

Virtual cataract surgery: clinical evaluation

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ABSTRACT

We have developed a simulator for phacoemulsification cataract extraction. In the current project, modules for clinical evaluation were developed. The system was structured into a processing computer and an administrator interface and a trainee interface. The simulation is defined by administrator adjustable parameters and trainee adjustable parameters. The parameters may be categorized as session characteristic parameters, patient characteristic parameters and trainee characteristic parameters. The simulation is measured in variables. Further an air bubble generator was created. We believe that simulator training in future will be required for becoming cataract surgeons.

Keywords: cataract surgery, phacoemulsification, simulator

1. INTRODUCTION

The present work is a further development of a simulator for phacoemulsification cataract surgery (PHACO) that we have developed [1, 2]

Phacoemulsification cataract surgery (PHACO) is today the most common surgical procedure in modern societies approaching 1/100 inhabitant/yr. With increasing population age the prevalence of cataract surgery is expected to increase further.

PHACO consists of an approximately 3 mm incision into the eye in the periphery of the cornea, opening of the crystalline lens by tearing an operculum in the anterior lens capsule, capsulorhexis, liquid dissection of the crystalline lens into cortical and nuclear components, ultrasound emulsification and simultaneous aspiration of the nucleus, aspiration of the cortical material and implantation of an artificial intraocular lens into the empty capsule. The success of the operation is related to the maintenance of an intact capsular bag.

For the practical learning of phaco, the student usually primarily observes an experienced colleague during 3-6 months. Under this period, the student also usually practice the procedure in wet lab surgery on enucleated animal eyes. Thereafter, the student practices the procedure in incrementing steps until he has done the complete procedure. This usually takes another 1-3 months. Finally, the experienced teacher sits on the side as a backup for complications, normally during another 1-3 months. Despite this extensive teacher intensive training, surgeons in training have reported an incidence of 5-20 % of capsular ruptures during their first 200 cases [3-6]. These figures are similar for experienced surgeons [7, 8]. Studies of experienced surgeons have shown that the number of complications decreased exponentially reaching the asymptote after 400 [9] and 1000 cases respectively [10].

Recent development of personal computers have made it possible to simulate virtual reality with relatively inexpensive computers. It has been demonstrated that virtual reality training leads to faster adaption to the psychomotor restrictions encountered by laparoscopic surgeons [11].

Our PHACO simulator [1, 2] consists a personal computer, simulation software and a surgeon interface (Figure 1).



Figure 1 Cataract surgery simulator

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. The surgeon interface consists of a phacoemulsification handpiece and a nuclear manipulator handpiece, both mounted with four degrees of freedom (three space dimensions and rotation), a microscope foot pedal controlling x and y-direction and focusing in the field and zoom, and a one dimensional phacoemulsification pedal that controls irrigation, aspiration and phaco-power depending on the pedal position.

The aim of the current work was to develop a parameter setting module and a measurement module on the simulator for clinical evaluation and to add an air bubble generator to the PHACO procedure.

1 METHODS

1.1 System structure

The system was structured into a processing computer, a trainee interface and an administrator interface (Figure 2).

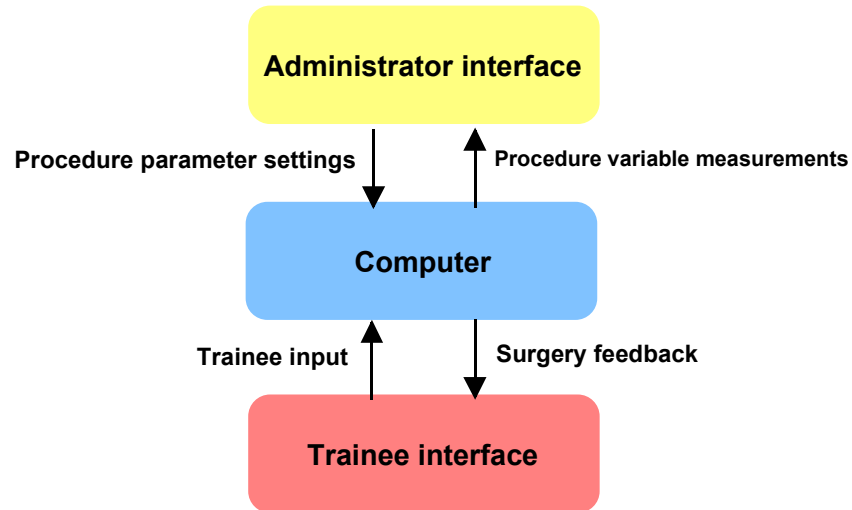


Figure 2 System structure of phacovision

The trainee is the person that will be trained on the simulator. The administrator is the person that outlines the simulation session and monitors the simulation. Before the simulation starts, the trainee provides personal ID information and optional settings of the system on a keyboard. The administrator builds the simulation and sets the parameters for the session (Figure 3).



Figure 3 Administrator interface

During the simulation, the trainee provides input to the system through the phacoemulsification handpiece, the nucleus manipulator, the microscope foot pedal and the phacoemulsification foot pedal and receives real time visual feedback through the 3D microscope interface. Further, the position of the tips of the handheld instruments and the positions of the foot pedals are monitored and interpreted to performance indices for the simulation procedure.

Currently, a phacoemulsification sculpting procedure has been developed allowing nuclear sculpting and nucleus rotation and a nucleus evacuation procedure that allows cracking of the nucleus and evacuation of nuclear fragments.

2 RESULTS

2.1 Simulation parameters

The simulation parameters were categorized as session characteristic parameters, trainee characteristic parameters and patient characteristic parameters. The session characteristic parameters determine the session, the trainee characteristic parameters define the trainee and the patient characteristic parameters define the qualities of the eye to be operated on.

All three categories may be either administrator or trainee adjusted.

The administrator adjusted parameters are adjusted on a keyboard and displayed on a computer screen prior to the simulation session. Currently implemented administrator adjusted patient characteristic parameters are nucleus hardness, nucleus rotability and nucleus crackability.

The trainee adjusted parameters are adjusted on a keyboard adjacent to the simulator microscope and displayed in the microscope display. Currently implemented trainee adjusted session characteristics are irrigation flow and maximum phacoemulsification power.

2.2 Simulation variables

Simulation variables are qualities measured during the simulation. Currently implemented variables for both the sculpting procedure and for the evacuation procedure are total procedure time, phacoemulsification energy used, out of field working time, out of focus working time and working time with too many bubbles. Variables measuring the movement of the instrument tips are under development.

2.3 Air bubble generator

In addition to the phacoemulsification module, an air-bubble generator has been implemented in the system. The air bubbles are presented randomly in the anterior chamber of the eye. The incidence of bubbles per time unit is set as an administrator adjusted session characteristic.

3 DISCUSSION

The current project aims at developing a simulator for training of cataract surgery. We have earlier reported on our development of the simulation software and the phacoemulsification hand piece and the nucleus manipulator [1] and our development of a 3D binocular visual interface for visual output to the surgeon and a microscope foot pedal interface for input from the surgeon [2]. In the current project, we developed the simulator to allow clinical evaluation.

The number of parameter settings both administrator adjusted and trainee adjusted need to be increased. There is also a large potential to increase the number of variables measured. The next step will be to clinically evaluate parameter settings and variables measured to identify reasonable adjustment intervals and steps on parameters and relevant variables to be measured.

We believe that simulators will be important future tools for initial training of becoming cataract surgeons and for continuing education of experienced surgeons on rare but difficult complications during surgery. There is a possibility that in the future, surgeons will be required to undergo a regulated amount of simulator training to be licensed for surgery [12].

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