Resident Perceptions and Cost Analysis of a Virtual Patient Application for Anesthesia-Related Critical Incidents

Howard A. Schwid, MD[1]
Karen J. Souter, MBBS[2]

Original Article

[1] Professor of Anesthesiology, University of California-Irvine
[2] Professor of Anesthesiology, University of Washington

Abstract

Background: Since there are limitations on the amount of time residents can spend in full-scale simulation sessions, we introduced a virtual patient application into our anesthesiology program to supplement mannequin-based simulation sessions. Previous investigations have demonstrated a positive educational effect for virtual patients, but suggest that further research is needed to clarify how to effectively implement virtual patients in medical education. We present a description of the implementation of a virtual patient application in our residency training program, the residents' evaluation of their experience with the application, and a cost analysis of incorporation of the application into the residency program, in order to determine the residents' perceptions of the value and estimate the cost of using virtual patients in anesthesia residency training.

Materials and Methods: For 20 years all anesthesia residents in our training program have been required to complete ten simulated cases using a virtual patient application prior to the end of their CA-1 year. Residents are given access to the anesthesia virtual patient application on departmental computers and also on their own personal computers. Residents complete 10 required cases on their own or in pairs and send printed case logs to an anesthesia attending for review and feedback. Participants anonymously completed surveys rating their perceptions of the virtual patient application's effectiveness. Cost to implement this program was estimated retrospectively.

Results: In total, 404 residents completed 3593 virtual patient cases in approximately 2800 hours.

Resident Perceptions: 252 residents completed the anonymous survey (62%). Almost all the respondents (97%) rated the virtual patient curriculum as worthwhile; 88% rated the application to be realistic; 97% felt better prepared to handle anesthesia-related critical incidents; 87% stated they had at least one event in a real operating room similar to an emergency presented in the virtual patient application, and 40% stated they experienced more than one such event. 93% were stimulated to read about management of anesthesia-related critical incidents after using the application.

Cost-analysis: The estimated cost to implement the screen-based

Corresponding Author:
Howard A. Schwid, MD
Dept. of Anesthesiology, University of California-Irvine
101 The City Drive South, Building 53, Room 226G
Orange, CA 92868
hschwid@uci.edu
Phone: 714-456-5885
Fax: 714-456-7321

curriculum for 20 years was $44,000 including the cost of software and faculty time. Therefore the cost for the 2800 hours of virtual patient simulation was about $16 per hour.

Conclusions: The anesthesia virtual patient application was easily incorporated into our residency training program at the University of Washington. The application was well-received by anesthesia residents, helped them feel more prepared to manage critical incidents, and stimulated them to read more concerning the management of anesthesia-related critical incidents. The virtual patient application is far less expensive than mannequin-based simulation and much more available. Therefore, virtual patients should be considered an easily accessible supplement to mannequin-based simulation training.

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Affiliation for Project: Department of Anesthesiology and Pain Medicine University of Washington, Box 356540 Seattle, WA 98195

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Introduction

The Association of American Medical Colleges (AAMC) defines virtual patients as "a specific type of computer program that simulates real-life clinical scenarios in which learners emulate the roles of health care providers to obtain a history, conduct a physical exam, and make diagnostic and therapeutic decisions"[1]. In 2010 Cook, et al, performed a systematic review of computerized virtual patients in health professions education. They reported a large positive educational effect for knowledge outcomes, clinical reasoning and other skills for virtual patients compared to no intervention and a small effect in comparison with non-computer instruction[2]. Although they concluded that further research is needed to clarify how to effectively implement virtual patients in medical education, their review did support improved learning outcomes with the use of deliberate practice, explicitly contrasting cases and formative feedback. In the current study, we describe a virtual patient application developed at the University of Washington Department of Anesthesiology in order to supplement the mannequin-based simulation training for our anesthesia residents for the management of anesthesia-related critical incidents. We describe how the virtual patient application was incorporated into our anesthesiology residency training program and the residents' perceptions of the value of the simulation software.

In addition to implementation efficacy and resident perceptions concerning the application, cost is an important consideration for inclusion of educational modalities into the anesthesiology training curriculum. Zendejas, et al, in their 2013 review of simulation-based medical education research found that cost was rarely taken into consideration[3]. They listed essential cost ingredients in simulation-based education including equipment (simulator, audiovisual for recording and viewing), training materials, cost of personnel (technicians, administrative staff), facility costs, learner costs (transportation, meals, course registration), and opportunity cost (lost clinical revenue from taking time to learn or teach). Zendejas identified four articles that were helpful in estimating the costs of mannequin-based simulation training. These studies reported the cost of mannequin-based simulation training at $160 - $800 per hour[4-7]. Although none of these mannequin-based studies focused on simulation for anesthesia-related critical incidents, we will make the assumption that the cost is similar for full-scale anesthesia simulation. Since we developed the virtual patient application as a low cost supplement to mannequin-based training, it was important to track the costs involved in using the application. Therefore, we studied not only how residents perceived the virtual patient application's implementation effectiveness but also analyzed how its cost compared to mannequin-based simulation.

Materials and Methods

This Educational Practices study of instructional strategies was certified as exempt by the University of Washington Human Subjects Committee.

Anesthesia Virtual Patient Application

Our anesthesia virtual patient application was first used by anesthesia residents at the University of Washington in 1989. For two years our department offered the simulator scenarios to our anesthesia residents on an elective basis in order to allow them to practice management of anesthesia critical incidents. In 1991 the department chair made completion of simulator scenarios a requirement for University of Washington anesthesiology residents. That requirement continues to today.

The virtual patient application has undergone a number of improvements over the years. First released for IBM compatible computers with Microsoft DOS as the Anesthesia Simulator-Recorder in 1989[8], the program recreated the operating room environment on the computer screen. The user interacted with buttons and menus to control the airway, breathing, fluids and drug administration. A set of mathematical models predicted the simulated patient responses while patient vital signs and all user choices were recorded in a text case log summary.

Over the years new features were added to the anesthesia virtual patient application, more case scenarios were included, and the simulator was converted from a MS-DOS program to a Windows desktop application[9]. The entire graphical user interface was updated and given the modern 'Windows' appearance. Other important improvements include context-sensitive 'What Next' help, automated debriefing and automated scoring of the scenario management. Figure 1 shows the graphical user interface for Anesthesia Simulator 5 (Anesoft Corporation, Issaquah, WA), the final version used in this study. The 'What Next' help feature (Figure 2) allows the user to ask the program the next best management step at any point in the simulation. The automated debriefing (Figure 3) provides a list of comments concerning appropriate and inappropriate management decisions made by the user during the case simulation. The automated scoring produces an overall High Pass, Pass, Fail, Incomplete grade, plus a numeric score with explanations for points earned and deducted. All of these features were designed to facilitate independent use of the application without the need for immediate intervention by teaching faculty. Our virtual patient application used many of the design characteristics identified as important for positive learning effectiveness in Cook's analysis of virtual patient applications. These include, branching with the patient condition evolving with learner decisions, feedback to learners, the opportunity for repetitive practice, virtual patient integration into the residency curriculum, wide range of case difficulty, and multiple learning strategies provided with learning objectives, hints (what next help), and feedback (debriefing and scoring).

Study Design Methods

Starting in the academic year 1991-1992, Clinical Anesthesia 1 (CA-1) residents at the University of Washington have been required to complete 10 case scenarios using the Anesthesia Simulator application. This requirement has continued to the current academic year, with the exception of 1997-1998 and 1998-1999 when the residents participated in a combined screen-

based and mannequin-based simulator study[11] and were therefore excluded from the current study. After completing the assigned cases, residents were asked to anonymously complete a survey evaluating the virtual patient application in order to assess the residents' subjective self-assessment of their simulation experience. The survey questions are shown in Table I.

Residents were given access to the anesthesia virtual patient application on departmental computers and also on their own personal computers. In August or September of their CA-1 year residents were given an instruction sheet and a 20 minute introductory session to learn to use the software. Residents completed the cases on their own or in pairs. On case completion they sent their case logs to an anesthesia attending (the primary author) for review and further feedback. Residents could run each case as many times as they wanted and had the option of submitting only their best case management. The first five cases were due in January and the second five were due in March. The survey was completed in June, the final month of the CA-1 academic year. The same survey was used for all 20 years of this study. In terms of Cook's analysis of virtual patient applications, our study design allowed learner collaboration since residents could work alone or in pairs, with outcome evaluated in terms of satisfaction and attitudes.

The ten case scenarios in the curriculum included: (1) routine intravenous induction to learn to use the program, (2) rapid sequence induction, (3) induction of a hypovolemic patient, (4) esophageal intubation, (5) bronchospasm, (6) anaphylaxis, (7) myocardial ischemia, (8) malignant hyperthermia, (9) rapid atrial fibrillation requiring cardioversion, and (10) acute hyperkalemia. Most participants required 6-8 hours to complete the ten case scenarios.

Cost to integrate the virtual patient application into the residency training program was estimated retrospectively. This included the cost of the software, and cost of the faculty attending to demonstrate how to use the application and review the case logs.

Results

During the study period of 1991-2013 (excluding academic years 1997-1998 and 1998-1999) 404 anesthesiology residents at the University of Washington completed 3593 case simulations on the anesthesia virtual patient simulator program. On the average each case takes about 30 minutes to complete so this study represents about 1800 hours of required simulated cases. Residents actually spent more time on the simulations since they often completed cases several times in order to turn in a good score. Most residents reported that they spent 6-8 hours using the simulator. Therefore the 400 residents in this study worked with the simulator about 2800 hours. The exact number of simulated case hours is impossible to report since residents were not required to track the time spent on cases that they repeated but did not submit for credit.

Of the 404 residents who completed simulated cases, 252 (62%) completed the surveys. Results of the surveys are shown in Table 1. The majority of respondents (97%) felt the virtual patient application was either definitely or probably worthwhile. Similarly, 88% felt the application was either very or 'pretty much' realistic. Furthermore, 97% of the respondents felt they were either definitely or probably more prepared to handle real emergencies in the operating room after using the program. 87% of respondents had experienced at least one case in the operating room similar to one of the simulated emergency cases, while 40% experienced more than one. 93% of

survey respondents stated that they increased their reading concerning management of anesthetic critical incidents after using the software.

Concerning the cost of the 2800 hours of resident simulation, no new computer hardware or space was required since the software was used on existing computers in the hospital and residents' personal computers at home. The virtual patient application software was donated to the department. However, if the department did have to purchase the software it would have cost a total of $4200 for the five institutional licenses for the five versions of the program used during the 20 years of this project. One faculty attending (the primary author) spent approximately two non-clinical days each year to introduce the program to the residents, remind the residents to complete their cases, review the printed case records automatically generated by the simulator program, and provide further feedback on their case management. No additional administrative support was provided by the department for this project. Assuming the average cost of a non-clinical day was approximately $1000, the total departmental investment was about $40,000. If the department would have had to purchase the software the total expense would have been $44,200 for the 2800 hours of simulator experience. Therefore the cost per hour of simulation time to implement this virtual patient curriculum with debriefing was approximately $16 per hour. Since 93% of survey respondents stated that they increased their reading due to virtual patient cases, cost per hour of learning was even lower.

Discussion

Since resident time in mannequin-based simulation sessions is limited, it would be valuable to supplement their simulation experience with more accessible virtual patient cases. Incorporation of the Anesoft Anesthesia Simulator into an anesthesiology residency program was felt by residents to be worthwhile, stimulated the residents to increase their reading concerning management of critical incidents, and was inexpensive. Survey results indicate that the virtual patient application is an activity residents will engage in on their own time because they see value in it. Based on the results of the resident surveys we conclude that the virtual simulation program met our educational objective to enable residents to practice the management of anesthesia-related critical incidents anytime and anywhere.

Resident Perceptions

The majority of residents responding to the survey rated the simulator cases as being realistic. The perception of clinical realism was especially important to measure for our virtual patient application since there was no patient mannequin or real monitor, and all interactions were by means of a computer graphical user interface. There were some criticisms of the application. Some residents commented that it took a little while to get used to making conscious mouse clicks for every maneuver rather than relying on muscle memory, especially for the many actions associated with induction of anesthesia. Furthermore, 6 respondents (1.5%) stated in the free verbal section of the survey that they had significant difficulty transferring from real operating room environment to the game-like user interface of the virtual patient application. The major criticisms concerning the realism of our virtual patient simulator were that some of the transitions in the simulated patient's condition were too abrupt and some interventions were not

recognized by the software if administered out of order. Other resident feedback pointed out that the simulated patients do sometimes die but this negative outcome was far less intimidating in private, self-study simulation setting compared to videotape-assisted group debriefing after full-scale patient simulation.

Despite these criticisms, the respondent ratings for the virtual patient application were overwhelmingly positive. We believe the favorable ratings are due to the program covering all nine elements of deliberate practice as described by McGaghie[11]. (1) The anesthesia residents were highly motivated to successfully complete this required task. (2) Our virtual patient application included well-defined learning objectives for each case. (3) The required cases were the appropriate level of difficulty for CA-1 residents. (4) Residents could repeat case management as many times as necessary to achieve the case objectives. (5) The automated scoring system provided rigorous and reliable measures of performance. (6) The automated debriefing system provided informative feedback. (7) The resident could monitor and correct management errors and practice again. (8) Minimal performance outcomes had to be met (patient survival) and mastery standard could be met (perfect score). (9) The resident then advanced to the next task (case).

Cost Analysis

The cost of simulation-based medical education is difficult to calculate and is rarely discussed in publications. Four previously published mannequin-based studies estimated the cost of full-scale simulation with debriefing at $160 - $800 per hour of training. In contrast, the virtual patient simulation curriculum with faculty debriefing cost about $16 per hour.

Limitations

One limitation of this study was that only 62% of residents completed the anonymous surveys. It is possible that survey completion may have been biased toward more favorable reviews. There are several reasons for residents not completing the surveys. One reason cited by some residents is that despite guarantees of anonymity some residents still feel they may be identified. The compliance rate for this survey is similar to others for non-mandatory educationally-based surveys administered to residents in our department.

We allowed residents the option of working alone or in pairs. Cook (3) found that students generally preferred group rather than individual case completion, citing the opportunity to learn both knowledge and alternative clinical approaches from each other. Since the resident surveys in our study were anonymous we could not differentiate resident responses for those completing the case simulations individually versus in pairs, so we cannot comment on resident preferences in this regard.

Furthermore, resident evaluations are not objective measures of the effectiveness of simulators. However, previous studies have demonstrated the educational impact of the virtual patient anesthesia simulator application and other screen-based simulation programs. One study measured residents' management of four standardized scenarios in a mannequin-based simulator after receiving handouts and lectures versus practice using the virtual patient anesthesia

simulator application[10]. The group that rehearsed critical incident management in the virtual patient application and received debriefing performed better, demonstrating positive transfer of learning from the virtual patient simulator to the mannequin-based simulator. In another study Nysson et al compared the training value of the virtual patient anesthesia simulator application versus a computerized mannequin-based simulator[12]. The results showed that learning the management of simulated crisis situations such as anaphylactic shock did not vary significantly between these two types of simulators despite the greatly reduced cost of the virtual patient application. Although these studies do not show a direct transfer of learning to the actual clinical environment, improved performance measured in a full-scale mannequin-based simulator does indicate effective learning of clinical management skills through the use of virtual patients.

The most common complaint from the residents concerning the virtual patient anesthesia simulator application is that it only operates on Windows computers. Therefore, residents with only Macintosh computers at home were forced to complete the case simulations using computers in the hospital. Version 6 which operates on Windows, Macintosh, iPad and Android tablets has been released since this study, making it even more convenient to use the anesthesia virtual patient application.

Retrospective cost analysis is another limitation of this study. The major cost element (90%) for the implementation of the virtual patient application into the anesthesia residency curriculum was faculty time involved in introducing the application to the residents, tracking resident completion of the required cases, and debriefing via the saved case records. The estimate of two days per year of faculty time is an approximation only, since the exact number of faculty hours was not tracked. Furthermore, cost of development of the virtual patient application is not included in the analysis since the University of Washington Department of Anesthesiology did not pay for development and other departments that may consider using the application would pay for the product but not its development. Although we do not know the exact number of hours the residents used the application or the exact cost involved, we are confident that our estimate of $16 per hour of virtual patient simulation time is far less than the cost of mannequin-based simulation training.

In conclusion, 20 years of experience with the anesthesia virtual patient application used by 404 residents completing 3593 simulated cases at a single Anesthesiology Residency Program demonstrate this modality to be well accepted and far less expensive than mannequin-based simulation. Therefore, virtual patients can be used as a cost-effective supplement to mannequin-based simulation training.

Acknowledgements, Disclaimers

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University of Washington, Box 356540 Seattle, WA 98195

Financial disclosures and potential conflicts of interest*:* Dr. Schwid founded Anesoft Corporation in 1987 in order to use the proceeds of sales of software to further develop the software. The project has been continuously funded for 25 years. In addition to his career benefitting, Dr. Schwid has benefitted financially from the success of the software as a paid consultant to Anesoft Corporation. The University of Washington has benefitted financially from royalties paid to its Graduate Research Fund and also for the free use of simulation software for anesthesia, ACLS, PALS, neonatal resuscitation, sedation, and bioterrorism.

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Figures

Figure 1 **–** The anesthesia virtual patient application presents the patient, monitors, anesthesia machine and all management options in a graphical interface. The user examines the patient, administers fluids and medications, controls airway and breathing, and communicates with the surgeon through mouse clicks.

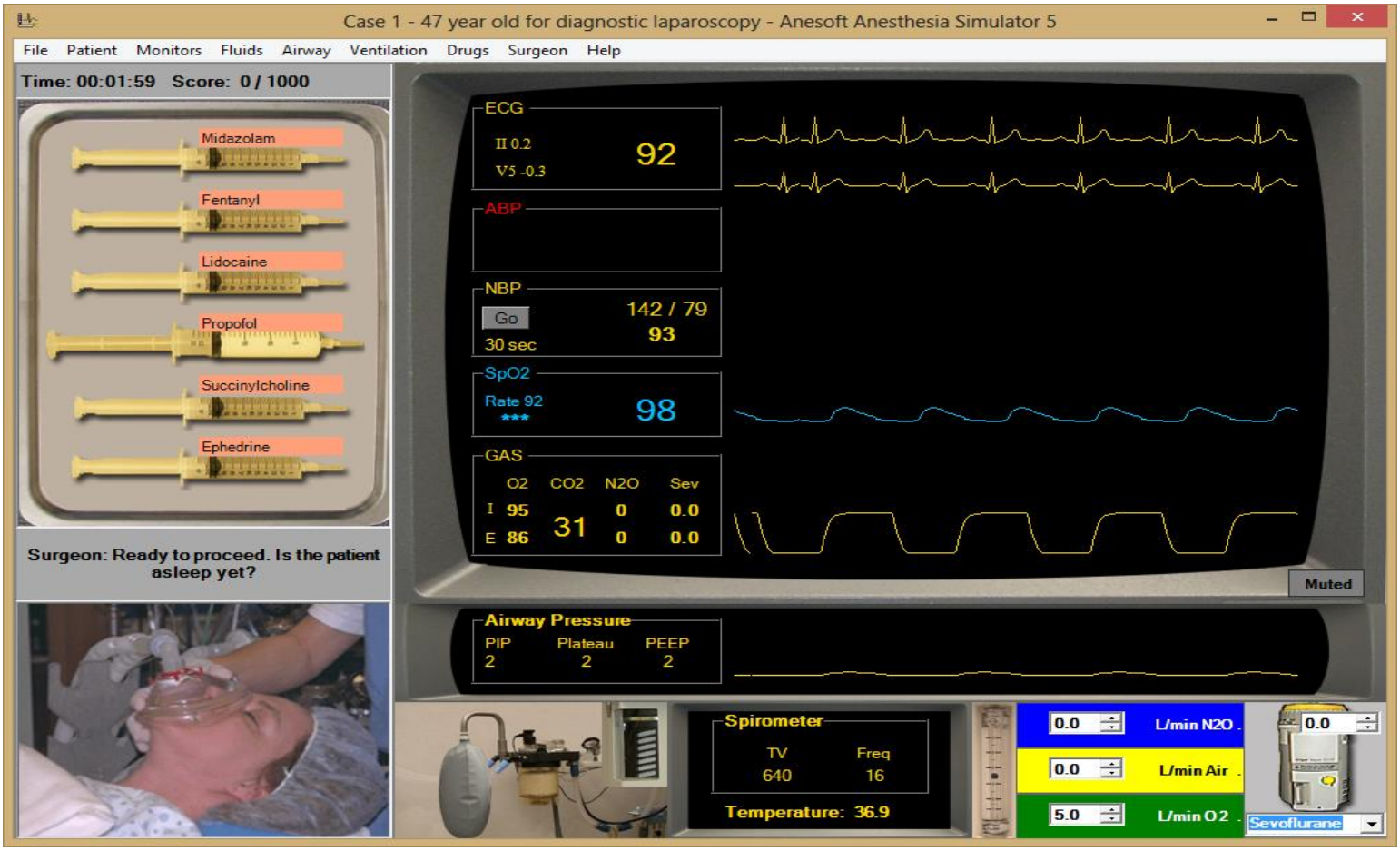

Figure 2 – At any point in the simulation the user can select "What Next" help to obtain management suggestions for the current clinical situation.

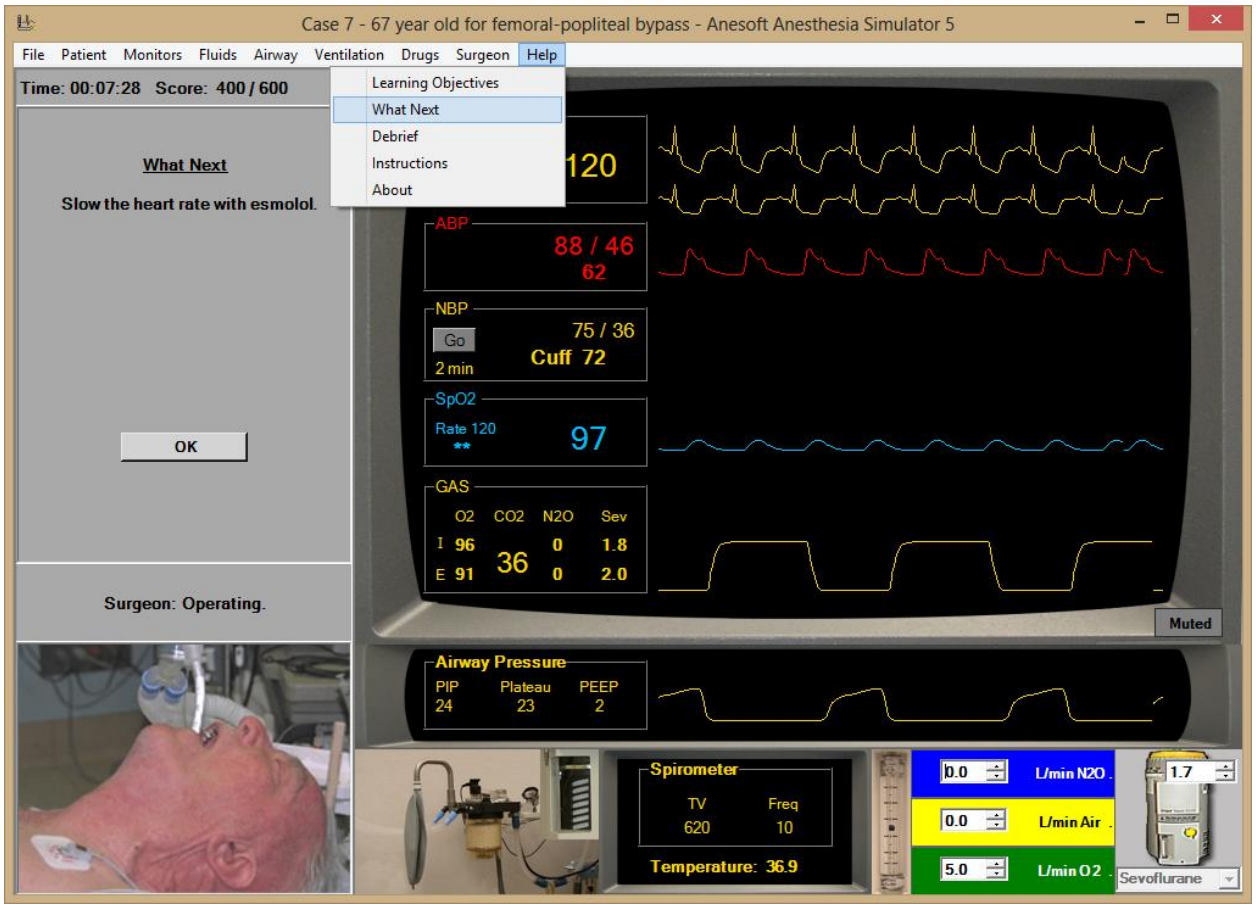

Figure 3 – At the end of the simulated scenario the user can obtain a debriefing for his/her case management. The debriefing consists of comments regarding diagnostic and therapeutic interventions with points awarded or deducted from the score.