The risk of developing glaucoma increases with age. Some 2% of people over the age of 50 have glaucoma, and more than 5% of those over 75. There are estimated to be more than 60 million patients with glaucoma globally, of which around 6 million are categorised as being visually handicapped.

The challenging thing about glaucoma is that in its early stages it exhibits no or very few symptoms. Early diagnosis is very important because any damage that has already occurred cannot be reversed. The objective with treatment is to prevent any visual handicap caused by glaucoma. With most patients, the condition advances gradually over many years. However, with a small percentage of patients, the disease may lead to damage in a shorter period.

For purposes of glaucoma detection and identification of progressing speed, it would be best if healthcare systems found the high-risk cases as early as possible. Artificial intelligence models are currently being developed for early detection of glaucoma.

Researcher and project manager Ara Taaalas specialises in data science, artificial intelligence and machine learning algorithms in medicine. One of his research objectives, in a joint project involving the Institute for Molecular Medicine Finland and Terveystalo health clinic, is to develop effective learning algorithms for glaucoma detection. Previously, Taaalas modelled stem cell differentiation processes and worked in drug design.

According to Matti Seppänen, chief physician and Head of Ophthalmology at Terveystalo health clinic, glaucoma diagnosis and classification are based on the examination of the optic nerve head, nerve fibre layer and anterior chamber angle, intraocular pressure measurement, and a visual field test.

"The pathogenesis of glaucoma is not known, but damage to nerve cell structures probably contributes to glaucoma damage." Probably some 30–50 per cent of patients have intraocular pressure which is

In the future, an algorithm may diagnose glaucoma from fundus photos

Glaucoma is a progressive disease of the optic nerve that causes damage to the optic nerve head and nerve fibre layer.
considered normal (10–21 mmHg). Patients have an individual susceptibility to the development of glaucoma damage at different intraocular pressure levels. Some patients develop glaucoma damage at lower pressure levels, while other patients may have minor damage even at higher pressure levels.

“At the moment, a glaucoma diagnosis requires examination by an ophthalmologist and several additional examinations. The optic nerve head can be examined by means of, for example, biomicroscopy and stereo papilla photography. The nerve fibre layer can be examined with colour fundus photography or optical coherence tomography (OCT) of the nerve fibre layer."

During an examination, glaucoma may be suspected on the basis of the shape of the optic nerve head, for example. The structure of the optic nerve head can be evaluated with a measurement of the cup/disc ratio, meaning that the size of the optic nerve cup is compared to the size of the outer edge of the optic nerve head.

“Damage to the nerve fibre layer may show in an OCT examination as a thinned nerve fibre layer. In colour fundus photography, defects in the nerve fibre layer may also be discovered. A glaucoma diagnosis is often based on several examinations, and currently there is no single method for screening the entire population for glaucoma. Artificial intelligence applications may in the future bring considerable help for screening and diagnostics.”

Algorithm recognises patterns in nerve layers

When developing the artificial intelligence model, Ara Taalas focused on how the nerve layers of the fundus appear in the photographs. The algorithm will help to detect changes in the fundus pictures that can indicate damage to the nerve fibre layer. The purpose of the model is to find out whether subtle changes in the network in the fundus, as they become darker and more monotonous, can be linked to damage in the nerve fibre layer.

“This is one of the factors the model is designed to focus on. In the future, the model will be taught more nerve fibre patterns in the fundus. The purpose of these algorithms is to find ways that will help doctors to make decisions. And advanced artificial intelligence system may detect changes that not even the most experienced clinician can see.”

Examinations on the eye’s structure and operation involves variations caused by the examination method used, experience of the person assessing the case, and the patient and how serious the disease is. Evaluating the optic nerve head does not always result in sufficient accuracy using the current methods. The result of the visual field examination may be normal even if the optic nerve and nerve fibre layers have been damaged. This is because structural damage usually occurs before any visual field defects. If we are able to develop applications that examine more accurately and more efficiently any structural changes, glaucoma diagnoses may be made earlier.

According to Taalas, one application for the model could be that the artificial intelligence model is always used when performing an eye examination.

“Population surveys have found that up to half of those who have glaucoma have not actually been diagnosed with it. The existing screening methods are not cost-effective enough and a general screening of the population cannot be done for lack of sufficiently good methods. If artificial intelligence applications were able to identify with sufficient accuracy patients that have a higher-than-average susceptibility to develop glaucoma, it would be easier to screen out those among the population that do not yet have the symptoms and offer them early treatment for best results.”

One of the future versions is that during a visit to the opticians or healthcare worker, the examination would include fundus photography, and at the same time artificial intelligence would analyse the patient’s fundus photo. If artificial intelligence indicated that the patient had a higher risk than average to develop glaucoma, the patient...
would be referred to further examinations at an early stage.

With artificial intelligence applications, the division of work would probably change dramatically in the optical field and the diagnosis of eye diseases. This would also result in significantly higher numbers of patients being treated. As the age structure of the population is changing, the number of glaucoma patients in Finland will double from the current figures by 2030.

Taalas uses the computing services of Finland’s ELIXIR Center CSC. He develops models together with researchers in FIMM’s Machine Learning in Biomedicine team, and the same source code can be used on the computing servers of both CSC and Terveystalo.

“With artificial intelligence applications, the division of work would probably change dramatically in the optical field and the diagnosis of eye diseases.”

“Finland is at a high level in terms of data management, but individual healthcare actors typically do not have a comprehensive picture of their patients – patient data is often scattered between various service providers. When customers go to a different organisation, the data does not follow them, which may make diagnosis and treatment more difficult. From the viewpoint of a researcher, the ideal thing would be to have a site for the entire country where each patient’s medical history could be found in its entirety.”

Data description should also be standardised.

“The structure of patient data systems has a major effect on the usability of any data entered into it. Fields where data can be entered in free form may be convenient for the person typing it in, but cause a lot of trouble to data analysts when trying to utilise it. Analysts often have to do a lot of work to standardise the data and to identify entries that contain errors. Modern patient data systems have in this respect become better in that they are much more structured.”

Ari Turunen