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Quantitative Description of the Workload Associated With Airway Management Procedures

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Study Objectives: *To measure the workload associated with specific airway management tasks.*
Setting and Intervention: *Written survey instrument.*
Patients: *166 Stanford University and 75 University of California, San Diego, anesthesia providers.*
Measurements and Main Results: *Subjects were asked to use a seven-point Likert-type scale to rate the level of perceived workload associated with different airway management tasks with respect to the physical effort, mental effort, and psychological stress they require to perform in the typical clinical setting. The 126 subjects completing questionnaires (overall 52% response rate) consisted of 43% faculty, 26% residents, 23% community practitioners, and 8% certified registered nurse-anesthetists (CRNAs). Faculty physicians generally scored lower workload measures than residents, whereas community practitioners had the highest workload scores. Overall, workload ratings were lowest for laryngeal mask airway (LMA) insertion and highest for awake fiberoptic intubation. Airway procedures performed on sleeping patients received lower workload ratings than comparable procedures performed on awake patients. Direct visualization procedures received lower workload ratings than fiberoptically guided procedures.*
Conclusions: *These kinds of data may permit more objective consideration of the nonmonetary costs of technical anesthesia procedures. The potential clinical benefits of the use of more complex airway management techniques may be partially offset by the impact of increased workload on other clinical demands.*

Keywords: Airway management; anesthesia tasks; human factors; intubation, fiberoptic; larynx: laryngeal mask airway, laryngoscopy; stress, psychological; workload.

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Introduction

The anesthesiologist works in a complex task environment in which performance may be impaired by a variety of factors. The occurrence of human error in this dynamic, high technology, high-risk task environment is common and, if not detected and corrected, can lead to adverse outcomes.[1] The effects of workload on the response to new task demands may be important determinants of one's ability to manage critical events. A formal description of the clinical workload associated with different anesthesia tasks would aid in our understanding of the anesthesiologist's job and guide the optimization of anesthetic scheduling, procedures, equipment, and training.

A central premise of this paper is that the performance of all clinical tasks is associated with workload related to the required perceptual, cognitive, and/or physical demands. Because human attentional, cognitive, and physical abilities are limited, existing task demands reduce the resources available to attend to new stimuli or to take on new tasks. As a consequence, when overall workload increases significantly, task routine may become disorganized, "less important" tasks may be neglected, and the capacity to deal with new task demands may be impaired.[1,2] Previous studies suggest that the induction of anesthesia and securing of the airway is a period of high workload during which vigilance may be impaired.[1,3] It also has been shown that the use of more complex techniques or procedures, such as the use of transesophageal echocardiography, will similarly increase workload and may decrease vigilance.[3] When the addition of a new task increases workload, this increment in workload represents the noneconomic "cost" of undertaking this task. Understanding the workload associated with different airway management procedures may permit a more rational basis for clinical decision-making, resource allocation, and the design of training strategies. Lower workload tasks may require less training to attain proficiency. For example, if laryngeal mask airway (LMA) insertion required less cognitive and physical effort than either blind nasal intubation or direct laryngoscopy, it may be more appropriate to teach this airway management technique first to novice physicians, respiratory therapists, or emergency medical technicians (EMTs).[4]

There are three principal methods of measuring workload: physiological, procedural, and subjective (perceptual).[5] Several physiological correlates of the stress response, such as an increase in anesthesiologists' heart rates (HRs) during induction and laryngoscopy,[*,†,6] and again during emergence,[‡] have been used to assess workload. Procedural techniques of clinical workload assessment, including measurement of the time spent on secondary tasks, and subjective assessment by using rating scales, have been introduced to anesthesia.[1,3,7] Although objective measures of workload are believed by some to be more accurate than their more subjective counterparts,[8,9] subjective workload assessments are less intrusive, are usually easier and less expensive to obtain, and, in many situations, have a high degree of concurrent and face validity and reproducibility.[10] In a study of pilot workload,[11] subjective measures were found to be sensitive and to provide meaningful data. Ostensibly "objective" approaches invariably contain subjective elements, including the application of the measurement tools, methods of data collection, and data analysis techniques.[12]

The relative workload of different airway management techniques has not previously been measured. Thus, anesthesia providers at two distinct academic institutions were asked to rate the level of workload they typically associate with ten common airway management procedures. This study tested several specific clinical hypotheses: 1) airway procedures performed on "awake" patients would be rated as higher in workload than the same procedures on sleeping patients; 2) fiberoptically guided procedures would be rated higher in workload than those involving direct visualization; 3) LMA insertion would be a lower workload alternative to direct laryngoscopy; and 4) level of experience would correlate inversely with workload ratings. This last hypothesis implied that anesthesia providers with greater experience (*e.g.*, faculty and private practitioners) would rate the workload associated with airway techniques lower than would residents in training.

Materials and Methods

After obtaining institutional review board approval from the UCSD Human Subjects Committee and the Stanford Committee on Human Subjects in Medical Research, questionnaires were distributed to 166 Stanford and 75 University of California, San Diego (UCSD) anesthesia providers (*i.e.*, nearly all anesthesia providers at both institutions). The questionnaire listed 71 clinical tasks, which encompassed the vast majority of intraoperative anesthesia activities. These tasks were chosen based on a preliminary survey of anesthesia providers and the results of several previous real-time operating room (OR) anesthesia task analysis studies.[1,3,13] The subset of ten of the most common airway management techniques described in this study were refined based on a review of the literature (cf. ref. 14) and consultation with Dr. Jonathan Benumof, a recognized authority on anesthesia airway management.

Because different tasks may impose different kinds of workload,[5] three different categories were scored: physical effort (PE), mental effort (ME), and psychological stress (PS) by using a seven-point visual analog scale (VAS) anchored with a "1" representing "virtually no effort/stress" and a "7" indicating the "highest effort/stress possible." To keep the questionnaire brief, optimize the response rate, and allow for variability in anesthesia provider experience, detailed descriptions of each task were

*Toung TJK, Donham RT, Rogers MC: The stress of giving anesthesia on the electrocardiogram of anesthesiologists [Abstract]. *Anesthesiology* 1984;61:A465.

†Toung TJK, Donham RT, Rogers MC: The effect of previous medical training on the stress of giving anesthesia [Abstract]. *Anesthesiology* 1986;65:A473.

‡Weinger MB, Shen HD, Culp M, Fehrenbacher N, Herndon OW: Real-time workload assessment during anesthesia [Abstract]. *J Clin Monit* 1995;11:259.

not provided. Subjects were asked to rate each task based on a uniform 1 min of task performance, considering an average rating for *all* of the times they had performed that task. Subjects were instructed not to rate tasks that they had never performed.

Distribution Procedure

To protect confidentiality, questionnaires were assigned code numbers. A key of code numbers with associated subject names was kept under lock and key by a departmental secretary who otherwise had no knowledge of the contents of the questionnaire. The questionnaire was distributed to subjects either using their departmental mailboxes or via U.S. mail. A cover letter explained the purpose of the study including the confidential and voluntary nature of the survey. If a subject failed to respond after one month, a second request letter and questionnaire were mailed to the subject's home address. On return of the completed questionnaire, the secretary removed the code number from the questionnaire. Data from the now blinded questionnaire were then analyzed.

Research Design

The study design was a 4 (Level of Experience: CRNA, Resident, Faculty, Community practitioner) by 2 (Institution: UCSD, Stanford) by 10 (Type of Task: Awake and Asleep Direct Laryngoscopy, Awake and Asleep Blind Nasal Intubation, Awake and Asleep Fiberoptically-Guided Intubation, Placement of a Laryngeal Mask Airway, Insertion of a Double-lumen Endotracheal Tube (DLET), and Confirmation of Correct Placement of a DLET via either Ausculation or Fiberoptic Visualization) repeated-measures multivariate analysis of variance (MANOVA). Level of Experience and Institution were between-subjects factors; Type of Task was a within-subjects factor. The three workload indices (i.e., PE, ME, and PS) served as dependent measures. Clinical fellows were treated as residents.

Prior to analyzing the data, a principal components analysis was performed to ascertain whether the three workload indices were independent or significantly correlated.[15] Data were first tested for homogeneity of variance and normality. A square-root transformation was applied to the one variable that was not normally distributed. Workload ratings were analyzed using a 4 (Provider) × 2 (Institution) × 10 (Type of Task) repeated-measures MANOVA. The sphericity assumption of equal variances and covariances was tested in each analysis, and when this assumption was violated, the Greenhouse–Geisser correction was used to assess statistical significance. A Bonferroni p-value of 0.01 was considered statistically significant. Data are presented as means ± standard deviation.

Results

Demographics

Completed questionnaires were returned by 89 (54%) Stanford and 37 (49%) UCSD anesthetists (*Table 1*). Of the 126 subjects who returned completed surveys, 26% were residents, 43% were faculty, 23% were community practitioners (all at Stanford except for one at UCSD), and 8% were CRNAs (only at UCSD). Overall, subjects' ages ranged from 27 to 62 yrs old, with a mean age of 41 ± 9 yrs. Their clinical experience ranged from 1 to 46 yrs, with an average of 12 ± 11 yrs of training and experience combined. The demographic information is presented in *Table 1*.

Table 1. Demographics of Subjects

	Respondent	n (126)
Status		
CRNA*	7.9%	10
Resident	26.2%	33
Faculty	42.9%	54
Community MD†	23.0%	29
Institution		
UCSD	29.4%	37
Stanford	70.6%	89
Age (yrs)		
<35	30.2%	38
35–45	40.4%	51
46–55	19.1%	24
>55	7.9%	10
no-response	2.4%	3
Gender		
Male	69.1%	87
Female	30.9%	39
Total Anesthesia Experience (yrs)		
<3.0	17.5%	22
3.0–9.0	30.9%	39
9.1–16.0	23.0%	29
16.1–25.0	10.3%	13
>25.0	18.3%	23

CRNA = certified registered nurse-anesthetist, UCSD = University of California, San Diego.

* All of the CRNAs were from UCSD.

† All but one of the community practitioners were from Stanford.

Lack of Independence of Workload Indices

The principal components analysis revealed that the three workload indices were not independent, but rather were highly correlated. A correlation analysis confirmed these findings and suggested that psychological stress was more closely related to mental effort than to physical effort (*Table 2*). Therefore, the three workload indices were

Table 2. Correlations (R) Among the Three Workload Indices

	Mental Effort	Physical Effort	Psychological Stress
Mental effort	—	0.798*	0.876*
Physical effort	0.798*	—	0.683*
Psychological stress	0.876*	0.683*	—

* $p < 0.01$.

Table 3. Mean Workload Ratings by Provider Type and Institution

	Resident		CRNA	Faculty		CMD
Task	**UCSD**	**Stanford**	**UCSD**	**UCSD**	**Stanford**	**Stanford**
PHYSICAL EFFORT		4.0 ± 1.3*			3.2 ± 0.9*	4.4 ± 1.2*†
Asleep direct laryngoscopy	3.4 ± 0.9	4.1 ± 1.0	3.5 ± 1.7	2.8 ± 1.4	3.8 ± 1.3	4.7 ± 1.6
Awake direct laryngoscopy	4.0 ± 1.0	4.7 ± 1.5	3.8 ± 1.3	3.9 ± 1.2	3.9 ± 1.3	5.0 ± 1.5
Awake fiberoptic laryngoscopy	3.8 ± 0.8	4.6 ± 1.5	4.3 ± 1.5	3.9 ± 1.3	3.3 ± 1.2	5.0 ± 1.7
Asleep fiberoptic laryngoscopy	3.8 ± 1.3	4.2 ± 1.8	3.7 ± 1.3	3.7 ± 1.1	3.3 ± 1.0	4.9 ± 1.4
Laryngeal mask placement	2.8 ± 0.4	3.1 ± 1.5	3.0 ± 1.2	2.8 ± 1.1	2.8 ± 1.0	3.3 ± 1.3
Awake blind nasal intubation	3.6 ± 1.3	4.0 ± 1.4	4.0 ± 1.0	3.2 ± 1.2	3.3 ± 1.1	4.8 ± 1.7
Asleep blind nasal intubation	3.4 ± 1.1	3.8 ± 1.4	3.6 ± 1.2	3.0 ± 1.4	3.1 ± 1.0	4.5 ± 1.4
Placement of double-lumen ETT	3.6 ± 0.5	4.1 ± 1.4	4.3 ± 1.6	3.4 ± 1.4	3.3 ± 1.0	4.6 ± 1.6
Auscultation to confirm DLETT	2.0 ± 0.7	3.3 ± 1.7	3.2 ± 1.8	2.7 ± 0.9	2.3 ± 0.8	3.2 ± 1.4
Fiberoptic confirmation DLETT	3.2 ± 0.4	3.6 ± 1.6	3.1 ± 1.6	2.9 ± 1.2	2.6 ± 1.0	3.9 ± 1.4
MENTAL EFFORT		4.4 ± 1.2*			3.7 ± 1.1*	4.9 ± 1.2*†
Asleep direct laryngoscopy	3.7 ± 1.2	3.7 ± 1.4	3.4 ± 1.5	3.6 ± 1.2	3.5 ± 1.3	4.5 ± 1.6
Awake direct laryngoscopy	4.5 ± 1.0	4.4 ± 1.8	3.8 ± 1.5	3.9 ± 1.4	3.9 ± 1.2	5.2 ± 1.4
Awake fiberoptic laryngoscopy	4.5 ± 0.5	5.0 ± 1.4	4.6 ± 1.7	4.2 ± 1.4	4.2 ± 1.4	5.6 ± 1.4
Asleep fiberoptic laryngoscopy	4.0 ± 0.6	4.5 ± 1.6	4.4 ± 1.7	3.8 ± 1.6	4.0 ± 1.3	5.4 ± 1.4
Laryngeal mask placement	3.2 ± 0.8	3.4 ± 1.3	3.2 ± 1.0	2.6 ± 1.3	2.8 ± 1.1	3.8 ± 1.6
Awake blind nasal intubation	4.2 ± 1.5	4.5 ± 1.1	3.9 ± 0.8	3.1 ± 1.4	3.9 ± 1.2	5.3 ± 1.4
Asleep blind nasal intubation	4.0 ± 1.4	4.4 ± 1.4	3.8 ± 1.1	2.8 ± 1.4	3.6 ± 1.2	4.9 ± 1.5
Placement of double-lumen ETT	4.0 ± 1.3	4.8 ± 1.2	4.6 ± 1.6	3.7 ± 1.3	4.0 ± 1.4	5.1 ± 1.3
Auscultation to confirm DLETT	3.7 ± 0.5	4.7 ± 1.4	3.8 ± 1.6	3.3 ± 1.4	3.4 ± 1.4	4.6 ± 1.4
Fiberoptic confirmation DLETT	4.0 ± 0.6	4.4 ± 1.3	3.3 ± 1.5	3.2 ± 2.0	3.5 ± 1.2	4.8 ± 1.2
PSYCHOLOGICAL STRESS		4.5 ± 1.0*			3.8 ± 1.1*	4.8 ± 1.1*†
Asleep direct laryngoscopy	3.7 ± 0.8	4.2 ± 1.2	3.4 ± 1.7	3.6 ± 1.7	3.6 ± 1.4	4.6 ± 1.2
Awake direct laryngoscopy	5.3 ± 1.4	5.1 ± 1.4	4.3 ± 1.5	3.7 ± 1.3	4.2 ± 1.6	5.3 ± 1.6
Awake fiberoptic laryngoscopy	4.7 ± 1.4	5.0 ± 1.0	4.6 ± 1.7	3.7 ± 1.7	4.4 ± 1.5	5.8 ± 1.2
Asleep fiberoptic laryngoscopy	4.5 ± 1.8	4.7 ± 1.6	4.0 ± 1.6	3.2 ± 1.7	3.9 ± 1.3	5.5 ± 1.1
Laryngeal mask placement	3.8 ± 1.2	3.1 ± 1.4	2.9 ± 0.9	2.4 ± 1.1	2.9 ± 1.3	3.3 ± 1.5
Awake blind nasal intubation	4.8 ± 1.5	4.6 ± 1.2	4.6 ± 1.0	3.3 ± 1.3	4.3 ± 1.4	5.3 ± 1.5
Asleep blind nasal intubation	4.5 ± 1.5	4.3 ± 1.5	3.7 ± 1.3	2.8 ± 1.3	3.7 ± 1.4	4.6 ± 1.3
Placement of double-lumen ETT	4.3 ± 0.8	5.0 ± 1.2	4.1 ± 1.6	3.2 ± 1.4	4.1 ± 1.5	5.1 ± 1.3
Auscultation to confirm DLETT	3.5 ± 0.5	4.4 ± 1.5	3.8 ± 1.9	2.9 ± 1.1	3.4 ± 1.2	4.2 ± 1.4
Fiberoptic confirmation DLETT	3.5 ± 0.5	4.1 ± 1.3	3.1 ± 1.8	3.2 ± 1.8	3.2 ± 1.2	4.5 ± 1.3

CRNA = certified registered nurse anesthetist; CMD = community practitioner; UCSD = University of California, San Diego; ETT = endotracheal tube; DLETT = double-lumen endotracheal tube.

* Analysis of only Stanford providers across all airway tasks (see text for details).

† Significantly different from Stanford Faculty, $p < 0.01$.

analyzed concurrently by using a MANOVA to assess the relative effects of task, institution, and provider experience on these ratings.

Test of Hypotheses

There was a significant multivariate main effect for type of task ($F(27, 2403) = 8.80$, $p < 0.01$), indicating that the 10 airway tasks varied significantly in perceived workload (*Table 3*). Univariate tests revealed a significant task main effect for each of the three workload measures. Specifically, the 10 airway tasks varied significantly in their perceived physical effort [$F(9,801) = 14.69$; $p < 0.01$], mental effort [$F(9,801) = 12.27$; $p < 0.01$], and psychological stress [$F(9,801) = 15.98$; $p < 0.01$]. There were no significant multivariate main effects for provider or for institution, nor were any of the interactions terms significant.

Planned comparisons were used to test the hypotheses related to the task effect. The hypothesis that airway procedures performed on "awake" patients would be rated as higher in workload than the same procedures on sleeping patients was tested by comparing workload ratings for awake *versus* asleep laryngoscopy, blind nasal intubation, and fiberoptically guided intubation. Significant differences were found between awake and asleep techniques for each of the three workload indices (*see Table 4*). Compared to procedures performed on asleep patients, procedures performed on awake patients were rated higher in physical effort [$F(1,98) = 20.00$; $p < 0.01$; $eta^2 = 17$], mental effort [$F(1,98) = 45.93$; $p < 0.01$; $eta^2 = 0.32$], and psychological stress [$F(1,98) = 45.08$; $p < 0.01$; $eta^2 = 0.32$].

The hypothesis that fiberoptically guided procedures would be rated higher in workload than those involving

Table 4. Mean Workload Ratings for All Providers Combined

Airway Task*	Physical Effort	Mental Effort	Psychological Stress	Overall Rating†
Laryngeal mask placement	2.87 ± 1.14‡	3.12 ± 1.28‡	3.05 ± 1.30‡	3.01 ± 1.10
Auscultation to confirm DLETT	2.80 ± 1.25	3.96 ± 1.44	3.78 ± 1.42	3.51 ± 1.18
Fiberoptic confirmation DLETT	3.21 ± 1.35	3.87 ± 1.41	3.60 ± 1.44	3.57 ± 1.2
Direct Laryngoscopy	3.79 ± 1.41	3.65 ± 1.42	3.79 ± 1.43	3.74 ± 1.24
Asleep blind nasal intubation	3.51 ± 1.35	3.95 ± 1.40	3.95 ± 1.42	3.81 ± 11.26
Awake blind nasal intubation	3.77 ± 1.42	4.23 ± 1.36§	4.52 ± 1.43§	4.18 ± 1.26
Placement of double-lumen ETT	3.84 ± 1.36	4.39 ± 1.35	4.38 ± 1.42	4.21 ± 1.22
Asleep fiberoptic laryngoscopy	3.91 ± 1.35	4.44 ± 1.39‡	4.39 ± 1.47‡	4.25 ± 1.23
Awake direct laryngoscopy	4.16 ± 1.39‡§	4.29 ± 1.43‡§	4.60 ± 1.53‡§	4.36 ± 1.34
Awake fiberoptic laryngoscopy	4.08 ± 1.43‡	4.66 ± 1.38‡§	4.74 ± 1.42‡§	4.50 ± 1.26

DLETT = double-lumen endotracheal tube, ETT = endotracheal tube.

* Note order of tasks different from previous tables.

† Overall rating calculated as the mean of all workload scores for each task from all subjects.

§ Significantly different from the same procedure performed asleep, $p < 0.01$.

‡ Significantly different from (routine or Asleep) Direct Laryngoscopy, $p < 0.01$.

direct visualization was supported for ratings of mental effort and psychological stress. Respondents reported greater mental effort [$F(1,108) = 65.75$; $p < 0.01$; $eta^2 = 0.38$] and psychological stress [$F(1,108) = 13.63$; $p < 0.01$; $eta^2 = 0.11$] when using fiberoptically guided procedures compared with direct visualization. No difference was found in physical effort ratings between fiberoptically guided procedures and comparable direct visualization procedures.

The hypothesis that LMA insertion would receive a lower workload level than direct laryngoscopy was supported for each of the workload measures. LMA insertion was rated higher in physical effort [$F(1,124) = 65.10$; $p < 0.01$; $eta^2 = 0.34$], mental effort [$F(1,124) = 21.28$; $p < 0.01$; $eta^2 = 0.15$], and psychological stress [$F(1,124) = 33.02$; $p < 0.01$; $eta^2 = 0.21$] than direct laryngoscopy.

Effects of Provider Experience on Workload Scores

The effects of experience were first tested by comparing the workload ratings of residents and faculty at both institutions combined by using a 10 (Type of Task) × 2 (Experience: Resident *vs.* Faculty) MANOVA. The multivariate main effect for experience approached significance [$F(3,58) = 2.65$; $p < 0.06$]. Faculty members consistently rated workload lower than did residents with significant univariate effects observed for physical effort [$F(1,60) = 6.06$; $p < 0.05$], mental effort [$F(1,60) = 5.31$; $p < 0.05$], and psychological stress [$F(1,60) = 6.95$; $p < 0.05$]. However, experience did not moderate the effect of task type [*i.e.*, neither the multivariate or univariate task × experience interaction terms attained statistical significance ($F < 1$)]. Experience also failed to moderate the differences observed for asleep *versus* awake airway tasks, for fiberoptically guided *versus* direct laryngoscopy procedures, or for the contrast between LMA insertion and direct laryngoscopy.

As shown in *Table 3*, Community practitioners (CMD) rated workload higher than any other group. Because of this surprising finding, a further analysis was undertaken to compare the ratings of Stanford faculty, residents, and community practitioners. A 10 (Type of Task) × 3 (Provider experience) univariate repeated measures ANOVA conducted on combined (global) workload ratings revealed a significant main effect for provider experience, [$F(2,70) = 9.56$; $p < 0.001$; $eta^2 = 0.22$]. *Post-hoc* Bonferroni tests revealed that Stanford CMD's reported significantly higher workload than Stanford faculty ($p < 0.01$). Although workload decreased linearly with experience (CMD > residents > faculty), residents did not significantly differ from faculty or CMD.

Analysis of Workload Scores by Airway Task

On a seven-point scale, the average workload scores ranged from a high of 4.5 ± 1.3 for awake fiberoptic intubation to a low of 3.0 ± 1.1 for insertion of an LMA (see *Figure 1, Figure 2, and Table 4*). In contrast, the task "observing monitors" received a workload score of 1.8 ± 1.1 for physical effort and 3.5 ± 1.5 for mental effort while "cardiac arrest/OR resuscitation" was given workload scores of 5.7 ± 1.4 for physical effort and 6.4 ± 1.0 for mental effort (unpublished data).

Except for routine direct laryngoscopy (asleep DL), all other tasks had lower physical effort than mental effort or psychological stress. Overall, most tasks were considered to be lower in physical effort (mean score for all tasks was 3.56 ± 1.11) than mental effort (4.03 ± 1.14), or psychological stress (4.05 ± 1.15) [$F(2,250) = 35.1$; $p < 0.01$].

Discussion

The present study provides a quantitative comparison of the relative workload of different types of airway management tasks. The results reveal that anesthesia providers differentiate among 10 common airway procedures in

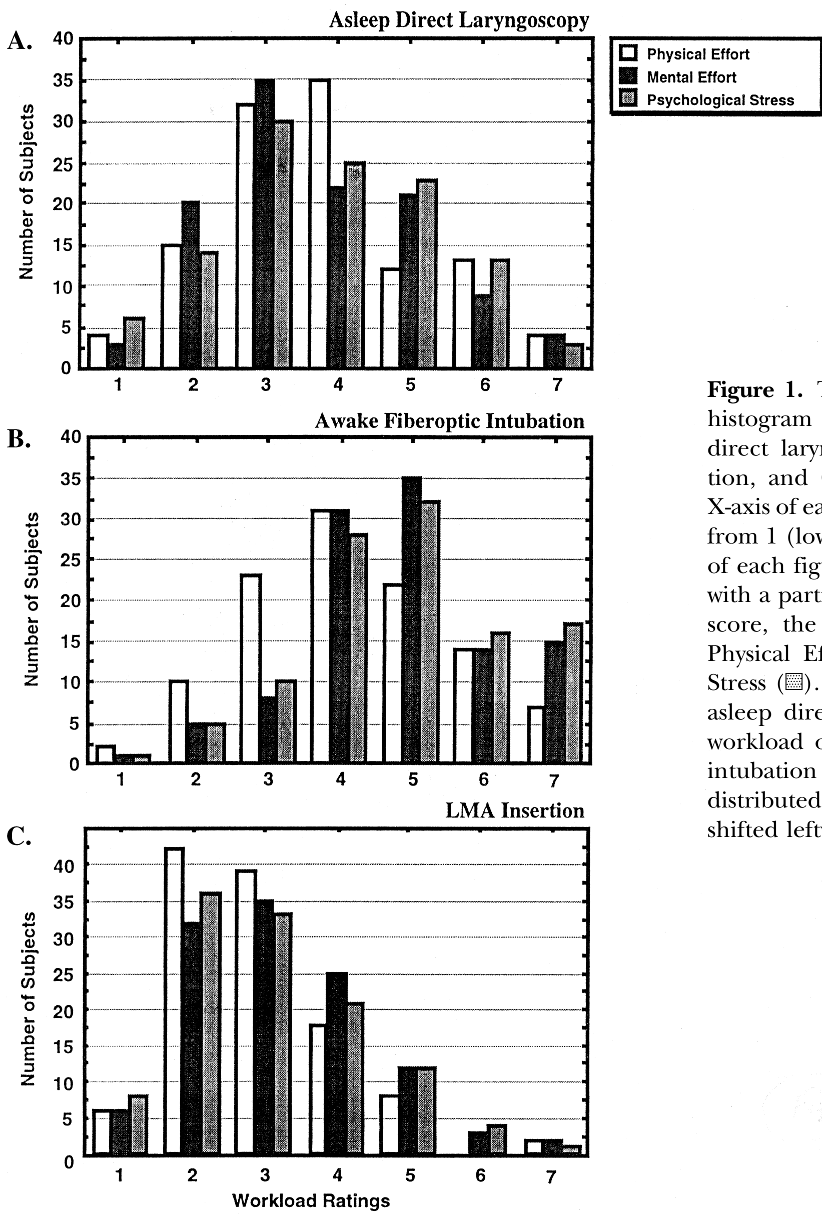

Figure 1. The raw scores from all subjects are displayed in histogram format for three airway procedures: **A.** asleep direct laryngoscopy, **B.** awake fiberoptically-guided intubation, and **C.** laryngeal mask airway (LMA) insertion. The X-axis of each figure shows the seven possible workload scores from 1 (lowest workload) to 7 (highest workload). The Y-axis of each figure shows the number of subjects that responded with a particular workload score. For each possible workload score, the three different types of workload are plotted: Physical Effort (□); Mental Effort (■); and Psychological Stress (▒). It can be seen that while the workload scores for asleep direct laryngoscopy are distributed about a median workload of 3–4, the workload scores for awake fiberoptic intubation are shifted rightward and more heterogeneously distributed while the workload scores for LMA insertion are shifted leftward.

their perceived level of workload. All of the initial hypotheses were supported in the present study: 1) airway procedures performed on "awake" patients were rated as higher in workload than the same procedures on sleeping patients; 2) fiberoptically guided procedures received higher workload scores than comparable procedures involving direct visualization; 3) LMA insertion was the lowest rated airway management technique; and 4) faculty rated workload significantly lower than did residents.

Workload is multidimensional and complex.[5] Nonmedical studies have demonstrated that mental effort is readily distinguishable from physical effort.[5,16] Psychological stress can be similarly distinguished from mental effort and this separation may help to differentiate the nature of work performed.[17] Based on the literature[5,18–21] and a pilot study,[3] we hypothesized that different workload indices would measure different aspects of the anesthesia provider's workload. Consequently, the survey asked anesthesia providers to assess the workload of different clinical tasks according to the amount of physical effort, mental effort, and psychological stress they each required. These three workload indices, however, did not independently describe the workload of the 10 anesthesia airway tasks examined in this study. In contrast, in two previous pilot studies,[*,3] the use of three workload indices facilitated the description and categorization of different *non-airway* management tasks. For example, moving the patient to/from the OR bed was ranked high in physical effort and

*Weinger MB, Shen HD, Culp M, Fehrenbacher N, Herndon OW: Real-time workload assessment during anesthesia [Abstract]. *J Clin Monit* 1995;11:259.

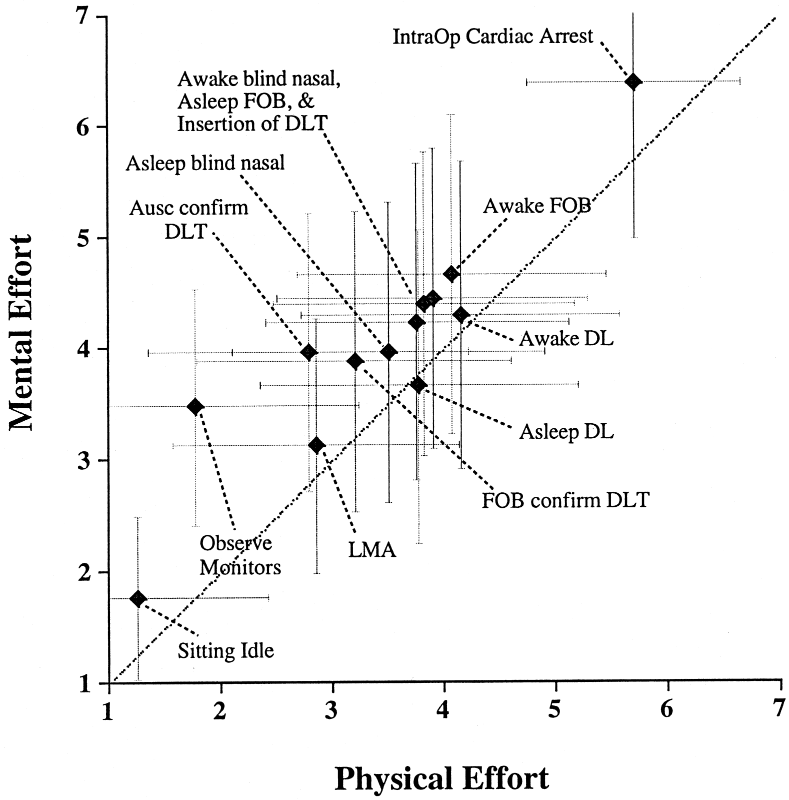

Figure 2. The mean workload values for all of the airway tasks are plotted on a graph in which the X-axis is the Physical Effort score while the Y-axis is the Mental Effort score. Standard error bars are shown for each task. For comparison, the workload values for two other tasks are also depicted (unpublished data from the same subjects): Intraoperative cardiac arrest (near maximal workload) and observation of one's monitors (relatively low workload). Statistical significance between airway task workloads is presented in Table 4. Intra Op = intraoperative, FOB = fiberoptic bronchoscopy, DLT = double-lumen tube, DL = direct laryngoscopy, LMA = laryngeal mask airway.

low in mental effort and psychological stress, whereas conversing with the surgeon was rated high in psychological stress, medium in mental effort, and low in physical effort. The present results suggest that different types of workload are not highly differentiated across *airway* management tasks.

Institutional and Provider Differences

The workload ratings at the two institutions were not significantly different. Because of their greater level of experience, it is not surprising that faculty rated the workload of complex airway tasks lower than anesthesia residents. It is widely accepted that both psychological and physiological workload are lower when performing tasks for which one has more experience, training, or recent familiarity*,†,[2,20] and subjective workload scores generally confirm this.[1] Familiarity with complex airway techniques may result in increased use, thus leading to even greater experience.[14]

In view of their clinical training and experience, one might *not* have expected community practitioners to rate airway task workloads *higher* than did faculty physicians at the same institution. However, community practitioners may use complex airway procedures less frequently—perhaps because of a lower incidence of "difficult airway" patients, greater skill with (and thus reliance on) direct laryngoscopy, or the absence of the need to perform these procedures for residents' educational benefit. Additionally, faculty physicians typically observe residents or CRNAs doing procedures whereas the community physicians must perform these tasks themselves. In an academic anesthesia practice, a team approach is more common, with several providers sharing the workload associated with anesthetic induction and airway management. Perhaps because community practitioners must take sole responsibility for the consequences of their medical decisions and actions, they may assign greater risk to the performance of more complex or uncommonly used procedures. Increased perceived risk is associated with greater stress and thus workload.

Study Limitations

As is the case with any survey instrument, the results may be affected by response bias. Generalization of the results to all anesthesia providers may be limited because the subject population was comprised of only two western U.S. academic medical centers. Because the number of CRNA subjects was quite small, these data may not be representative of this clinical cohort. Particularly because of differences observed between community (*e.g.*, private practice) and academic anesthesiologists, further investigation is needed to determine whether the results obtained in this

*Toung TJK, Donham RT, Rogers MC: The stress of giving anesthesia on the electrocardiogram of anesthesiologists [Abstract]. *Anesthesiology* 1984;61:A465.

†Toung TJK, Donham RT, Rogers MC: The effect of previous medical training on the stress of giving anesthesia [Abstract]. *Anesthesiology* 1986;65:A473.

study are applicable to a broad cross-section of anesthesiologists. However, there were no significant differences between the academic anesthesia providers at the two institutions studied, thus suggesting generalizability among university-based anesthesia faculty and residents.

Data from subjective assessment techniques may be influenced by a variety of cognitive biases, such as availability (the greater impact of more frequent, recent, or more salient experiences) and framing (how a question is phrased or the order of the questions).[22] The airway task questions were imbedded within a larger questionnaire that surveyed the workload of a broad cross-section of anesthesia tasks. The use of a different survey instrument or response format (other than three distinct indices and seven-point numeric scales) could affect the results. Because task descriptions were not provided to the subjects, it is possible that each individual's (mental) definition of a task may have differed slightly. However, the resultant variability should enhance rather than detract from the validity of any differences observed or the generalizability of the overall results.

Some of the airway techniques tested are more commonly performed as a routine elective procedure (*e.g.*, asleep direct laryngoscopy, LMA insertion), whereas others may more likely be undertaken after an initial airway management plan has failed (*e.g.*, attempted asleep fiberoptic intubation after a failure of direct laryngoscopy). It is possible that the greater frequency of emergent use of some tasks would bias their workload to higher values. It should be noted, however, that these data are from academic institutions where more complex airway procedures are just as likely to be performed electively for teaching purposes as in emergency situations. To further clarify the present results, a future study could present detailed clinical scenarios and then inquire as to the workload associated with different airway management approaches to each of those specific scenarios.

Not all possible clinical airway techniques were included. However, the excluded techniques, including Combitube (Kendall Sheridan Health Care Products, Argyle, NY), Bullard laryngoscope (Circon Acmi, Stamford, CT), lighted stylet, retrograde wire, and cricothyroidotomy, are still used infrequently in anesthesia practice in the United States.[14] We chose not to include surgical airway procedures because the study focused on anesthesia task performance.

The present survey approach does not *explicitly* measure vigilance, disorganization, or other task-related aspects of the anesthesia job. Subjective workload scores, by virtue of their subjective and holistic nature, may indirectly account for some of these other important markers of clinical performance. However, these other attributes can be measured more directly in other ways. For example, vigilance can be explicitly measured by using the time to detect changes in clinical stimuli such as illumination of an alarm light[*,1,3] or a simulated clinical variable.[7]

*Weinger MB, Shen HD, Culp M, Fehrenbacher N, Herndon OW: Real-time workload assessment during anesthesia [Abstract]. *J Clin Monit* 1995;11:259.

Validity and Reproducibility of the Results

The validity of these data can be supported in several ways. First, the results appeared reasonable to clinicians familiar with the airway techniques, thus suggesting a degree of face validity. Second, academic anesthesia providers with similar experience and training at two different institutions scored airway task-specific workload very similarly (interrater agreement). Third, the survey's results appear consistent with data obtained from two prior analogous workload questionnaires. The first survey, using only UCSD anesthesia providers, employed only a three-point (low, medium, high) scale to rate the workload of each task and a smaller subset of tasks was included.[3] A subsequent unpublished pilot study, again using only UCSD providers, employed the seven-point scale used in the present study but did not include complex airway tasks. Finally, Tsang and Vidulich,[10] using a similar rating methodology, showed that three different subjective rating measures established concurrent validity with task performance. Furthermore, both the performance measure and the three subjective rating measures demonstrated significant test-retest reliability.

Because there is no gold standard for the measurement of clinical workload, a comparison study to demonstrate construct validity is difficult. However, in a previous study, the results of a continuous workload metric, termed workload density, that incorporated task-specific workload values derived from the results of the earlier workload survey correlated well with other measures of clinical workload.[*,3] A future avenue of research should be to compare these other approaches with the technique described in the present manuscript.

This study represents only the initial stages of development of a new measure of workload as it relates to airway management and, as with any psychometric investigation, a single study is insufficient to assure validity. Additional studies employing different kinds of anesthesia providers from diverse practice settings are important to establish the accuracy and generalizability of the results.

Conclusions

The kinds of quantitative performance data reported in this study permit more deliberate consideration of the "cost" side of the cost/benefit analysis of technical anesthesia procedures.[1] In some cases, it is possible that the potential clinical benefits of the use of more complex airway management techniques may be partially offset by increased workload or a reduced ability to attend to unanticipated problems or new task demands.

The low workload rankings for LMA insertion in this study cannot be explained on the basis of greater subject familiarity; LMAs are not as available or as frequently used as endotracheal tubes at either Stanford or UCSD. The LMA's low workload along with other potential clinical benefits (*e.g.*, one may be able to use lower anesthetic concentrations) may help to explain its increasing popularity.

The present results suggest that, during high workload airway procedures (*e.g.*, awake fiberoptic intubation), it may sometimes be advantageous to have extra anesthesia personnel available to help. This idea is consistent with the widely espoused maxim that two (especially experienced) pairs of hands are better than one pair, particularly in a crisis situation. In such a circumstance, the arrival of additional experienced personnel will reduce the primary anesthesia provider's workload. Similarly, in a difficult airway situation where other clinical conditions (such as deteriorating hemodynamics) are increasing workload to very high levels, insertion of an LMA rather than undertaking more complex airway management techniques (*e.g.*, awake fiberoptic intubation) may be a prudent *initial* choice until the situation has clarified itself, more help is available, or workload becomes more manageable.

In the past, there has been some controversy regarding the necessity of employing a fiberoptic bronchoscope to confirm the correct placement of double-lumen endotracheal tubes. Some clinicians have claimed that clinical confirmation (*e.g.*, auscultation) is usually sufficient and the use of the fiberoptic bronchoscope represents unnecessary workload and cost. However, in the present study, there was no statistically significant difference in the workload scores of the ausculatory and fiberoptic techniques. Additionally, Klein *et al.*[23] recently showed that fiberoptic bronchoscopy demonstrated malposition of the double-lumen endotracheal tube in 79 of 172 patients in which the tube's position had already been judged correct by clinical assessment. In combination, these findings strongly support the routine use of fiberoptic bronchoscopy for confirmation of the correct placement of double-lumen endotracheal tubes.

The results of this study will facilitate the development of new techniques to measure real-time clinical workload and performance.[3] For example, during actual or simulated cases, workload density can now be calculated in real-time while conducting task analyses. This action is accomplished by multiplying the task(s) being performed at any instant by the task-specific workload values calculated from the present and related studies. The end result is a continuous quantitative workload profile of an entire anesthetic case. This technique will permit controlled prospective studies of the effects on clinical workload of specific interventions such as the impact of extended duty shifts (*e.g.*, sleep deprivation and fatigue), the introduction of new technologies, or the use of novel training strategies.

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