Physiopathology - Visual prostheses

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Retinal diseases

(1) **Macula degeneration**: Ageing-linked dysfunction of *macula lutea* cells (loss of central retina, impaired foveal vision). RGC often intact.

(2) **Diabetic retinopathy**: Retina vascular system dysfunction depriving retina of blood supply. Blood vessels may also leak fluid during advanced stages, destroying retinal tissue.

(3) **Glaucoma**: Increased intraocular pressure damages retinal ganglion cells, causing loss of peripheral and later also of central vision.

(4) **Cataract**: Clouding of lens leading to blurred vision, blindness.

(5) **Retinitis pigmentosa**: Rare eye disease associated with photoreceptor loss, causing peripheral loss of vision, loss of night vision.
Visual acuity

Normal visual acuity is the ability to recognize an optotype when it subtends 5 minutes of arc, corresponding to Snellen's chart 20/20 feet.

If you have **20/20 vision (normal acuity)**, it means that when you stand 20 feet away from the chart you can see what an average observer with good eyesight can see.

If you have **20/200 vision**, you can see at 20ft distance what an average healthy observer can see from 200ft away.
Types of visual prostheses

Subretinal

Optic nerve

Epiretinal

Along optic nerve

Optic tract

Lateral geniculate body

Geniculo-calcarine tract

Primary visual area (= striate cortex)

Cortical

Ophthalmologica 2011;225:187–192
DOI: 10.1159/000318042
Array kept in place ~20 years in blind patient extrastriate visual cortex.

Patient learned to read letter symbols 10cm wide at 1.5m distance.

Risks: Brain tissue damage and infection risk during implantation, epileptic seizures due to current injection.
Cortical Visual prosthesis - retinotopy

Electrical stimulation caused phosphenes with loose retinotopy.
Cortical Visual prosthesis – cortical magnification
Tracer injections were made in a number of adjacent RGCs.

Some retinotopy is present in the optic nerve close to the disk.

This retinotopy is lost as one follows the axons to the LGN.
Optic Nerve prosthesis - retinotopy

Implantation of four-contact cuff electrodes around optic nerve, stable over several years.

Phosphenes of various types elicited by «open-loop» stimulation with various frequencies.

Note: 4 windows: Each stim channel vs. gnd. 24 windows: channels vs. Each other and gnd.
Patients can learn to discriminate set of symbols (Symbols shown at 20cm size, viewing distance 0.5m).
The retina

Subretinal

Epiretinal
Subretinal prosthesis – SUBRET consortium

Subretinally placed device containing light-sensitive photodiodes, which produce local electrical current to excite bipolar cells.

Can benefit from local processing (bipolar cells / amacrine cells, etc.). Uses optics of the eye for image formation.

Surgical access complicated, as it requires retinal detachment from sclera.

Unreliable performance in patients:
• Out of the 11 subjects, 3 could not reproducibly perceive phosphenes elicited by the DS array.
• Five had sufficient vision recovery to detect bright light sources in an otherwise dark environment and large objects like a plate.
• Patient eleven reached the best visual performance achieved so far in, including passing a Landolt “C” test with a visual acuity of 20/1000.

Doi: 10.1109/IEMBS.2010.5627549
Subretinal prosthesis – other approaches
A schematic illustration showing the surgically implanted stimulating microelectrode array, and inductive coil telemetry link of the Argus II system (left). The external portions of the system consist of a video processing unit (VPU) (middle) and a miniature camera mounted on a pair of glasses (right).

This epiretinal prosthesis uses signals from video camera to stimulate ganglion cells in the inner layers of the retina.

Prosthetic function does not use the optics of the eye for image generation.

This technique was tested in advanced *retinitis pigmentosa* patients with no measurable visual acuity but some residual brightness perception.
Epiretinal prosthesis

Subjects had to touch a 5cm\(^2\) target on a 19 inch flat panel display placed 30cm from the subject.

The prosthesis allowed significant improvement in targeting for most subjects, except those with still good residual visual functions.
## Epiretinal prosthesis – current devices

<table>
<thead>
<tr>
<th></th>
<th>IMI Intelligent Medical Implants GmbH, Bonn, Germany</th>
<th>Epiret GmbH, Giessen, Germany</th>
<th>Second Sight, Sylmar, Calif., USA</th>
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</thead>
<tbody>
<tr>
<td><strong>Number of electrodes</strong></td>
<td>49</td>
<td>25</td>
<td>16/60</td>
</tr>
<tr>
<td><strong>Maximum time retained within the eye</strong></td>
<td>&gt;30 months</td>
<td>4 weeks</td>
<td>&gt;6 years/&gt;6 months</td>
</tr>
<tr>
<td><strong>Data transfer</strong></td>
<td>wireless</td>
<td>wireless</td>
<td>wireless/wireless</td>
</tr>
<tr>
<td><strong>Signal receiver placement</strong></td>
<td>epiretinal</td>
<td>lental</td>
<td>retroauricular/episceral</td>
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<tr>
<td><strong>Specificities</strong></td>
<td>freely programmable retina encoder</td>
<td>completely implantable</td>
<td>devices with 250+ and 1,000+ electrodes in preparation/planning</td>
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<tr>
<td><strong>Homepage</strong></td>
<td><a href="http://www.imidevices.com">www.imidevices.com</a></td>
<td><a href="http://www.epiret.de">www.epiret.de</a></td>
<td><a href="http://www.2-sight.com">www.2-sight.com</a></td>
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More important than a decision for the best implantation site will be the understanding of the neurophysiological basis of signal processing in the visual system. This is required to adjust and optimize the design and function of a visual prosthesis. In theory reading should be possible with an array of only 60 electrodes [43].