	
Microvascular	24 (61.54)
Tumor	6 (15.38)
Trauma	6 (15.38)
Idiopathic	3 (7.69)

DISCUSSION

The mean visual angle of the abducens palsy group was smaller than the healthy eye group and it was statistically significant. Additionally, the post-treatment abducens palsy

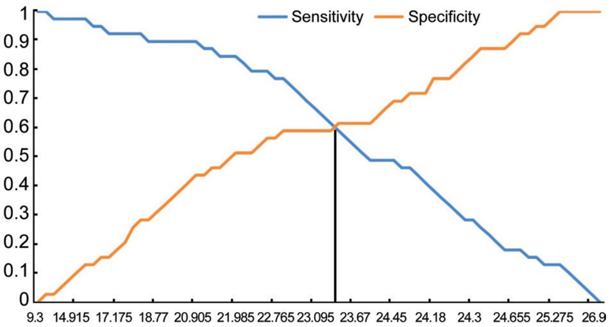


Figure 7 Cut-off sensitivity and specificity.

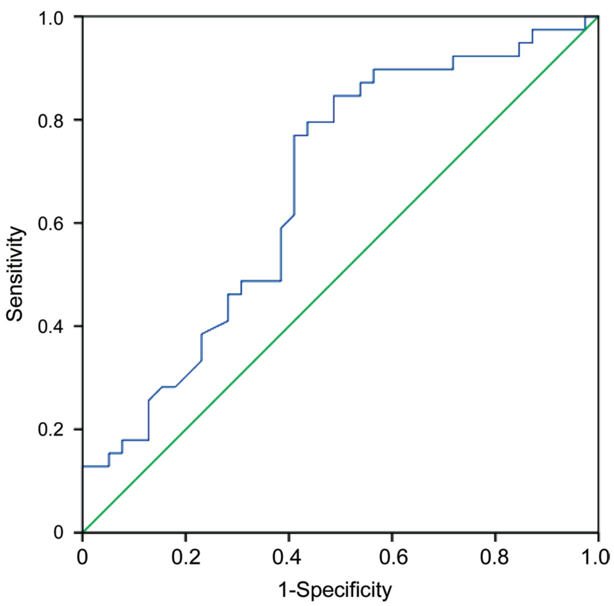


Figure 8 Receiver operating characteristic (ROC) curve with area under the curve (AUC): 0.667 (more than 0.5).

group demonstrated a visual angle improvement compared to the pre-treatment measurements. These results align with expectations, as a smaller visual angle is observed in cases of Abducens palsy. The GENICULA application was used to objectively measure the visual angle. However, no previous studies have established a cut-off point for the visual angle to classify the abducens palsy diagnosis. Lim *et al*[23] described a photographic method for measuring ocular maximum versions in the nine cardinal positions of gaze. In our study, we modified this method by measuring the visual angle from the central point to each of the nine cardinal positions of gaze. This approach allows us to obtain precise visual angle measurements. Specifically, because we focused on abducens nerve palsy, we measured position 4 for the left eye and position 6 for the right eye, corresponding to lateral gaze (Figure 2).

Currently, the degree of palsy is assessed using the cover-uncover test, Krimsky test, and Maddox test. Additionally, some clinicians use a simple grading scale, assigning scores from -4 to 0 to +4 to classify the degree of the palsy. If an abduction deficit was present, it was assessed on a scale from -1 to -4 during duction and version ocular motility testing, following a grading method similar to the Jampolsky ranking scale[7,24-25]. However, these methods rely on subjective interpretation, leading to potential variability in results. We hope that the use of GENICULA can reduce result variability and subjectivity. This would enable easier and more consistent examination of patients with abducens palsy.

In conclusion, the GENICULA real time video-based gaze tracking program application was easy to use, efficient, and accurate, as well as it is cheap in development. It was shown that a slight decrease in visual angle measurement can be detected using GENICULA. Therefore, this system is promising for future use as objective deviation angle detection method for ocular motor palsy.

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Conflicts of Interest: Angsana NC, None; **Indriasari AD,** None; **Mahayana IT,** None.

REFERENCES

1 Graham C, Mohseni M. Abducens Nerve Palsy. In: *StatPearls*. 2022. https://pubmed.ncbi.nlm.nih.gov/29489275/

2 Nguyen V, Varacallo M. Neuroanatomy, Cranial Nerve 6 (Abducens). *StatPearls*. 2019;6(Cn Vi):4–6. http://www.ncbi.nlm.nih.gov/pubmed/28613463.

3 Moore KL, Dalley AF, Agur AM. Cranial nerves. In: *Clinically Oriented Anatomy*. 6th ed. Wolters Kluwer - LIppincott Williams & Wilkins; 2010:1053-1086.

4 Al Kahtani ES, Khandekar R, Al-Rubeaan K, *et al*. Assessment of the prevalence and risk factors of ophthalmoplegia among diabetic patients in a large national diabetes registry cohort. *BMC Ophthalmol* 2016;16:118.

5 Erdal Y, Gunes T, Emre U. Isolated abducens nerve palsy: comparison of microvascular and other causes. *North Clin Istanb* 2022;9(4):353-357.

6 Husain ZI, AlSayegh R, Humaidan H. A case report of isolated abducens nerve palsy: idiopathic or ophthalmoplegic neuropathy *Egypt J Neurol Psychiatry Neurosurg* 2021;57(1):162.

7 Carter BT, Luke SG. Best practices in eye tracking research. *Int J Psychophysiol* 2020;155:49-62.

8 Khan AO, Chang TCP, El-Dairi MA, *et al*. *Basic and Clinical Science Course Section 6: Pediatric Ophthalmology and Strabismus*. San Fransisco: American Academy of Ophthalmology 2024.

9 Chen ZH, Fu H, Lo WL, *et al*. Strabismus recognition using eye-tracking data and convolutional neural networks. *J Healthc Eng* 2018;2018:7692198.

10 Garcia SSS, Santiago APD, Directo PMC. Evaluation of a hirschberg test-based application for measuring ocular alignment and detecting strabismus. *Curr Eye Res* 2021;46(11):1768-1776.

11 Elder C, Hainline C, Galetta SL, *et al*. Isolated abducens nerve palsy: update on evaluation and diagnosis. *Curr Neurol Neurosci Rep* 2016;16(8):69.

12 Blumenfeld H. *Neuroanatomy through Clinical Cases*. 2nd ed. Sunderland: Sinauer Associates 2010.

13 Rapuano CJ, Stout JT, McCannel CA. Basic and Clinical Science Course Section 5: Neuro-Ophthalmology. San Fransisco: American Academy of Ophthalmology 2022;246-248.

14 Nyström M, Hooge ITC, Hessels RS, *et al*. The fundamentals of eye tracking part 3: How to choose an eye tracker. *Behav Res Methods* 2025;57(2):67.

15 Adhanom IB, MacNeilage P, Folmer E. Eye tracking in virtual reality: a broad review of applications and challenges. *Virtual Real* 2023;27(2):1481-1505.

16 Pleshkov M, Zaitsev V, Starkov D, *et al*. Comparison of EOG and VOG obtained eye movements during horizontal head impulse testing. *Front Neurol* 2022;13:917413.

17 Eggert T. Eye movement recordings: methods. *Dev Ophthalmol* 2007;40:15-34.

18 Larrazabal AJ, García Cena CE, Martínez CE. Video-oculography eye tracking towards clinical applications: a review. *Comput Biol Med* 2019;108:57-66.

19 Warszawski U, Płużyczka M. The first hundred years: a history of eye tracking as a research method. *Appl Linguist Pap* 2018;4/2018(25): 101-116.

20 Saxena S, Fink LK, Lange EB. Deep learning models for webcam eye tracking in online experiments. *Behav Res Meth* 2024;56(4):3487-3503.

21 Kaduk T, Goeke C, Finger H, *et al*. Webcam eye tracking close to laboratory standards: Comparing a new webcam-based system and the EyeLink 1000. *Behav Res Meth* 2024;56(5):5002-5022.

22 Li Q, Joo SJ, Yeatman JD *et al.* Controlling for participants' viewing distance in large-scale, psychophysical online experiments using a virtual chinrest. *Sci Rep* 2020;10(1):904.

23 Lim HW, Lee DE, Lee JW, *et al*. Clinical measurement of the angle of ocular movements in the nine cardinal positions of gaze. *Ophthalmology* 2014;121(4):870-876.

24 Schalij-Delfos NE, de Graaf ME, Treffers WF, *et al*. Long term follow up of premature infants: detection of strabismus, amblyopia, and refractive errors. *Br J Ophthalmol* 2000;84(9):963-967.

25 Pihlblad MS, Yuen T, Pihlblad MS, *et al*. Assessment of eye movements ocular rotations assessment of eye alignment. *AAO Eyewiki* 2024:1-8.