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# **APPLICABILITY OF FUNDUS PHOTOGRAPHY IN EXAMINATION OF NEUROLOGICAL EMERGENCY ROOM PATIENTS COMPARED TO OPHTHALMOSCOPY**

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# Abstract

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## Background

Examination of the fundus is an important part of the diagnostics of several acute neurological disorders. However, dilation of the pupil is not recommended for neurological patients, which complicates ophthalmoscopy. Due to a failed ophthalmoscopy, a finding suggestive of increased intracranial pressure or other medical condition requiring immediate treatment may go unnoticed. In our pilot study we investigated whether a portable fundus camera could produce better results than an ophthalmoscope in fundus examinations of neurological emergency patients.

## Population and methods

The population consisted of 60 patients who were treated in the neurological emergency department at Oulu University Hospital between 18 August 2016 and 31 May 2017. The inclusion criteria were: age at least 18, voluntary participation and a work diagnosis of either headache, cerebrovascular disorder or acute confusional state (delirium). Some of the patients showed multiple symptoms. Seventeen of the patients were male and forty-three female. The median age was 59 years. Thirty patients suffered from a headache, 28 from a cerebrovascular disorder and seven from an acute confusional state. Patient co-operation was evaluated by determining a Modified Rankin Score and Glasgow Coma Score (GCS).

Patients were subjected to a non-mydriatic fundus examination first with an ophthalmoscope and then with a SmartScope Pro fundus camera. The success of the examination by both methods was assessed using three categories: succeeded, partially succeeded, failed. Possible fundus changes were recorded for subsequent comparison to an ophthalmologist's opinion.

## Results

Fundus photography in the fundus examination succeeded in 56 (93.3%), partially succeeded in 2 (3.3%) and failed in 2 (3.3%) cases. Ophthalmoscopy in the fundus examination succeeded in 35 (58.3%), partially succeeded in 14 (23.3%) and failed in 11 (18.3%) cases. The statistical significance of the difference is  $p < 0.0005$ . In the images of 58 patients, the researcher and the ophthalmologist made the same findings in 54 cases (93%). In six cases (7%), the researcher had failed to detect a non-critical finding.

## Conclusions

The fundus camera is better suited for a neurological fundus examination than an ophthalmoscope. The difference is statistically and clinically significant. Further research is needed.

**Key words:** Fundus camera, ophthalmoscope, fundoscopy, neurology, ophthalmology

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# 1. INTRODUCTION

## 1.1 Theoretical background

Examination of the fundus is a vitally important part of the diagnostics of several acute neurological disorders (Bruce, Lamirel, Wright et al. 2011, Bruce, Biousse et al. 2015, Bruce 2015). However, direct ophthalmoscopy is difficult without dilating the patient's pupils, which hinders neurological monitoring, especially if the patient's co-operation is poor due to their neurological condition (Thulasi, Fraser et al. 2013, Bruce 2015). Due to a failed ophthalmoscopy, findings may go unnoticed that threaten the patient's sight or are even life-threatening and would require immediate treatment (Bruce et al. 2015, Bruce, Lamirel, Biousse et al. 2011, Bruce 2015). Fundus examination can provide information on, for example, increased intracranial pressure and cerebrovascular disorders requiring further tests and procedures (Thulasi et al. 2013, Bruce 2015, Vuong, Thulasi et al. 2015).

Fundus photography is a quick examination that does not require the dilation of the pupil and, therefore, does not hinder the neurological monitoring of the patient (Bruce et al. 2011, Lamirel, Bruce et al. 2012). The fundus camera is also more patient-friendly compared to a conventional ophthalmoscope because in fundus photography, the amount of light directed into the eye is much smaller. Fundus photography can also be taught to nurses quickly and easily, which could speed up the treatment process (Bruce et al. 2011, Lamirel et al. 2012). According to previous studies, fundus photography provides diagnostically high quality images that help detect findings that have been missed by physicians carrying out traditional direct ophthalmoscopy (Bruce, Thulasi et al. 2013, Bruce et al. 2011, Vuong et al. 2015). Admittedly, in these studies the patients have been co-operative. This study may provide additional information on the suitability of more difficult patient groups for fundus photography.

## 1.2 Objectives of the study

The aim of our qualitative pilot study is to investigate the suitability of a non-mydratic fundus camera for the examination of neurological emergency room patients, compared to traditional direct ophthalmoscopy. Our hypothesis is that a fundus camera provides a better picture of the condition of the patient's fundus than direct ophthalmoscopy. Earlier studies have found that fundus photography provides additional diagnostic benefit compared to direct ophthalmoscopy, but in our study we purposely examined more difficult, poorly co-operative patient groups such as headache and cerebrovascular disorder patients and patients suffering from an acute confusional state. Secondly, we also evaluated the diagnostic differences between the interpretations of the photographic fundus images by an on-call physician and an ophthalmologist. Our hypothesis is that the on-call physician is able to detect the most significant findings from the photographic fundus image almost as well as the ophthalmologist.

## 1.3 Significance of the study

Several studies have already been conducted on the benefits of using a fundus camera. On the other hand, there are hardly any previous studies on the assessment of the status of the fundus in patients

with decreased level of consciousness and in patients who are poorly co-operative. This study investigates the applicability of fundus photography in the examination of difficult-to-examine patients. Based on the results, further research can be planned for larger patient populations and consideration can be given to the introduction of fundus cameras as part of the routine examination of neurological emergency patients in support of conventional ophthalmoscopy. The examination can reveal various contraindications of treatments and diagnostic tests in patients, such as hemorrhagic retinopathy and papilledema.

#### 1.4 Ethical aspects

Each patient volunteering for this study or, alternatively, his or her close relative, if the patient was not able to decide on his or her treatment, was asked for informed written consent. Preliminary authorisation could also be asked by telephone, but no data was used without a written permission. The study was explained to the patient/close relative either verbally or in writing and the patient had the right to withdraw from the study without giving any particular reason. Examinations were conducted so that they did not slow down the patient's actual treatment. It is possible that the examination did not have immediate benefit to the patient, but if the researcher noticed a significant finding that had not emerged in a previous examination, the finding was immediately reported to the treating physician.

Fundus examination is non-invasive and painless and does not cause any health risks. During the examination, the patient may, however, experience short-term irritation by light. The research material is kept under lock and key in the hospital where unauthorised persons cannot access patient data. The participants remain anonymous when the results of the study are published. The study does not incur any additional cost to the patient, and the patients are not remunerated.

The primary ethical concern was that some of the examinees, due to their illness, were unable to give their informed consent. We solved this problem by asking the consent of a close family member of the examinee, as explained above. The examination did not and could not cause any health hazard to the examinees—on the contrary, it enabled the identification of factors relevant to the patient's treatment, such as an indication of increased intracranial pressure that would otherwise have gone unnoticed in a poorly co-operative patient.

### 3. DATA

The study material consisted of 60 adult neurological emergency room patients who volunteered for the study. Our aim was to include 20 cerebrovascular disorder patients, 20 headache patients and 20 patients suffering from acute confusional state, who, due to their condition, were poorly co-operative for a fundus examination. The patients were categorised according to work diagnoses. The criterion for acute confusional state was a lower-than-normal (15) score on the Glasgow coma scale. Patients were asked for a written consent to be examined and if a patient was unable to give his or her consent due to their condition, we asked for written consent from a close family member. If the consent was obtained from a close family member, we tried to obtain the patient's consent afterwards, either by telephone or in writing.

Data was gathered between 18 August 2016 and 31 May 2017 at the Oulu region joint emergency department. Table 1 shows some of the key indicators of the study population. Sixty patients participated in the study. We were not quite able to meet the original goal of 20 patients per inclusion criterion, because there were very few patients with acute confusional state whose next of kin were able to give their consent for the examination. Some patients met multiple inclusion criteria. Twenty-eight of the examinees were in the cerebrovascular disorder category, thirty in the headache category and seven in the confusional state category. Seventeen (28.3%) patients were men and forty-three (71.7%) women. The median age of the examinees was 59.5 years and the standard deviation 18.9 years. The minimum age was 18 and maximum 88.

Table 1. Key figures

	Freq.(%)	Average	Median	SD	Min.	Max.
Age		55,6	59,5	18,9	18	88
Gender (male/female)	17/43 (28% / 72%)					
GCS		14,8	15	0,6	11	15
MRS		0,9	1	1,1	0	4
Finding in optic papilla	6 (10%)					
Finding in retina	8 (13%)					
Cerebrovascular disorder	28 (47%)					
Headache	30 (50%)					
Confused	7 (12%)					

## 4. METHODS

The examinees were subjected to fundus photography on both eyes using a non-mydratic fundus camera Optomed Smartscope Pro, as well as direct ophthalmoscopy on both eyes using a Welch Allyn 97200-BIL Elite LED ophthalmoscope without pupil dilation. The ophthalmoscopy was performed prior to the fundus photography. Both the ophthalmoscopy and fundus photography were assessed using three categories: successful, partially successful and failed. The criterion for a successful fundus examination was the successful examination of both optic papillae. In a partially successful examination, the optic papilla of at least one eye was examined completely. In a failed examination, neither of the optic papillae could be examined completely.

The fundus was examined for papilledema, spontaneous venous pulsations, retinal redness/paleness and hemorrhagic retinopathy. The fundus photographs were primarily examined by the researcher Mikael Alm and, afterwards, Nina Hautala, specialist in ophthalmology, together with the researcher, to compare the diagnostic differences between the ophthalmologist and the on-call physician. The patients examined were also assessed for a GCS and modified Rankin Scale (MRS) score. The GCS and MRS are used for evaluating the co-operative ability of the patient.

Modified Rankin Scale (MRS):

0 = No symptoms

1 = No significant disability despite symptoms; able to carry out all usual duties and activities

2 = Slight disability; unable to carry out all previous activities, but able to look after own affairs without assistance

3 = Moderate disability; requiring some help, but able to walk without assistance

4 = Moderately severe disability; unable to walk and attend to bodily needs without assistance

5 = Severe disability; bedridden, incontinent and requiring constant nursing care and attention

6 = Dead

The fundus camera manufacturer trained the researcher to use the camera and taught the right technique. Before starting collecting data, the researcher practised by photographing the fundi of ten volunteers.

The results were analysed using IBM SPSS Statistics software. By comparing the groups, we tried to find out whether there is a statistically significant difference between fundus photography and direct ophthalmoscopy, and what is the most appropriate form of fundus examination for each patient group or whether fundus examination is at all possible for a particular patient group.

## 5. RESULTS

Fundus photography yielded significantly more diagnostic information than the ophthalmoscope. Table 2 shows the success rates of both examination methods. Statistical significance was calculated using the marginal homogeneity test and the MacNemar-Bowker test. The null hypothesis of the marginal homogeneity test is that the distribution of the ophthalmoscopy and fundus photography results are similar. The resulting value  $p < 0.0005$  supports the counter-hypothesis that the distributions of the results of these examination methods are different. The MacNemar-Bowker test is a kind of symmetry-hypothesis test. The null hypothesis is that the both examination methods perform equally well. The resulting value  $p < 0.0005$  supports the counter-hypothesis, i.e. the difference between the success rates of the two examination methods is statistically significant. Figure 1 and Figure 2 show pie charts of ophthalmoscopy and fundus photography successes in all patient groups combined.

Table 2. Success of fundus examination in all patient groups combined.

	Ophthalmoscopy (%)	Fundus photography (%)	p-value
Success	35 (58,3)	56 (93,3)	
Partial success	14 (23,3)	2 (3,3)	
Failed	11 (18,3)	2 (3,3)	
Marginal homogeneity test			$p < 0,0005$
MacNemar-Bowker test			$p < 0,0005$



## Ophthalmoscopy

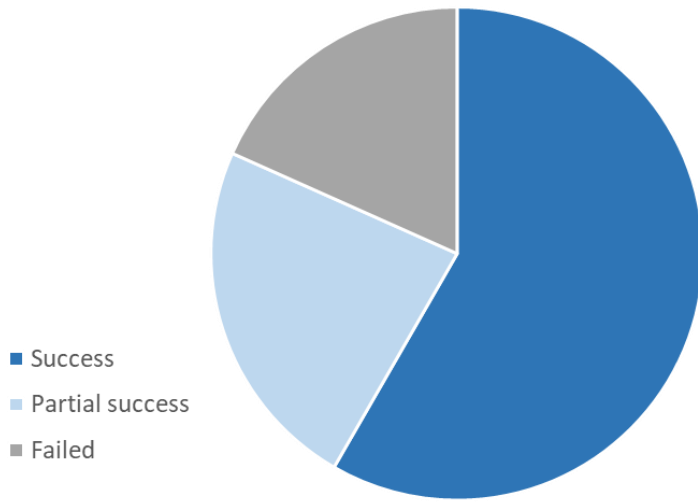


Figure 1. Success of ophthalmoscopy in all patient groups together.

## Fundus photography

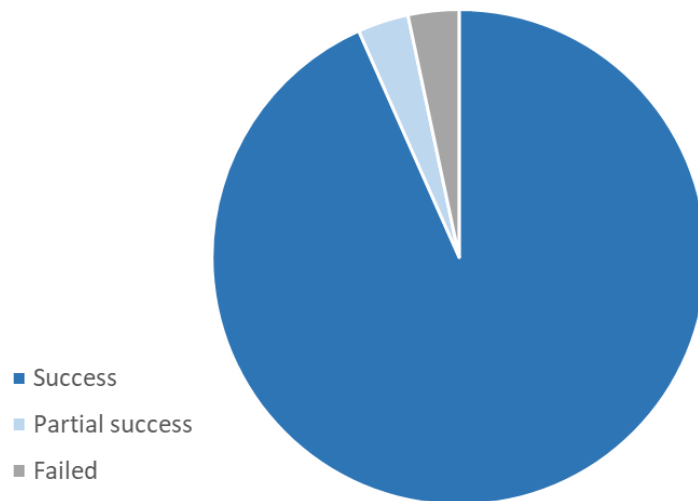


Figure 2. Success of fundus photography in all patient groups together.

If we categorise the patients in the data by symptoms and look at the fundus examination success rates in Tables 3.1 and 3.2, we can see that an acute confusional state predicts a failure of the

examination. The second most difficult cases to examine were the cerebrovascular disorder patients. The headache patients were the easiest to conduct a fundus examination on. This indicates good cooperation of headache patients compared to cerebrovascular disorder and delirium patients. The difference between the success rates of ophthalmoscopy and fundus photography was the biggest in cerebrovascular disorder patients; in this category, fundus photography was successful in 26 patients and ophthalmoscopy in 12 patients. The second biggest difference was observed in delirium patients, 5 vs. 3, and the smallest in the category of headache patients, 29 vs. 22. However, the small number of delirium patients makes it difficult to draw reliable conclusions in this regard and the matter should be investigated with a larger sample size.

Table 3.1. Success of ophthalmoscopy by symptoms

	Cerebrovascular disorder	Headache	Confused
<b>Success</b>	12 (42,9%)	22 (73,3%)	3 (42,9%)
<b>Partial success</b>	9 (32,1%)	5 (16,7%)	0 (0%)
<b>Failed</b>	7 (25%)	3 (10%)	4 (57,1%)

Table 3.2. Success of fundus photography by symptoms

	Cerebrovascular disorder	Headache	Confused
<b>Success</b>	26 (92,9%)	29 (96,7%)	5 (71,4%)
<b>Partial success</b>	0 (0%)	1 (3,3%)	1 (14,3%)
<b>Failed</b>	2 (7,1%)	0 (0%)	1 (14,3%)

The data also showed that the fundus camera did not perform worse than ophthalmoscopy on any patient, but if ophthalmoscopy failed or succeeded in part, fundus photography was also more challenging. The most common causes of ophthalmoscopy and fundus photography failure were, from the most common to the least common: miotic pupils, oculomotor disorder, ptosis, light sensitivity. The majority of the failures were caused by too small pupil size.

Figure 3 shows an example of a fundus image in the research data. Existing fundus cameras available on the market are more than capable of meeting the fundus examination needs of on-call neurologists and general practitioners. Image quality is excellent and the use of mydriatic agents is not necessary. The device is so easy to use that it could encourage physicians to examine patients' fundi more routinely, as the ophthalmoscopy of a non-dilated pupil can be challenging even for experienced clinicians.

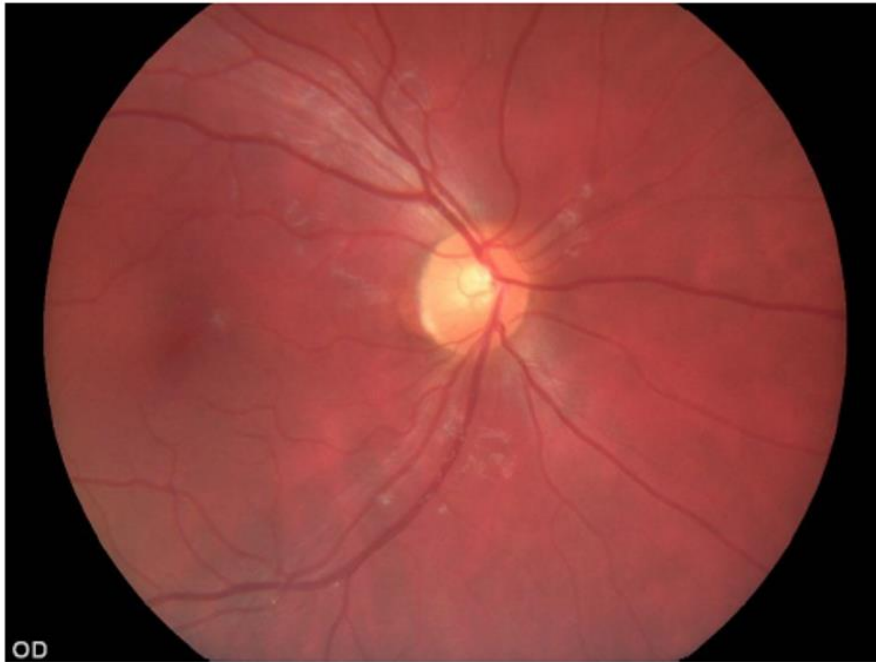


Figure 3. A normal fundus finding in a patient.

In our study, the patients were asked whether the referring physician or on-call neurologist had examined their fundi. Table 4 shows the patients' answers. It should be noted, however, that some of the patients were recruited and interviewed before the on-call neurologist had a chance to examine them. However, fundus examination is part of a neurological patient's status examination, so the referring physician should preferably conduct it when carrying out a status examination. Only 16.7% of the patients who answered the questions had had their fundi examined, and 83.3% had not been examined.

Table 4. An on-call physician/referring physician has examined the fundi.

	Yes	No
Has the on-call physician/referring physician examined the fundi?	10 (16,7%)	50 (83,3%)

The fundus photographs were reviewed with Nina Hautala, a specialist in ophthalmology experienced in interpreting fundus images. The aim was to find out how an ophthalmologist's diagnostic skills compare to the diagnostic capabilities of an on-call neurologist or general practitioner, in this case the researcher. The researcher had received a brief introduction to the most important neuro-ophthalmologic findings in fundus images before starting the collection of data. The researcher

analysed the images immediately after the photography and recorded the detected anomalies on a study form. Table 5 lists the observations made by the researcher and the ophthalmologist.

Table 5. Findings by interpreter

	Found by researcher	Found by ophthalmologist
Abnormal finding in retina	5	8
Abnormal finding in optic papilla	5	6

In the images of 58 patients, the researcher and the ophthalmologist made the same findings in 54 cases (93%). In four cases (7%), the patient had minor hemorrhages in the retina or optic papilla, which the researcher did not notice in the primary interpretation. The hemorrhages were, however, so small that they would not have been a contraindication to thrombolysis or endangered the patient's safety critically. In addition, one patient was suspected to have a small cholesterol embolism in a retinal vein, which was unnoticed by the researcher. The diagnostic success was thus quite good even with such a short briefing. Incidental findings were also made: one patient was diagnosed with ocular findings suggestive of glaucoma, another one had diabetic retinopathy, and two patients had a nevus in the retina, one requiring follow-up due to cancer risk. In three cases, the neurologist interpreting the images consulted an on-call ophthalmologist urgently. The fundus images significantly sped up the consultation process. In terms of time, there appeared to be no significant differences in the speed of fundus photography and ophthalmoscopy, although no times were clocked in this study.

## 6. CONCLUSIONS

Fundus examination in neurological emergency room patients involves quite a unique challenge: dilating the pupil is not recommended because of the requirements of neurological monitoring. This greatly increases the challenge associated with fundus examination. In addition, the symptoms of neurological patients may impair their co-operative ability, further complicating the examination. There exists evidence, based on previous studies, of the applicability of a fundus camera to fundus examinations at emergency departments but, as far as we know, no previous comparative study has been conducted on how the fundus camera and the ophthalmoscope perform in non-mydratic fundus examinations of neurological emergency patients.

In our pilot study we obtained, in line with our hypothesis, a statistically significant difference between the fundus camera and ophthalmoscope in respect of the success of the fundus examination, although our sample size was relatively small. Two separate tests produced a statistical significance of  $p < 0.0005$ , meaning the difference is statistically very significant. In addition to the statistical significance, the differences were so great that the clinical significance is also indisputable. More research on the subject is needed with larger samples—both for neurological patients and patients in other specialties utilising fundus examination. Based on our study, it would appear that the fundus camera is well suited to the special requirements of neurological emergency services and to examining challenging patients. The results of our study also support the findings of earlier studies conducted on fundus photography.

Our goal was to have poorly co-operative patients in the study by choosing the work diagnoses of cerebrovascular disorder, headache and acute confusional state as inclusion criteria, but most of the patients recruited for the study co-operated rather well in the examination. The research permit stipulated that the examinees or their next of kin give their written consent for participation in the fundus examination, which meant that the examination of more challenging patients, i.e. those suffering from acute confusional state, was in most cases impossible as their next of kin often was not available to give their informed written consent. More research is therefore needed on fundus photography of severely confused patients. The researcher's preliminary interpretation of the fundus images was also quite good when compared to an ophthalmologist's interpretation. Thus, our second hypothesis concerning the accuracy of the researcher's and ophthalmologist's fundus image interpretations was also correct. It remains to be speculated how large a difference there would be in the diagnostic accuracy between non-mydratic ophthalmoscopy performed by an on-call physician and non-mydratic ophthalmoscopy performed by an ophthalmologist, but as ophthalmoscopy and the interpretation thereof is fairly subjective compared to fundus imaging, it may prove rather challenging to investigate this difference.

Incidental findings made from the fundus images included diabetic retinopathy, bleeding, findings suggestive of glaucoma and large nevi that require follow-up due to cancer risk. Fundus images stored immediately in electronic form in patient records provide a new opportunity to consult an ophthalmologist, even remotely, and to diagnose these common illnesses already at primary health care. The technology already exists for this kind of digitalisation of health care. By teaching clinicians how to analyse fundus images we could provide them with the ability to screen for diseases involving

fundus changes. Thus, with a very small investment, we would be able to diagnose these common diseases earlier, generating savings in the long term.

As far as cost is concerned, fundus cameras are more expensive than conventional ophthalmoscopes. The fundus camera used in the study is in the €5,500 price range, which, as a one time investment, is not very much compared to many other diagnostic instruments. We are then left with the question whether the better performance and better diagnostics are worth the price. In any case, the differences are quite significant, so perhaps in the near future, the fundus camera will become an essential tool in clinical work in addition to the ophthalmoscope.

The study indicated that referring or on-call physicians do not necessarily examine neurological patients' fundi very systematically. It is likely that there are many reasons for this, the most important ones being the difficulty of the examination due to the non-mydriatic pupil, lack of routine and, perhaps, skepticism with regard to the detection of fundus findings or their significance. With a fundus camera, a physician does not have to rely so heavily on his or her visual memory, as he or she will be able to examine a large area of the fundus as a whole. The ease of fundus photography and consultation could encourage both the referring and the on-call physician to once again include the fundus examination in their routine neurological status assessment.

With regard to potential sources of error in the study, one should bear in mind that the success of ophthalmoscopy, as well as fundus photography, depends on the skills of the clinician. The level of skill of the researcher may thus distort the results. Another possible source of error is the accuracy of the work diagnoses of the neurological emergency room patients. A flawed work diagnosis may mean that patients were enrolled for the study whose problem was not neurological. The conditions in which the examination was conducted were often suboptimal. Some of the patients were examined in a separate room, while some had to be examined in the emergency room lobby where the lighting and environmental distractions hampered the examination. In particular, the most seriously ill patients had to be examined in the emergency room lobby instead of a separate room.

## REFERENCES

BRUCE, B.B., 2015. Nonmydriatic Ocular Fundus Photography in the Emergency Department: How It Can Benefit Neurologists. *Seminars in neurology*, 35(5), pp. 491-495.

BRUCE, B.B., BIOUSSE, V. and NEWMAN, N.J., 2015. Nonmydriatic ocular fundus photography in neurologic emergencies. *JAMA Neurology*, 72(4), pp. 455-459.

BRUCE, B.B., LAMIREL, C., BIOUSSE, V., WARD, A., HEILPERN, K.L., NEWMAN, N.J. and WRIGHT, D.W., 2011. Feasibility of nonmydriatic ocular fundus photography in the emergency department: Phase I of the FOTO-ED study. *Academic Emergency Medicine*, 18(9), pp. 928-933.

BRUCE, B.B., LAMIREL, C., WRIGHT, D.W., WARD, A., HEILPERN, K.L., BIOUSSE, V. and NEWMAN, N.J., 2011. Nonmydriatic ocular fundus photography in the emergency department. *New England Journal of Medicine*, 364(4), pp. 387-389.

BRUCE, B.B., THULASI, P., FRASER, C.L., KEADEY, M.T., WARD, A., HEILPERN, K.L., WRIGHT, D.W., NEWMAN, N.J. and BIOUSSE, V., 2013. Diagnostic Accuracy and Use of Nonmydriatic Ocular Fundus Photography by Emergency Physicians: Phase II of the FOTO-ED Study. *Annals of Emergency Medicine*, 62(1), pp. 28-33.e1.

LAMIREL, C., BRUCE, B.B., WRIGHT, D.W., DELANEY, K.P., NEWMAN, N.J. and BIOUSSE, V., 2012. Quality of Nonmydriatic Digital Fundus Photography Obtained by Nurse Practitioners in the Emergency Department: The FOTO-ED Study. *Ophthalmology*, 119(3), pp. 617-624.

THULASI, P., FRASER, C.L., BIOUSSE, V., WRIGHT, D.W., NEWMAN, N.J. and BRUCE, B.B., 2013. Nonmydriatic ocular fundus photography among headache patients in an emergency department. *Neurology*, 80(5), pp. 432-437.

VUONG, L.N., THULASI, P., BIOUSSE, V., GARZA, P., WRIGHT, D.W., NEWMAN, N.J. and BRUCE, B.B., 2015. Ocular fundus photography of patients with focal neurologic deficits in an emergency department. *Neurology*, 85(3), pp. 256-262.