VR-simulation cataract surgery in non-experienced trainees, evolution of surgical skill

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ABSTRACT

Conclusion: The current data imply that the performance index as defined herein is a valid measure of the performance of a trainee using the virtual reality phacoemulsification simulator. Further, the performance index increase linearly with measurement cycles for less than 5 measurement cycles. To fully use the learning potential of the simulator more than 4 measurement cycles are required. Materials and methods: Altogether, 10 trainees were introduced to the simulator by an instructor and then performed a training program including 4 measurement cycles with three iterated measurements of the simulation at the end of each cycle. The simulation characteristics was standardized and defined in 14 parameters. The simulation was measured separately for the sculpting phase in 21 variables, and for the evacuation phase in 22 variables. A performance index based on all measured variables was estimated for the sculpting phase and the evacuation phase, respectively, for each measurement and the three measurements for each cycle were averaged. Finally, the performance as a function of measurement cycle was estimated for each trainee with regression, assuming a straight line. The estimated intercept and inclination coefficients, respectively, were finally averaged for all trainees. Results: The performance increased linearly with the number of measurement cycles both for the sculpting and for the evacuation phase.

Keywords: cataract surgery, phacoemulsification, simulator, performance index, evolution.

1. INTRODUCTION

Phacoemulsification cataract surgery is currently the most common surgical procedure in modern societies, the incidence amounting to 1/100 inhabitants/yr [1]. It has been estimated that by the year 2020, the prevalence of cataract will double [2].

In modern cataract surgery, an approximately 2 mm incision is made in the periphery of the cornea. Then, the crystalline lens is opened by precise tearing of an operculum in the anterior surface of the lens, capsulorhexis. Thereafter, the lens nucleus is mobilized with saline by liquid dissection along the interior surface of the lens capsule. The lens nucleus is removed by ultrasound emulsification and simultaneous aspiration with a fine relatively sharp metal tip. The remaining lens cortex adhering to the lens capsule is removed by aspiration with a blunt cannula. Finally, the lens capsule is expanded with a viscoelastic gèle and an intraocular lens is implanted. The critical quality factor of the surgery is that the posterior capsule of the crystalline lens remains intact throughout the surgery.

Surgeons in training have reported an incidence of 5-20 % of capsular ruptures during their first 200 cases [3-5] despite teacher intensive training [6, 7]. Experienced surgeons reported that the number of complications decreased exponentially from the first case, reaching the asymptote after 400 [8] or even 1000 cases [9].

Rigorous monitoring of surgical skill is becoming increasingly demanded [10]. Current computing capacity of modern personal computers is sufficient for simulation of virtual reality and is expected to increase quickly, making it possible to make more sophisticated simulation algorithms. Virtual reality models have been developed for various surgical procedures such as arthroscopy, bronchoscopy, cystoscopy, transurethral prostate resection, gastroscopy, colonoscopy, intravascular procedures, coronary stint or cardiac lead placement and laparoscopic surgery [11].

Extensive research in motor skill learning has demonstrated that the incidence of complications due to wrong motor behavior decreases sigmoidally as a function of the number of training sessions from a high level towards a low level

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asymptote. Contemporaneously, the motor skill ,or *the performance*, increases as a function of number of training sessions from a low level asymptote, sigmoidally towards a high level asymptote. The integral of the performance as function of number of training sessions is defined as *instructional effectiveness*, IE. Instructional effectiveness measured with the same strategy for the same trainees, may be used to compare different simulators. Instructional effectiveness measured with the same training curriculum on the same simulator may be used to evaluate the learning capacity of an individual trainee. Measurement of instructional effectiveness requires a relevant definition of performance index.

There have been several attempts to measure performance with VR simulators [11-13]. It has been demonstrated that virtual reality training leads to faster adaptation to the psychomotor restrictions encountered by laparoscopic surgeons [14].

We have developed a virtual reality phacoemulsification simulator, PhacoVision® [15-18]. The simulator consists of a personal computer, simulation software, a surgeon interface and an administrator interface. A preliminary clinical evaluation indicated that the simulator authentically simulates cataract surgery [19]. In a recent study of 8 medical or optometry students, 31 response variables were identified and the variability of measurements of theses variables was analyzed [20]. It was found that the variability's in the measurements were larger for the sculpting phase than for the evacuation phase, resulting in a need for larger sample size to measure changes during the sculpting phase than during the evacuation phase [20]. Based on the analysis of the variability of the various variables measured a performance index was defined [21] and the performance of 9 experienced surgeons was estimated [22].

The aim of the present study was to evaluate the evolution of performance in trainees familiar to the anatomy and physiology of the eye but without prior experience of cataract surgery.

1 METHODS

1.1 Subjects

The subjects were medical students in their forth year immediately after their undergraduate training in ophthalmology.

1.2 The simulator

The simulator (PhacoVision®, Melerit AB, Sweden) consists of a personal computer, simulation software and hardware interfaces.

The simulation software is based on a generalized simulation software (M-base®, Melerit AB, Sweden) working on top of Cosmo 3D/Optimizer (Silicon Graphics Inc., USA). M-base has been used to write the phacoemulsification procedure.

In the trainee input interface, the trainee provide input to the software through a manipulator hand piece, a phacoemulsification hand piece, a commercial microscope foot pedal controlling x and y direction of the field, focusing and zoom., and a phacoemulsification foot pedal triggering irrigation in step one, and adding aspiration in step two and ultrasound energy in step three. The trainee simultaneously, in real time, receives 3-D feed-back of the alterations, provoked in the surgical field by the trainee manipulation, through two organic light-emitting diode (OLED) displays observed through two eye-pieces.

In the administrator interface, the patient characteristics are defined in 14 parameters (Table 1).

Table 1
Light scattering induced after in vivo exposure to near-infrared radiation at 1090 nm as a function of exposure time

Id	Parameter
	1 Patient movement
1	1.1 Average frequency of x-y patient field drift calculated for no drift period
2	1.2 Maximum velocity for x-y patient field drift
3	1.3 Maximum x-y patient field drift
	2 Pupillary parameters
13	2.1 Pupillary diameter
	3 Lens Parameters
17	3.1 Maximum allowed stretching of the zonulae before lost lens
31	3.2 Maximum allowed zonular load
20	3.3 Nucleus hardness
21	3.4 Nuclear angular speed when dialled
23	3.5 Force required to produce cracking
	4 Phacoemulsification instrument related
25	4.1 In frontal plane counter-clockwise angle between 12 a' clock and phacoemulsification handle axis
26	4.2 In frontal plane counter-clockwise angle between 12 a' clock and manipulator handle axis
27	4.3 Distance tip-irrigation port center
29	4.4 Average incidence of occurrence of bubbles
30	4.5 Average number of bubbles per group

Id is a unique parameter identifier

1.3 Procedure

The virtual reality phaocoemulsification procedure was divided into an initial sculpting phase and a subsequent evacuation phase. During the sculpting phase, a cross is sculpted in the lens nucleus. During the evacuation phase, the lens nucleus is cracked into four sectors and thereafter each sector is evacuated by simultaneous ultrasound emulsification and vacuum aspiration.

Each trainee went through the surgical training steps outlined in (Figure 1).

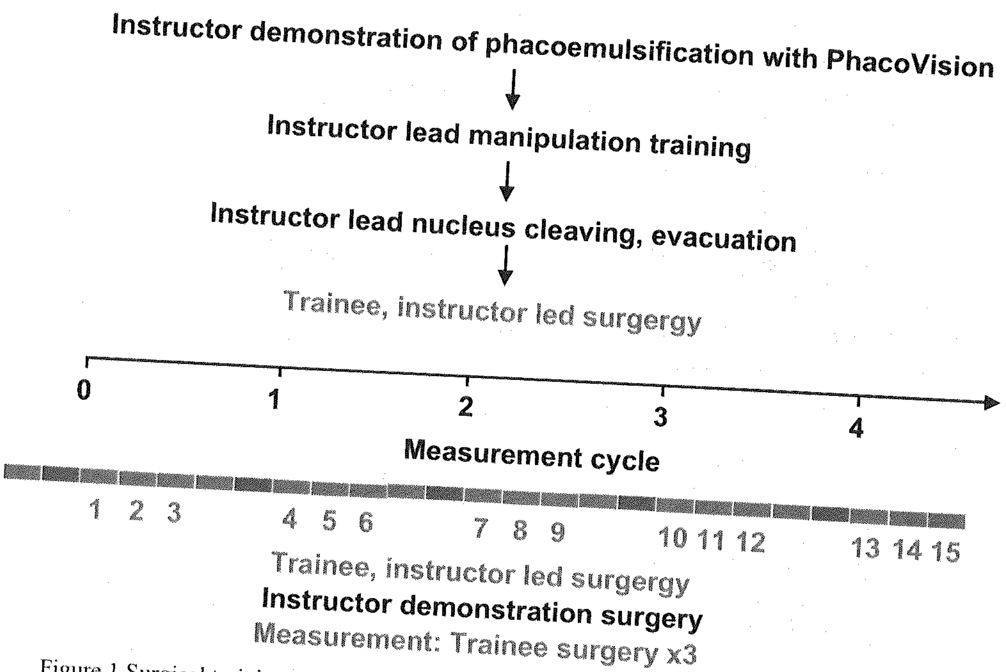

Figure 1 Surgical training steps.

1.4 Variables measured

For all surgeries, the sculpting phase and the evacuation phase were measured separately. For the sculpting phase, altogether 21 variables were measured and for the evacuation phase 22 (Table 2).

Table 2
Variables measured

Id	Variable
1. Overall procedure	
1	TotalProcedureTime (s)
2	SculptingTime/Evacuation (s)/
3	PhacoEnergyUsed (rel.)
2 Foot pedal technique	
5	DecentrationSurgicalField (s)
3 Phacoemulsification technique	
2	PhacoPathX (mm)
3	PhacoPathY (mm)
4	PhacoPathZ (mm)
6	ManipulatorPathX (mm)
7	ManipulatorPathY (mm)
8	ManipulatorPathZ (mm)
4 Erroneous manipulation	
1	BubbleOcclutionTime (s)
2	NoIrrigationTime (s)
3	ManipulatorBehindIrisTime (s)
4	PhacoBehindIrisTime (s)
5 Damage to ocular structures	
5.1 Corneal endothelial damage	
1	PieceCorneaPushTime (s), only evacuation
2	PhacoCorneaHitTime (s)
4	IrisDamageTime (s)
6. Damage to capsule	
1	PhacoRhexisDamageTime (s)
2	PhacoBeyondPosteriorCapsuleTime (s)
3	ManipulatorBeyondPosteriorCapsuleTime (s)
4	ZonulaStretch $(mm)^2$

The overall performance index [21] was calculated for each of the sculpting phase and the evacuation phase.

1.5 Experimental design

The experimental design is outlined in (Figure 2).

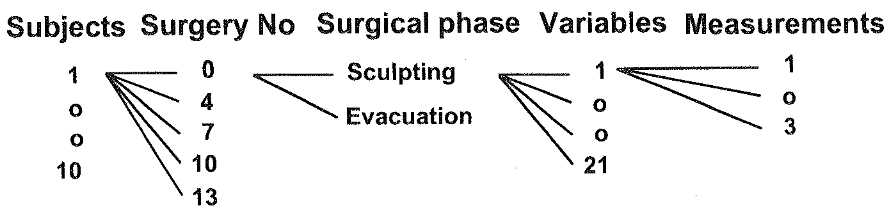

Figure 2 Experimental design.

2 RESULTS

The trainee performance of sculpting increased linearly with measurement cycle (Figure 3).

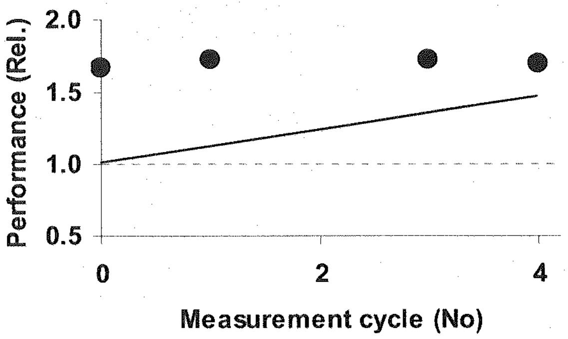

Figure 3 Sculpting, evolution of performance. Circles are instructor. Filled line is trainee's best fit regression to a linear regression model with zero and first order terms. Dotted line is performance of untrained trainees.

The trainee performance of evacuation increased linearly with measurement cycle (Figure 3).

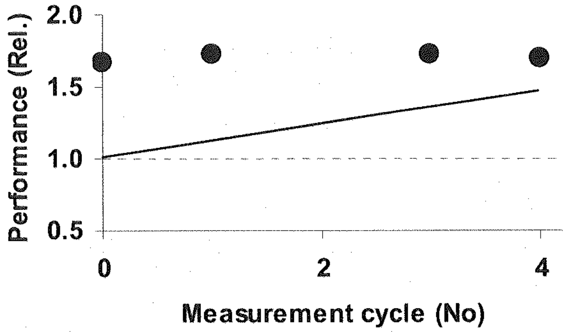

Figure 4 Evacuation, evolution of performance. Circles are instructor. Filled line is trainee's best fit regression to a linear regression model with zero and first order terms. Dotted line is performance of untrained trainees.

3 DISCUSSION

The purpose of the current study was to determine the evolution of sculpting and evacuation during the initial training of trainees, familiar to the anatomy and the physiology of the eye but without prior experience to surgery.

The current finding that the trainee performance increases as a function of number of measurement cycles (Figure 3, Figure 4) demonstrates that the current definition of performance index [21] is a valid variable for overall performance with the simulator. The fact that the performance increased linearly within the interval of measurements cycles measured indicates that use of the full learning potential of the simulator requires more measurement cycles than 4 since with increasing number of measurement cycles, the increase is expected to level of towards an asymptote.

It is concluded that the performance index measures the performance of the trainee using the simulator. Further, a curriculum including more than 4 measurement cycles is required to fully use the learning potential of PhacoVision®.

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