Phacoemulsification cataract surgery requires motor skills close to the limit of the capacity of the human motor system. Classically, surgical skill is transferred in a master-apprentice relationship in which the trainee observes the skilled surgeon often for months and then gradually starts to perform a larger and larger fraction of the procedure under the supervision of an experienced surgeon. Classical surgical skill transfer is time consuming for both the experienced surgeon and the trainee, and therefore expensive. In addition, phacoemulsification cataract surgery is currently performed under local anesthesia making oral communication between teacher and trainee difficult if not impossible. Further, it has been demonstrated in a number of studies that phacoemulsification cataract surgery requires approximately 500 procedures before the asymptote in complications is reached.

The evolution of powerful inexpensive computers has made it possible to create virtual reality systems for training of motor skill. This is already since decades a required standard for commercial airline pilots and is becoming an established standard for learning endoscopic surgery. The fact that many ophthalmic surgical procedures depend almost only on visual feedback renders them particularly suitable for virtual reality simulation.

The current course is intended to provide a state of the art overview of virtual reality phacoemulsification cataract surgery.

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Per Söderberg, Carl-Gustaf Laurell
Course leaders

Complete handout with references:
Learning motor skills in virtual reality and its evaluation

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According to behavioral science, a motor skill is learnt in a sequence of steps starting with cognition and understanding, during which the theoretical concepts of motor skill is acquired, integration, during which a level of motor skill is achieved that allows to perform the task without inefficient movement and then finally, automation, which represents a level where the skill is performed without conscious thought.

During the process of learning, the number of complications decreases sigmoidally from a high level towards an asymptote with increasing number of training procedures. Concurrently, the performance increases sigmoidally towards an asymptote. Skill is achieved when the number of complications reaches an acceptable level. Skill transfer has evolved from the master-apprenticeship model used in artisan activities, through the physical reality model developed by military science as a schematic activity, realized in games and later during the second world war, as realistic training used e.g. by the British military forces to train pilots, and in ophthalmology the wet labs for cataract surgery training. With the development of the computer, artificial reality became available, first as pure mathematical models, used e.g. in meteorology, then as schematic simulators e.g. for surgery, where reality is transformed into schematic objects, and finally virtual reality (VR), where a computer generated artificial reality is interfaced to interact realistically with the human senses of the trainee.

Typically, a VR simulator consist of a computer with software that generates the virtual reality, an administrator interface that allows setting the parameters for the training session and a measurement interface that allows measuring the training procedure, and finally trainee interfaces that allows trainee input to the virtual reality, and real-time feed back to the trainee. The VR simulator allows training without risk, skill acquisition and testing new strategies without risk.

Instructional efficiency is mathematically defined as the surface area under the performance as a function of number of training sessions measured from zero to an arbitrary limit, corresponding to an adequate performance. In order to measure the instructional efficiency, performance and adequate performance have to be defined.

We have defined an overall normalized relative performance index (PI) for VR phacoemulsification surgery which summarizes 28 variables measured during a training session. In the normalized relative PI, the performance is compared to performance in a reference population of naive trainees. The overall relative PI may be broken down into class specific-, and further into variable specific PIs. An experiment was performed on 9 experienced cataract surgeons (>5 years of phacoemulsification cataract surgery). It was demonstrated that overall rel. PIs for sculpting as well as evacuation are approximately normal distributed. One and the same experienced surgeon got a low overall rel. PI, both for the sculpting and the evacuation phase. It was identified that the low overall PI for both phases was due to that the surgeon for extended periods positioned the manipulator tip behind the iris.

Virtual reality ocular surgery offers a possibility to train surgical procedures under constant monitoring without any risk for the patient. The performance accumulated during training until skill is achieved is a measure of instructional efficiency. The individual overall relative performance index can be used as a summary of the performance for a trainee. The overall relative performance index can be broken down into class specific-, and further into variable specific relative performance index.
There are now two functional VR simulators on the market for learning phacoemulsification cataract surgery. The next steps are to learn how we can optimally implement the simulator in phacoemulsification cataract surgery training and to feed back to the companies how they can improve the VR simulator as a tool for cataract surgery training.
Evolution of surgical skill during cataract surgery with VR-simulation in non-experienced trainees

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The data from the study in this presentation was gathered using the virtual reality cataract surgery simulator PhacoVision™ version 3.1.0. Ten trainees were recruited from medical students who recently had completed the course in ophthalmology in Uppsala or Stockholm. None of the trainees had previous microsurgical experience, but all trainees had seen cataract surgery being performed during the ophthalmology course.

The surgical technique currently available in the PhacoVision™ simulator is Divide&Conquer, and in this study only the phaco part was included, i.e. phaco sculpting, quadrant division and phaco evacuation.

Design: One hour introduction which included a quick repetition of the anatomy of the anterior segment, explanation of the hand and foot controls, practice drills with rotating and dividing of pre sculpted nuclei and one full surgery. The rest of the day was divided in five sessions: The trainee first performed a full surgery with instructions. The instructor then performed a full surgery to show how the trainee could improve his/her surgery. The session was completed with three consecutive full surgeries by the trainee during which the instructor took notes but did not speak. Thus a total of 21 full surgeries by the trainee during the day.

The average time consumption to complete a full surgery decreased from an average of 18 minutes (11-27) for the first surgery to 4.5 min (3.2-6.0) for the last. For reference the instructor performed 21 consecutive VR surgeries with a progress from 1.6 to 1.3 minutes.

The performance index (PI) in PhacoVision™ has been developed in previous studies. The score 1.0 represents the “Average beginner” and 2.0 is the theoretical maximum score. The data in this presentation is calculated as a mean of the three consecutive surgeries without instructions for the five sessions (op no 3-5, 7-9, 11-13, 15-17, 19-21).

The average PI for the trainees increased during the day (1.0, 1.2, 1.2, 1.4, 1.4) for the five measurement points (instructor reference 1.7, 1.8, 1.8, 1.8, 1.8). There was a tendency to perform slightly worse directly after the lunch break than before (PI 1.22-1.18).

The trainees had an average of 2.5 (0-6) posterior capsule breaks during the day, mostly done with the phaco tip. The trainees also had phaco tip endothelial touch in average 3 times (0-9).

There were no drop-outs and all trainees expressed positive opinions when the day was completed. One trainee had cramp in the right hand and started trembling, but succeeded to complete the day. Many trainees were tired after having been so concentrated for such a long time.

The VR-simulator gives for the trainee unsurpassed volume training in short time and makes it possible to learn hand and foot coordination in a safe environment. It is also a perfect tool for the instructor to see the trainee perform microsurgery without risking patient injury and develop a “surgical relationship” with the trainee before entering the OR.
Learning phacoemulsification with a simulator

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Currently, phacoemulsification surgery is learnt by theoretical knowledge transfer through literature, lectures and videos followed by motor training in wet labs using animal eyes. Then, the trainee has to spend an extended time period in the surgery room, observing an experienced surgeon. Next, the trainee is allowed to perform isolated steps in the surgical procedure under supervision of the experienced surgeon and finally the trainee is allowed to perform the complete surgery under the supervision of the experienced surgeon. This process is time consuming and thereby expensive since two ophthalmologists are spending extended time periods during which the experienced surgeon could easily make several surgical procedures.

The master-apprenticeship model for teaching during live phacoemulsification surgery is seriously hampered by the fact that phacoemulsification surgery is done under local anesthesia, making communication between teacher and trainee difficult.

Several studies have monitored the incidence of complications during the first years of phacoemulsification cataract surgery. These studies have demonstrated that there is a long learning period during which a large number of unwanted complications to the surgery occur, due to trainee lack of experience. There is therefore an urgent need to improve the training of phacoemulsification cataract surgery.

Virtual reality (VR) allows training of phacoemulsification cataract surgery completely without risk for the patient. VR-surgery makes it possible for the teacher to demonstrate correct and incorrect manipulation in a realistic environment. VR-surgery allows free communication between the teacher and the trainee during the surgery. The surgery can be stopped at any time and reversed for rehearsal. Everything the trainee does during the surgery can be measured and analyzed after the training session.

VR phacoemulsification cataract surgery is much more realistic than wet-lab surgery. It is not associated with risk for infectious contamination or ethical hesitation.

VR phacoemulsification cataract surgery is an important complement to literature, lecture room teaching and video seminars and provides a more realistic training of surgical skill than wet-lab training. Hopefully, VR phacoemulsification cataract surgery training will reduce incidence of surgical complications during the first years of phacoemulsification surgery for the newly trained surgeon.
Cataract surgery with VR-simulation, a tool in the undergraduate education of medicine

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Dept. of ophthalmology, Malmö Almänna sjukhus has an EYESI ophthalmic surgery simulator (VR-magic, Germany). The simulator is used in the undergraduate education to provide a possibility for the medical students to try cataract surgery without risk for patients. The students report a positive experience of using the simulator. They consider that the simulator increases the understanding of the technical difficulties of cataract surgery and believe that the simulator increases the knowledge of the three dimensional surgical anatomy.
References


