SHORT COMMUNICATIONS

A Canadian simulation experience: faculty and student opinions of a performance evaluation study

P. J. Morgan1* and D. Cleave-Hogg2

1University of Toronto, Department of Anaesthesia, Sunnybrook and Women's College Health Sciences Centre, Women's College Campus, 76 Grenville Street, Toronto, Ontario, Canada M5S 1B2
2Medical Education, Department of Anaesthesia, University of Toronto, Centre for Research in Education at the Toronto Hospital, 585 University Avenue, Bell Wing 6-600, Toronto, Ontario, Canada MSG 2C4

*Corresponding author

One hundred and forty-three students and 18 faculty at the University of Toronto participated in a study of the anaesthesia simulator as an evaluation tool. Both student and faculty opinions regarding the experience were elicited using questionnaires with a five-point scale, 1=strongly disagree, 5=strongly agree. Faculty and student opinion were similar and positive with respect to the use of the simulator and matching of educational objectives, its use as a learning experience, its use as an evaluation tool and the need for familiarity with the tool before use as an assessment method. This study supports the use of the simulator as an evaluation tool based on faculty and student opinions provided that prior exposure to the environment is offered.

Br J Anaesth 2000; 85: 779-81

Keywords: education, medical students

Accepted for publication: June 5, 2000

At the University of Toronto, medical students spend 2 weeks during their final year of medical school in an anaesthesia rotation. Final clinical evaluation is based on faculty assessments of daily student performance in the operating room. A written examination at the end of a 6-week block, consisting of 10 short answer questions, comprises 60% of the final mark. Educational literature documents many studies attesting to the complexity of the evaluation of medical competence.1-3 Undergraduate medical education has been fraught with arguments regarding the reliability and validity of assessments that are neither consistent nor standardized.4 The introduction of the objective structured clinical examination (OSCE) by Harden in 1975 as an examination tool is now widespread in Canada and many other parts of the world.5 However, due to the nature of the practice of anaesthesia, the use of the OSCE does not lend itself to comprehensive examination of anaesthesia skills and knowledge. The purchase and availability of the CAE-link simulator at the University of Toronto supplies the means whereby the standardized assessment of performance of undergraduates can be undertaken during their anaesthesia rotation. The validity and reliability of any new assessment tool is important and has been addressed in a previous pilot study.6 Using the same methodology as the pilot project, a subsequent study involving all final year medical students was undertaken. As part of this study, it was deemed important to gather opinions from participants to see if they endorsed the use of this innovative technology for evaluation and educational purposes.

Methods and results

The Canadian Simulation Centre for Human Performance and Crisis Management Training, housed at Sunnybrook Health Sciences Centre, incorporates a full-sized simulated operating room with adjacent control and storage areas and two debriefing rooms. The computer mannequin, complete with a drug recognition system, responds in an appropriate manner to pharmacological and physiological interventions. The mannequin itself has the ability to emit vocal sounds from a distant operator, has breath and heart sounds, and eyelid movements. Technical skills such as manual ventilation of the lungs, tracheal intubation and chest tube
insertion can be performed. Emergency carts for difficult intubation and defibrillation are available for use when needed.

After ethics approval from the University of Toronto Research Ethics Board was obtained, all 177 final year medical students at the University of Toronto were invited to participate in this study during the 1998–1999 academic year. Eighteen faculty agreed to be either video evaluators or simulator facilitators. A workshop for faculty was held to review the purpose of the study and to ensure that protocols used for simulator sessions and evaluation were understood. Ten faculty were assigned as video viewers and eight as facilitators in the simulator.

Six scenarios were designed incorporating the learning objectives of the curriculum. Evaluation protocols for each scenario were developed with five sections: preoperative assessment, preparation, induction, and two intraoperative problems.

All students were given an information sheet regarding the purpose of the study. It was also made clear that their simulator performance evaluation would not be used towards their final grade nor would they receive a mark related to the session. If they agreed to participate, a consent form was signed. On a scheduled educational day during the second week of their 2-week rotation, students worked through a 15-min faculty-facilitated simulator scenario. These sessions were videotaped. Two faculty reviewed and evaluated each student’s videotaped performance. At the end of the simulator sessions, students met with the attending faculty and group feedback was given, and the learning objectives were addressed in detail. After the feedback session was completed, students were asked to complete an evaluation form summarizing their impression of the experience. Students were asked to respond to nine items using a five-point Likert scale from 1 to 5, 1=strongly disagree, 5=strongly agree. Comments were solicited. Opinions regarding the specifics of the simulator experience, content of the scenarios, realism and value of the simulator as an educational and evaluation tool were addressed. Responses were anonymous.

At the completion of the study, faculty, including the study co-ordinator, were asked to provide feedback regarding the experience using a questionnaire and the same Likert scale (n=19). Responses to 15 items were solicited together with comments pertaining to the items. Comments on the audio-visual qualities, the educational content and the value of the simulator as an evaluation tool were requested. The final item addressed the willingness to participate in further simulator research.

There was a 100% return rate of student questionnaires (n=145). Not all students completed all items, medians and range reflect the number of students who completed the items.

Table 1 shows the median and range of students’ responses. Students rated the simulator highly as a learning experience and felt strongly that prior exposure to the simulator was needed if it were to be used as an evaluation tool.

There was a 94% return rate of faculty questionnaires (n=18). Four identical items were given to both faculty and students. These items are as follows: (i) matching of simulator scenarios to curriculum learning objectives; (ii) the value of simulation as a learning experience; (iii) use of simulator as an evaluation tool; (iv) prior exposure to simulator before its use as an evaluation tool. The median of faculty opinions was identical to those of students for items (i) and (iii) with a median of 4 and 3, respectively. The response to item (i) supported the belief that scenarios represented the undergraduate curriculum objectives. The reservation of both faculty and students regarding the use of the simulator as an evaluation tool appeared to be related to the fact that the environment was foreign to most students. Faculty felt that prior exposure to the simulator setting less important than students did with a median response of 4 by faculty and 5 by students. Faculty felt more positive than students with respect to the use of the simulator as a learning experience, although both groups rated its use as a learning experience very highly (median: faculty 5, student 4). Videotapes provided an adequate view of students’ performance (median 4, range 3–5), but the audio system was found to be less than adequate during a few scenarios (median 2, range 1–4). Faculty indicated a desire to continue their participation in future simulator research (median 4, range 1–5).
Comment
Students found the sessions to be an excellent learning experience and pages of comments to this effect were elicited. The response of participants to the use of the simulator as an evaluation tool was less enthusiastic than its use as a learning tool. Thirty-eight percent of students agreed or strongly agreed and the same percentage disagreed or strongly disagreed on the use of the simulator as an evaluation tool, with faculty opinions demonstrating a similar trend. Students and faculty who disagreed expressed the need for experience in a simulator setting before an evaluation process.

In order for this tool to be introduced as an evaluation method, participants’ opinions should be addressed, and where appropriate, integrated into the proposed assessment technique. With respect to undergraduates and faculty at our institution, important opinions have been elicited that will strengthen the ultimate integration of this innovative tool into undergraduate evaluation.

Acknowledgements
This study was supported in part by a research grant from the Canadian Anesthesiologists’ Society. The authors would like to acknowledge the efforts of the faculty from the Department of Anaesthesia and the medical students from the University of Toronto.

References
2. Van Der Vleuten CPM, Newble DI. How can clinical reasoning be tested? Lancet 1995; 345:1032–4

Anaesthetists’ attitudes to monitoring instrument design options

T. Nazir1 and P. C. W. Beatty2*

1Department of Anaesthesia, South Manchester University Hospitals NHS Trust, Withington Hospital, Nell Lane, Manchester M20 8LR, UK. 2Division of Imaging Science and Biomedical Engineering, The Stopford Building, The University of Manchester, Oxford Road, Manchester M12 9PT, UK

*Corresponding author

A survey into the attitudes of anaesthetists to features in monitoring instruments, particularly the design of alarms, visual warnings, alarm limits and the general instrument interface is reported. Questions in the survey had short introductions outlining a clinical scenario followed by items that proposed alternative design features that an instrument might have. Participants were asked to grade their responses to these alternatives on a scale of 1 (strongly disagree) to 5 (strongly agree). The results suggest that anaesthetists would welcome the use of more advanced technology in instrument design. They prefer context-specific messages and alarms. They reject overt control systems for delivering anaesthesia, except for use in exceptional circumstances. Generally, the preferences of anaesthetists are consistent with known principles of safe, ergonomic design.

Br J Anaesth 2000; 85: 781–4

Keywords: anaesthetists, attitude to computers; equipment, safety; equipment, alarms; monitoring, computerized

Accepted for publication: June 26, 2000
This communication reports the results of a nationwide survey into the attitudes of anaesthetists to features in monitoring instruments, particularly the design of alarms, visual warnings, alarm limits and the general instrument interface. We set out to answer three questions. First, what sorts of design features are preferred by anaesthetists? Secondly, are these preferences consistent with the principles of safe, ergonomic design? Thirdly, do attitudes indicate ways to improve instrument design?

Methods and results

Survey design

The survey had three sections and was based on a previously validated questionnaire. The first section consisted of a series of questions about the features of monitoring instruments. The questions were usually prefaced by a short clinical scenario. Responses were then invited to proposed alternative instrument design features relevant to the scenario. Participants were asked to grade their responses to each of these items on a scale of 1 (strongly disagree) to 5 (strongly agree). The wording of the questions and the items is shown in Table 1.

The second section requested details of the respondent and self-assessment on a five-point scale of computer literacy, computer access, general computer use and the use of computers in the operating theatre. The final section allowed free-form comments.

The questionnaire was sent to 1500 anaesthetists selected randomly from the British Medical Association membership list. Return was by Freepost through an enclosed pre-addressed envelope. Non-returners were followed up after 1 month with a new copy of the questionnaire and after 2 months by telephone to obtain information which was taken to be representative of non-responders.

Statistical analysis

Statistical analysis followed a standard form using SPSS for Windows version 8.0. Responses were placed in order of popularity using the Friedman rank (highest, most popular). The mode was used to indicate the extent of agreement. After adjustment for item score skewness, exploratory factor analysis was performed using principal components analysis, which produces the most parsimonious description of factors. Used in this way, factor analysis seeks to find underlying groupings concordant with an identifiable underlying attitude.

Responses

In total, 504 valid replies were received, of which 382 were returned initially and 122 as a result of reminders. This return rate of 33.6% is disappointing but compares favourably with the best group in the preliminary study. No significant differences between the background of responders and non-responders were demonstrated.

Question 1: how much control should a decision support system have?

The design options in the items for this question concerned the instrument having direct control of treatment and methods of presenting alarms and warnings. Three factors were identified. The first was about giving control of treatment to the machine, and was characterized by low ranks and modes for machine-centred approaches. The only acceptable situation identified as a candidate for machine control was when there were distinct signs of danger.

The second and third factors were about how warnings might be given. Public warnings (i.e. warnings that are visible/audible to other staff) characterized the second factor, whereas in the third factor the warnings were private. We conclude that anaesthetists see private warnings as serving functions different from public warnings.

Question 2: how should a computer decision support system communicate with the clinician?

In this scenario both warnings/alarms and advice were to be given by the instrument. The items contrasted flow diagrams and/or text with structured sounds and spoken alarms. Advice was contrasted with warning in the items under this question. Three factors were identified: factor 1, all graphical; factor 2, all sounds; and factor 3, flow diagrams used off-line. The anaesthetists showed a preference for thinking of audible systems only in terms of warnings. Audible advice had a low rank and mode.

Question 3: what is the best design of visual warnings on individual monitors?

In the situation of limited display space, idiographic symbols were contrasted with different text-based systems, and ranged from simple short messages to displays that had to be interpreted from an error code. Again, three factors were identified. The first concerned text-based options, in which the ranks, modes and factor weights were good. Factors 2 and 3 were non-homogeneous in design type. Idiographic designs appeared in both, mixed with text-based approaches.

Question 4: what is the optimal way of displaying alarm limits?

The final question concerned the design and positioning of alarm limit displays. Novel limit displays such as polygons were included, along with more conventional colour-coded, numerical and graphical methods. Position options were also included. Two factors emerged from the analysis,
Table 1: Attitudes to monitoring instrument features. Rank = mean Friedman rank for each item; mode = the mode of the item; weight = factor weightings using principal components analysis, the varimax rotation with Kaiser normalization. No factors with eigenvalues below 1.0 or items with a factor weight <0.4 are reported. Thus, all factors reported have equivalent statistical significances of P<0.01. Negative weights indicate that the scale of the item runs in the opposite direction to normal, i.e. the higher the respondent rating the lower the score on the scale.

<table>
<thead>
<tr>
<th>Items grouped by factors within questions</th>
<th>Rank</th>
<th>Mode</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>How much control should a decision support system have? A computer decision support system connected to a machine (e.g. a ventilator) being used to treat a patient detects a hazardous condition. It should...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under no circumstances change a patient’s treatment automatically</td>
<td>7.72</td>
<td>4</td>
<td>-0.62</td>
</tr>
<tr>
<td>Change the patient’s treatment if alarm is not cancelled and the vital signs show an unequivocally dangerous condition</td>
<td>6.75</td>
<td>4</td>
<td>0.93</td>
</tr>
<tr>
<td>Change the patient’s treatment if alarm is not cancelled after given time</td>
<td>4.55</td>
<td>1</td>
<td>0.86</td>
</tr>
<tr>
<td>Change the patient’s treatment without warning</td>
<td>2.30</td>
<td>1</td>
<td>0.92</td>
</tr>
<tr>
<td>Set off a non-specific audible alarm and put up a condition-specific visual alarm on a display</td>
<td>8.43</td>
<td>4</td>
<td>0.52</td>
</tr>
<tr>
<td>Set off a condition-specific audible alarm heard by other staff and patients</td>
<td>7.64</td>
<td>4</td>
<td>0.54</td>
</tr>
<tr>
<td>Set off a non-specific visual alarm and put up a condition-specific visual alarm</td>
<td>6.93</td>
<td>4</td>
<td>0.55</td>
</tr>
<tr>
<td>Set off a non-specific audible alarm heard by other staff and patients</td>
<td>5.28</td>
<td>2</td>
<td>0.78</td>
</tr>
<tr>
<td>Set off a non-specific visual alarm seen by other staff and patients</td>
<td>5.07</td>
<td>2</td>
<td>0.70</td>
</tr>
<tr>
<td>Set off a non-specific audible alarm only heard by staff treating the particular patient</td>
<td>6.65</td>
<td>3</td>
<td>0.73</td>
</tr>
<tr>
<td>Only put up a condition-specific message on the patient monitor but issue no general alarm</td>
<td>4.68</td>
<td>2</td>
<td>0.75</td>
</tr>
</tbody>
</table>

How should a computer decision support system communicate with the clinician? Audible alarms and advice are to be given by the computer decision support system. They should...

| Offer extra physiological instrument displays | 6.46 | 4    | 0.65   |
| Offer graphical animated displays that suggest what is happening in the body but can be expanded into other displays on request | 5.98 | 4    | 0.82   |
| Include displays with more derived numerical information                                              | 5.52 | 3    | 0.70   |
| Offer graphical animated displays that suggest what is happening in the body                          | 5.41 | 3    | 0.80   |
| Have audible alarms that are structured, i.e. bleeps, warbles, etc., indicating which measurement and intensity of alarm | 6.44 | 4    | 0.46   |
| Have alarms in words, e.g. The blood pressure is too high                                             | 5.29 | 4    | 0.70   |
| Give instructions/advice about procedures as step-by-step text only                                   | 4.19 | 3    | 0.49   |
| Not offer advice to the anaesthetist visually but by voice e.g. The carbon dioxide is rising so watch the placement of the laryngoscope | 2.25 | 1    | 0.75   |
| Give instructions/advice about procedures as flow diagram boxes that can expanded into a full text explanation if required | 7.69 | 4    | 0.84   |
| Give instructions/advice about procedures as flow diagrams                                           | 5.78 | 4    | 0.84   |

What is the best design of visual warnings on individual monitors? Many instruments used by anaesthetists are small with limited display space. On such instruments visual warnings should...

| Combine an audible indication of urgency, e.g. a structure sound, with a grammatical message on the main display | 7.22 | 4    | 0.67   |
| Use short sentences of written text in English on the main display to describe the situation, e.g. Warning—the oxygen concentration is too low | 6.49 | 4    | 0.74   |
| Combine a front panel-mounted indication of urgency, e.g. a red light for most urgent warning) with a grammatical message on the main display, e.g. Oxygen low! | 6.48 | 4    | 0.52   |
| Use short grammatical messages, e.g. Oxygen low!, on the main display                                | 6.33 | 4    | 0.70   |
| Use idiographic symbols on the front panel of level of urgency, e.g. very urgent, combined with a grammatical message on the main display e.g. Oxygen low! | 6.00 | 4    | 0.53   |
| Use idiographic symbols on the front panel, which are visible before they are activated and illuminated | 4.02 | 3    | 0.83   |
| Use an annunciator style warnings with short text messages, where the warning is visible all the time but becomes illuminated when a warning occurs | 3.77 | 3    | 0.73   |
| Use numbers or letters for warning codes that have to be learned or looked up by the anaesthetist, e.g. Error no. 38 = temperature too high | 1.59 | 1    | 0.47   |
| Use idiographic symbols presented on the main display, e.g. = alarms muted                           | 7.47 | 4    | -0.69  |
| Combine an audible indication of urgency, e.g. a structured sound, with an idiographic symbol on the main display, e.g. = alarms muted | 6.95 | 4    | 0.74   |
| Use idiographic symbols on the front panel which are invisible before they are activated and back-lit | 5.02 | 3    | 0.56   |

What is the optimal way of displaying alarm limits? Research indicates that knowing what the alarm limits are whilst using anaesthetic equipment may be important in reducing the time it takes the anaesthetist to react to critical incidents. Given the limitations of display space on most instruments, alarm limits should...

| Be colour-coded so they are linked with the waveform on the main waveform display | 6.61 | 4    | 0.62   |
| Be displayed permanently on the main graphical display of the instrument in relation to the measurement waveform | 6.34 | 4    | 0.54   |
| Be colour-coded for urgency                                                                  | 6.29 | 4    | 0.58   |
| Be displayed numerically on the main waveform display                                         | 6.04 | 4    | 0.43   |
| Be displayed graphically at the periphery of the waveform display                            | 5.59 | 3    | 0.59   |
| Be displayed graphically on the main waveform display                                        | 5.37 | 3    | 0.68   |
| Be displayed on a specially designed display that integrates current values with the display limits, e.g. a polygon display or a riverbed display | 5.08 | 3    | 0.59   |
| Be displayed on demand on the main graphical display instrument in relation to the measurement waveform of the instrument | 5.79 | 4    | 0.57   |
| Be displayed numerically on a separate display away from the graphical display               | 4.45 | 2    | 0.68   |
| Be displayed graphically on a separate display away from the graphical display              | 3.45 | 2    | 0.75   |
differentiated by whether the alarm limits are permanently visible near to the main display or further away. Close association of limits with the raw measurement data was preferred.

**Comment**

**Bias**

The biggest potential source of bias was that the responders were a self-selected group with a non-representative interest in instrument design. This sort of bias would explain the low return rate and is consistent with the tone of some of the comments made in the third section. We conclude that it is very hard, if not impossible, to avoid such self-selection. However, this may not be significant since these anaesthetists were most likely to have had an interest in equipment and were representative of those we most need to sample if improvements are to be made.

**What sorts of design features are preferred by anaesthetists?**

The results reported do not suggest that anaesthetists fear the use of more advanced technology in instrument design. In fact, many of the responses gave a cautious approval to more radical approaches than those incorporated in current instruments. Context-specific visual messages were preferred, as were sound-based designs with greater complexity, such as structured sounds. New measurements and more sophisticated displays were preferred, but detailed advice should be available off-line. Designs of visual warnings and alarm limits were considered immaterial provided they were easy to understand and closely associated with the main display of an instrument. The anaesthetists did not like systems that control the delivery of anaesthesia.

**Are these preferences consistent with known principles of safe, ergonomic design?**

Best practice in instrument design emphasizes consistency, simplicity, redundancy and visibility as being good design principles. Most of the preferences of the anaesthetists were consistent with this approach. For example, the anaesthetists preferred condition-specific alarms in a hierarchy of alarms going from non-specific towards specific. However, offering more physiological measurements and more complex displays in an already overcrowded environment is not consistent with good ergonomics.

**Can attitude research guide future safer designs?**

The direct testing of instrument human factors performance in normal practice is virtually impossible because critical incidents are too rare. Therefore, testing requires simulation and measurements of performance which are surrogates of performance in the field (e.g. reaction time). Some design features preferred by anaesthetists might be tested in this way. The results of such testing will demonstrate the validity of this attitude-based approach to detecting key features in design. If it is valid, the type of attitude survey reported here may prove useful in any environment.

**Acknowledgements**

We are happy to acknowledge the financial support of this study by Medical Industrial Equipment Ltd., Exeter.

**References**

7. AAMI Human Factors Committee. Human factors engineering guidelines and preferred practices for the design of medical devices. American National Standards Institute, 1993
8. Morris RW, Montano SR. Response times to visual and auditory alarms during anaesthesia. Anaesth Intens Care 1996; 24: 682-4
Effect of remifentanil compared with fentanyl on intraocular pressure after succinylcholine and tracheal intubation

H.-P. Ng¹, F.-G. Chen²*, S.-M. Yeong¹, E. Wong² and P. Chew²

Departments of ¹Anaesthesia and ²Ophthalmology, National University Hospital, Singapore, 5 Lower Kent Ridge Road, Singapore 119074

*Corresponding author

Rapid sequence induction using succinylcholine is associated with an increase in intraocular pressure (IOP). This may lead to loss of ocular contents in open globe injuries. No method has previously been shown to prevent this increase in IOP. We investigated whether remifentanil, an ultra-short-acting opioid, could attenuate this increase in IOP during rapid sequence induction of anaesthesia. Forty-five patients were randomized blindly to receive remifentanil 1 µg kg⁻¹, fentanyl 2 µg kg⁻¹ or placebo 1 min before thiopental, succinylcholine and tracheal intubation. IOP and haemodynamic variables were measured before, 1 min after the test solution, 30 s after thiopental, 30 s after succinylcholine, immediately after intubation and then every 3 min for 9 min. Remifentanil obstunted the increase in IOP after succinylcholine and intubation, so it could be suitable for use in open globe injuries.

Br J Anaesth 2000; 85: 785–7

Keywords: eye, intraocular pressure; Tonopen; neuromuscular block, succinylcholine; anaesthetics i.v., thiopental; analgesics opioid, remifentanil

Accepted for publication: July 3, 2000

Rapid sequence induction is an established technique in emergency anaesthesia to minimize the risk of pulmonary aspiration. Succinylcholine is the neuromuscular blocking agent of choice in this clinical situation because of its short onset time. It is, however, associated with an increase in intraocular pressure (IOP). Laryngoscopy and tracheal intubation further aggravate the increase in IOP.

Remifentanil is an ultra-short-acting mu-receptor agonist. It has a rapid onset of analgesia, with a peak effect 1 min after administration.¹ Alexander, Hill and Liphim found that remifentanil 1 µg kg⁻¹ given after induction with propofol 2 mg kg⁻¹ prevented an increase in IOP after succinylcholine and tracheal intubation.² The effect of remifentanil with thiopental on IOP has not been described. This study was undertaken to determine if a bolus of remifentanil given before induction of anaesthesia with thiopental can obstund the IOP effects and haemodynamic changes associated with rapid sequence induction.

Methods and results

After obtaining Hospital Ethics Committee approval and informed consent, we studied 45 unpremedicated (ASA I or II) patients scheduled for elective surgery. Patients with ocular, respiratory or cardiovascular disease were excluded. The patients were randomized into three groups using sealed envelopes. Group R received remifentanil 1 µg kg⁻¹, group F received fentanyl 2 µg kg⁻¹ and group P received normal saline as test solution. An applanation tonometer (Tonopen XL, Mentor O&O, Norwell, Massachusetts, USA) was used to measure the IOP in triplicate (mean value recorded) by one of the investigators (H.-P.N. or F.-G.C.) who was unaware of the test drug to be given.

Amethocaine 1% drops were instilled on the patient’s left eye and baseline IOP was measured (time I). After 3 min of preoxygenation, a bolus of test solution diluted to 10 ml was administered over 30 s. Measurement was repeated 1 min later (time II) and anaesthesia was then induced with i.v. thiopental 5 mg kg⁻¹. At loss of eyelash reflex (time III), IOP was recorded and succinylcholine 2 mg kg⁻¹ administered. Thirty seconds later (time IV), IOP was measured. Laryngoscopy and intubation were then performed and IOP was measured immediately and every 3 min for 9 min (times V–VIII). Anaesthesia was maintained with 1% isoflurane and 66% nitrous oxide in oxygen and ventilation adjusted to maintain normocarbia. At each IOP measurement, mean

¹Presented in part at the International Anaesthesia Research Society, 2000.
arterial pressure (MAP), heart rate, oxygen saturation, end-tidal PCO2, peak airway pressure and inspiratory concentration of isoflurane were recorded. Intravenous atracurium was given after time VI to maintain muscle relaxation. Surgery only began after the study was complete.

Physical characteristics (except for gender, which was analysed using the χ² test), IOP, MAP and heart rate between groups were compared using one-way analysis of variance (ANOVA) with post hoc Bonferroni correction. Intra-group comparisons of IOP, MAP and heart rate differences from baseline were done using repeated measures ANOVA and post hoc Bonferroni correction. Results are expressed as mean (SD). A P value of <0.05 was considered significant.

There were no significant differences in physical characteristics (age, ASA status, gender or height) between groups except for weight between groups F and P (P=0.021). There were 10, 7 and 12 males in groups R, F and P, respectively. Mean (SD) ages were 31.8 (11.1), 35.5 (8.8) and 31.0 (10.1) yr; mean (SD) weights were 59.7 (11.1), 57.9 (7.6) and 69.1 (13.1) kg; and mean (SD) heights were 163.5 (7.0), 161.1 (7.4) and 169.0 (6.2) cm in groups R, F and P, respectively.

The values of heart rate, MAP and IOP are shown in Figure 1. No significant differences in heart rate among the three groups were recorded at any time. When comparing MAP between groups, significant differences were seen at times V–VII. The MAP of group R was significantly lower than that of group P at times V (P=0.018) and VI (P=0.004). Similarly, MAP in group F at times VI (P=0.024) and VII (P=0.006) was significantly lower than that in group P.

There were no significant differences in baseline IOP between the three groups. After giving the test solution, there was a significant decrease, compared with baseline, in IOP in group R (P=0.011) but not in group P or F. Thiopental decreased IOP significantly compared with baseline in all groups (point III in Figure 1) (P<0.001). Succinylcholine and intubation increased IOP in all groups. However, IOP in group R after intubation was not significantly different from that at baseline (point V in Figure 1), unlike that in the other groups (P<0.001 in group P; P=0.046 in group F).

There were significant differences in IOP between the three groups at times V–VII. The IOP of group R was lower than that of group P at times V (P=0.027), VI (P=0.02) and VII (P=0.015). When comparing differences from baseline IOP between the three groups, the difference in group R is lower than that at group P at times II and IV–VII and that of group F is significantly lower than that of group P at times V and VI (P<0.05).

**Discussion**

Succinylcholine is used during rapid sequence induction despite its effects on IOP because its speed of onset and effect allow intubation in 30–60 s. Its short half-life also allows fast recovery of muscle power if the airway conditions are difficult.

Rocuronium, a new non-depolarizing neuromuscular blocking drug with a short onset time, has been found not to increase IOP. Unfortunately, it does not provide as rapid and predictable intubating conditions as succinylcholine unless doses of three times the ED₉₅ are used. Its long duration of action may then cause problems in the presence of an unexpectedly difficult airway.

In our study, fentanyl 2 μg kg⁻¹ failed to attenuate the increase in IOP. Sweeney and colleagues found that fentanyl 2.5 μg kg⁻¹ and alfentanil 10 μg kg⁻¹ attenuated the increase in IOP associated with succinylcholine and intubation. In their study, the larynx and tracheal were sprayed with lidocaine 1.5 mg kg⁻¹ to reduce the deleterious effects of intubation. This is not usual practice in an emergency because attenuation of the gag reflex potentially
increases the risk of aspiration. Our protocol attempts to simulate as closely as possible a rapid sequence induction technique.

Remifentanil is a new short-acting narcotic with a rapid termination of effect and a half-life of 8–10 min. It provides a profound, yet brief, period of analgesia of almost immediate onset. The main untoward effects of remifentanil are respiratory depression, bradycardia and muscle rigidity. We did not observe any of these effects despite giving the bolus of remifentanil over 30 s. There was also no complaint of nausea or difficulty in breathing.

In our study, remifentanil outperformed the increases in IOP associated with succinylcholine and intubation. This may be a result of the short onset time of remifentanil, producing a maximum decrease in IOP by the time of administration of succinylcholine and intubation. We administered succinylcholine at doses of 2 mg kg⁻¹ and none of our patients coughed or gagged during intubation. In the study by Alexander and colleagues, succinylcholine 1 mg kg⁻¹ was used. Four patients either coughed or gagged and had to be excluded, possibly because of the low dose of succinylcholine used.

We chose thiopental as an induction agent instead of propofol, as it is more widely used for rapid sequence induction. Propofol decreases IOP more than thiopental, but causes significantly more hypotension. Its combination with remifentanil may not be appropriate in elderly or hypovolaemic patients.

This study has limitations. The gold standard for measurement of IOP is the Goldman Tonometer, but this is impractical during rapid sequence induction of anaesthesia. The Tonopen XL is an electronic applanation tonometer which uses a micro strain gauge transducer. Previous studies had shown that IOP measurements made with the Tonopen were sufficiently close to those made with the Goldman tonometer and can be considered clinically accurate.

The second limitation of this study was that it was conducted in patients with normal eyes rather than on patients with open globe injuries. The sequence of IOP changes in patients with open globe injuries may not be similar to those in patients with normal eyes. In an open globe, IOP is atmospheric and any increase in pressure results in further loss of ocular contents rather than an increase in IOP.

The third limitation of this study is that we used remifentanil at doses of 1 μg kg⁻¹; a dose of 2 μg kg⁻¹ would be equipotent with the dose of fentanyl used (2 μg kg⁻¹). We were concerned about the side-effects of giving a bolus of remifentanil of >1 μg kg⁻¹ over 30 s. The effect of remifentanil on IOP may be more pronounced had we given doses equipotent to that of fentanyl.

In conclusion, we found that remifentanil 1 μg kg⁻¹ outperformed the increase in IOP associated with succinylcholine and tracheal intubation without any unwanted haemodynamic effects.

References

4 Magorian T, Flannery KB, Miller RD. Comparison of rocuronium, succinylcholine and vecuronium for rapid-sequence induction of anaesthesia in adult patients. Anesthesiology 1993; 79: 913–8
6 McCollum JS, Dundee JW. Comparison of induction characteristics of four intravenous anaesthetic agents. Anaesthesia 1986; 41: 995–1000