Teknologisk Nyt
DØO

OCT-update

Which OCT should I buy ?

This is the question raised by many clinicians – not easy to answer

Af Birgit Sander, M.Sc. Ph.D.

OCT is becoming an integrated part of an ophthalmological clinic and at the same time, the development of technology and number of manufacturers have lead to concerns – do I buy the right one? Before investment, please take an overview of the past and future.

First generation Time-Domain OCT: The issue of using OCT in ophthalmology was introduced in 1991 (Huang) and the first commercially available OCT (also called OCT 1) was on the market in 1996. The instrument went through some technical improvements, the last version called OCT3 (or Stratus) has been used extensively in research and hospital clinics. This system is also called time domain or TD OCT based on the basic optical system, where the short coherence light stimulus from the source is directed towards a mirror and the eye and the reflected light leads to an inforced signal (positive interference). The time delay of light from various depths in the retina gives rise to a positive interference if the mirror is placed in an equivalent distance – ie. the mirror has to be moved to match the different layers of the retina (the A-scan). After finalizing one run through the retina, the system is moved and the next A-scan is taken. For the last versions of the machine, the TD system takes a maximum of 512 A-scans with a speed of 400 A-scans pr. seconds, typically used to scan a line of 6 mm (the B-scan).

Spectral Domain OCT

Time is critical and to speed up the system, the current generation has a fixed mirror, enabling scanning speeds of appr. 25.000 to 50.000 A-scans pr. sec. and experimental systems runs much faster. The increase in speed goes together with a change in the detecting system. Now the reference mirror is fixed and the very complex signal backscattered from the different depths of the retina is analysed instantaneously by a spectrometer and calculated by a Fouirer transformation to obtain standard images. Therefore, this system is termed Spectral Domain or Fourier Domain.

Which OCT ?

Many different instruments and protocols are available and you may want to image both the anterior and posterior segment. In the table included, you see the technical information provided by major companies marketing OCT's in the Nordic Countries. We also asked them to present the most outstanding macular scan of a healthy subject to give an impression of the maximal quality.

Basic technical information is given in table 1, including the aspects of averaging and anterior segment possibilities. The instruments are fairly similar with respect to the basic light sources, with a center wavelength of the incident light in the range 840-880 nm, the half bandwidth appr. 50 nm. Spectral Domain / Fourier Domain system are used in all instruments, with a trend towards faster scanning. All scans provided by the manufacturers (healthy subjects, macular scan) were of high quality with a clear visualisation of the retinal layers (not shown).

Though color images are impressive, the optimal visualisation is achieved with grey, where 256 shades are possible and one high-quality example is shown in figure 1 (healthy subject, imaged in our clinic with averaging of 100 B-scans), with a horisontal and a vertical scan through the fovea. For evaluation of quality, the appearance of retinal vessels are useful as the vessel should show up in high intensity in the inner retina, with a well demarcated shadow below (fig 1, right). The appearance of the posterior retina, and in particular the choroid, is dependent on absorption in the layers above and for this part of the eye, averaging is a great advantage.

With different kinds of pathology, where intraretinal scatter and absorption is a problem, the choice of instrument and the various details of scanning speed, protocol and averaging is important and may lead to substantial differences in difficult cases.

In daily routine, you also have other points of interest: Does the system match the rest of my clinic

Name	Resolution (optical) axial transversal	A-scans scans /sec max. number for a B.scan	Averaging Yes/No max.number	Anterior segment	Follow-up	Normative database Nerve fiber layer Retina	Additional features
Nidek RS-3000	7 µm 20 µm	53.000 1024	Yes 50	With adaptor	Yes	Yes Yes	SLO
Optovue OCT scanner	5 µm 15 µm	26.000 1024	Yes 50	With adaptor	Yes	Yes Yes	SLO, Color
Zeiss Cirrus OCT 4000	5 µm 15 µm	27.000 4096	Yes 20	Without adaptor	Yes	Yes Yes	SLO
Topcon 3D OCT-2000	5-6 µm ≤20 µm	27.000 4096	Yes 50	With adaptor	Yes	Yes Yes	IR CCD, Color
Opko / OTI	6 µm 15 µm	27.000 1024	Yes 25	With adaptor	Yes	Yes Yes	SLO, Microperimetry
Heidelberg Spectralis	7 µm 14 µm	40.000 1536	Yes 100 Eye-tracker	With adaptor	Yes Eye tracker	Yes No	SLO, Red-free and flu.ang. depending on the machine type

Table 1. Technical specification for common OCT-instruments. The axial resolution is determined from the center wavelength and the half-width of the incident light, standard values are appr.840-880 nm and 50 nm. The speed and number of A-scans are important, both for fast aquisition of raster scans (also used for 3D) and for aquisition of many A-scans and multiple B-scans for averaging. A confocal scanning ophthalmoscope image (SLO image) and/or an OCT image shown en-face (equivalent to a fundus image) are standard in most systems. For the purpose of avaraging, different algoritms are used to register and align the OCT image and fundus images, these are not specified in the table except eye-tracking, indicating a real time tracking. Be aware that access to normative databases and other features may not be standard, but access is increasing for all systems.

regarding databases and additional features of the instrument ? Some systems have an integrated color fundus photography, others fluorescein angiography or microperimetry. How much do you focus in retinal nerve fiber layer or anterior segment ? This is your decision, but a bit more background may be useful.

Resolution

The nominal axial and transversal resolution are fairly close for the present generation of Spectral Domain OCT's, the axial being determined by the center wavelength of the incident light and the half-width spread of the source (better resolution with broad-band sources). The transversal resolution is determined by the optics of the eye and unless you get access to an experimental instrument with adaptive optics, the resolution is approximately 15-20 microns.

Speed

This is important and should be considered in connection with the protocol you are using. Do you favour 3D and films ? take a fast system. Is your priority on AMD and diabetic macular edema, you need both speed and quality. In eyes with intraretinal scatter and absorption, high quality and contrast are optimal for evaluation of intraretinal fluid and pathology and high quality is equivalent to many A-scans and averaged B-scans, an example is shown in fig. 2 using 4096A-scans. For determination of retinal thickness, a radial or a raster pattern are used and standard protocols uses a more limited number of A-scans and B-scans to reduce scanning time. The scanning time for a raster of 6*6 mm is appr. 1 to 2 seconds, and to decrease acquisition time in elderly AMD patients or children you may want to use a fast radial scan pattern, a very fast OCT or limit the scanning area.

Averaging

OCT images includes noise (partly speckle noise) and to decrease the noise level and thereby increase contrast, averaging is needed. Optimal quality is obtained averaging B-scans and/or to use many overlapping A-scans, as already mentioned. In practice, this is closely connected to: speed, choice of protocol and efficacy of the averaging technique. The most optimal being a perfect eye-tracker, a very fast scanning and a compliant patient. Up to 100 B-scans may be averaged, but fewer will also improve quality substantially.

Protocols

The most simple feature is a single B-scan through the fovea, and for many purposes this is very nice, giving the opportunity of maximal quality and fast examination time. Many systems offers a 5 of 7 lines standard with a flexible distance between these B-scans and this is excellent for many low visual acuity patients, as you nearly always will have the fovea in one of those scans. If you like to have the retinal thickness, the square raster of 6*6 mm mentioned above is the standard, giving the retinal thickness corre-

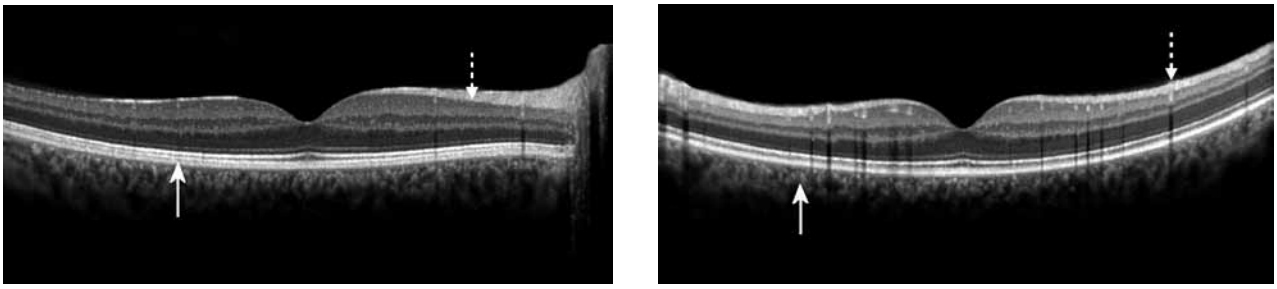

Fig. 1. OCT scans in a healthy subject, both are centered on the fovea and based on averaged B-scans and shown in grey for optimal visualisation. Left: horisontal scan with the optic nerve to the right. The nerve fiber layer is marked with a stippled arrow, the retinal pigment epithelium with an arrow. Right: vertical scan with a large number of retinal vessels (stippled arrow). Retinal vessels appear as high intensity signals (comparable to the retinal nerve fiber layer), with dark shadows below. The choroideal vessels are clearly visible in this subject (arrow). The individual level of pigmentation leads to substantial differences in the visibility of the choroid. Averaging of images and inversion of the image (possible in some instruments) increases the visibility of the outer retina and the choroidea

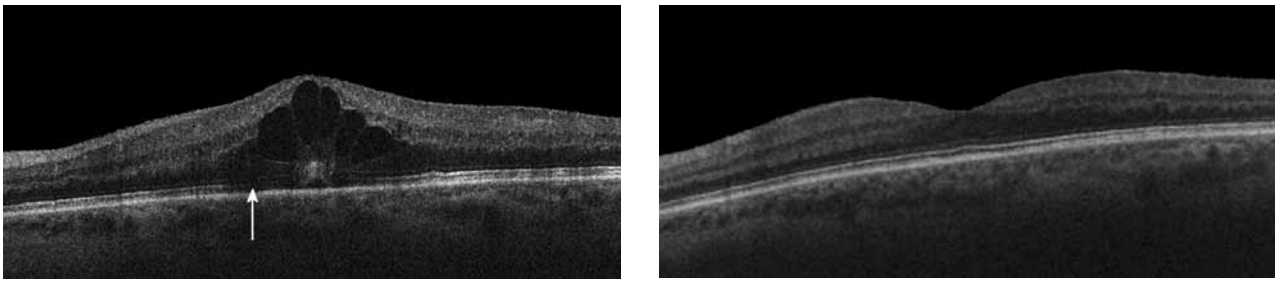

Fig.2. Line scans from a patient with central vein occlusion. At baseline, the visual acuity was 0.3 and the patient was treated with intravitreal injections with Lucentis. After the third treatment, visual acuity was improved to 1.0. The OCT at baseline shows central cysts and a serous deteachment is seen in the fovea. The signal intensity from the outer retina is decreased in the foveal region, probably due to increased scatter and absorption in the neuroretina (arrow). At follow-up, all layers appear normal. The contrast is lower than in figure 1, as often the case in patients and when averaging of B-scans has not been applied.

sponding to the 9 ETDRS fields used for diabetic retinopathy.

No matter what protocol you use, centration of the scan is needed and this requires a lot of practice. Centration is not only important to evaluate foveal thickness but also other features like small macular holes, and delicate changes of the outer retina which may explain reduced visual acuity. AMD patients are not easy, due to centration problems and intraretinal scatter. Also, the interpretation is not always obvious as the neovascular complex, RPE and fibrous tissue do not differ substantially in intensity and if you want to measure the retinal thickness, manual measurement or correction is needed quite often. Intraretinal fluid and PED is almost black and much easier to evaluate and if the programme includes follow up sessions, changes are easily visualized. The retinal nerve fiber layer thickness measurement and evaluation of optic nerve morphology is highly relevant for glaucoma and papiledema. As with retinal thickness, quantitation needs some expertise with centration and some programmes are easier in this respect and miscalculations are a problem in all systems.

The algoritms used for segmentation of the retinal layers differs between instruments. Apart from the vitreo-retinal border, everything else seem to differ between the companies and instruments (sometimes also with the software version). From the time domain to spectral domain, most systems changed the definition of the outer retinal border from the well-defined junction of the inner and outer segments to various positions in the layer of the outer segments to various positions in the layer of the outer segments and the RPE, thus you cannot compare exactly to any other OCT type. The software is also different and some features may be of special interest to you. Does the software allow manual corrections, microsaccade correction, re-position of the area you want to calculate in patients with poor fixation ?

Future OCT's

Many experimental systems are used in research: adaptive optics for improved resolution, increased penetration with longer wavelengths, blood flow and polarisation for improved visualisation of drusen and RPE. Slit-lamp based systems and specialized OCT's for the anterior segment are other possibilities and no doubt, the next OCT's will be even better than the present. ■