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RESEARCH ARTICLE

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Influence of airway trolley organization on efficiency and team performance: A randomized, crossover simulation study

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Abstract

Background: Failed management of unanticipated difficult airway situations contributes to significant anesthesia-related morbidity and mortality. Optimization of design and layout of difficult airway trolleys (DATs) may influence outcomes during airway emergencies. The main objective of the current study was to evaluate whether a difficult airway algorithm-based DAT with integrated cognitive aids improves efficiency and team performance in difficult airway scenarios.

Methods: In a crossover design, 16 teams (anesthetist, nurse anesthetist, assistant nurse) completed two high-fidelity simulated unanticipated difficult airway scenarios. Teams used both an algorithm-based DAT and a comparison, standard DAT, in the scenarios and were randomized to order of trolley type. Outcome measures included objective efficiency parameters, team performance assessment and subjective user-ratings. Linear mixed models ANOVA, including DAT type and order of condition as main factors, was utilized for the primary analyses of the team results.

Results: Usage of the algorithm-based DAT was associated with fewer departures from the difficult airway algorithm ($p = .010$), and reduced number of unnecessary drawer openings ($p = .002$), but no significant differences in time to retrieval of airway devices or time to first effective ventilation, compared to the standard DAT. There were no significant differences in team performance, although participants expressed strong preference for the algorithm-based DAT (all user-rated measures $p < .0001$). Higher percentage of female members of the team improved adherence to the difficult airway algorithm ($p = .043$).

Conclusions: Algorithm-based DATs with integrated cognitive aids may improve efficiency in difficult airway situations, compared to traditional DATs. These findings have implications for improvement of anesthetic practice.

KEYWORDS
anesthesia, difficult airway, equipment, intubation, simulation

Editorial Comment

In this simulation crossover trial including 16 anesthesiological teams, the integration of cognitive aids improved adherence to an unexpected difficult airway algorithm but did not improve time to effective ventilation compared to a standard algorithm which was around 6 min in both settings. This duration could potentially result in severe desaturation episodes demonstrating need for further improvements in unexpected difficult airway management routines and training in general.

1 | INTRODUCTION

Failed airway management is the most important anesthesia-related cause of severe brain damage and death.[1] Anatomically difficult airways are challenging to predict,[2,3] and emergency airway management is often complicated by physiological derangements of patients in high-risk settings, for example, emergency departments and intensive care units (ICUs).[4] Moreover, psychological and human factors contribute to the complexity of airway crises.[5]

When an unanticipated difficult airway situation arises, it is crucial to act rapidly to avoid critical deoxygenation of vital organs.[6,7] One key element for successful management of airway emergencies is immediate access to adequate resources. Unfortunately, previous reports show that delays in provision of airway equipment contribute to poor outcomes.[8,9] Recently, increased effort has been directed toward optimization of design and layout of portable difficult airway equipment units (hereafter referred to as difficult airway trolleys, DATs). Given that stress-induced deterioration of decision-making and situation awareness are associated with unsuccessful management of airway incidents,[10,11] DAT designs which promote adherence to difficult airway algorithms and mitigate cognitive overload might improve team performance and enhance implementation of rescue strategies. Accordingly, two recent major guidelines recommend organization of DATs to facilitate stepwise progression through a difficult airway algorithm,[12,13] and several designs have been suggested.[10,14,15]

Comprehensive training, to develop and maintain both technical and nontechnical airway management skills, is mandated universally by airway societies throughout the world.[12,16] By contrast, prior studies have shown deficiencies in practice of airway management techniques,[17,18] as well as lack of simulation training.[19] Less than half of Swedish anesthesiologists report undergoing team-based difficult airway training annually.[16] Moreover, practice involving DATs is uncommon,[20] and surveys indicate that knowledge of the contents of DATs may be low.[21]

The primary aim of the current randomized, crossover simulation study was to evaluate whether a difficult airway algorithm-based DAT with integrated cognitive aids contributes to increased efficiency and improved team performance during simulated difficult airway scenarios, compared to a "traditional" DAT (hereafter referred to as standard DAT). The algorithm-based DAT was created according to findings from a recent critical review of DAT organization and design, including features such as limited range of equipment ("less-is-more" concept), clearer links between devices and airway strategy, and integration of cognitive aids to enhance decision-making and prompt sequential execution of airway management strategies.[14] Almost 90% of Swedish anesthesiologists believe that a DAT design which promotes adherence to difficult airway algorithms might improve outcomes in clinical real-life airway emergencies.[16] Benefits associated with specific DAT designs may have implications for reduction of morbidity and mortality related to difficult airway management.

2 | METHODS

2.1 | Study design

This randomized, crossover simulation study primarily evaluated whether an airway algorithm-based DAT with integrated cognitive aids, compared to a standard DAT, contributes to improved efficiency and team performance during simulated difficult airway scenarios. All simulations were conducted at Practicum Clinical Skills Centre, Skåne University Hospital, Malmö, Sweden, October 25–29, 2021. The simulations were carried out in team-format (anesthetist, nurse anesthetist, assistant nurse); all teams underwent two unanticipated difficult airway scenarios, with access to one DAT per scenario (order randomized, either airway algorithm-based DAT or standard DAT). Scenarios were video-recorded and participants completed questionnaires upon completion of the exercises.

Prior to initiation of study activities, the study protocol was submitted to the national ethics committee (Etikprövningsmyndigheten) and deemed exempt from full review (Dnr 2020-06517); the requirement for written informed consent was waived by the ethics committee. Since the current research was not considered a clinical trial, the study was not registered in a public trials registry. No changes were made to methods after commencement of study activities.

2.2 | Study participants

Study participants were selected from the staff at the Department of Anaesthesiology and Intensive Care, Skåne University Hospital, Malmö, Sweden. Participants were selected to reflect varying levels of experience. No invited participant had previously worked with any of the two DATs which were used in the study; no further inclusion/exclusion criteria were applied. The study researchers were not involved in the participant selection process.

In total, 48 participants, that is, 16 teams consisting of anesthetist, nurse anesthetist and assistant nurse, were invited to participate in the study. Given that the Swedish Society of Anaesthesiology and Intensive Care Medicine (SFAI, Svensk Förening för Anestesi och Intensivvård) recommends team-based difficult airway training at least once per year, participation in the study was considered part of the training mission at the Department of Anaesthesiology and Intensive Care, Skåne University Hospital, Malmö, Sweden.

2.3 | Study procedure

All teams completed two difficult airway scenarios. The simulations were carried out at Practicum Clinical Skills Centre, Skåne University Hospital, Malmö, Sweden, using a SimMan 3G Patient Simulator (Laerdal Medical, Stavanger, Norway), which enables high-fidelity patient simulation. The airway can be complicated through multiple measures including, for example, trismus, pharyngeal obstruction, laryngospasm, and restricted neck mobility. The scenarios, and order of scenarios, were identical for all groups. The format of the simulation training was: introduction/prebriefing (~20 min), Scenario 1 (~10 min), debriefing/prebriefing 1 (~20 min), Scenario 2 (~10 min), debriefing/acquisition of user-rated outcomes (~30 min). All personnel involved in the execution of study activities were experienced with the simulation methodology and DIMS/CAMES-certified (Dansk Institut for Medicinsk Simulation/Copenhagen Academy for Medical Education and Simulation). All instructions and briefings were structured, standardized and the study personnel had unchanged roles throughout the course of the study. Video-recordings of simulations were obtained through three cameras. In addition to the SimMan 3G Patient Simulator, the simulation room contained a patient monitoring screen, a Zeus anesthetic machine (Dräger AG, Lübeck, Germany), a C-MAC videolaryngoscope (KARL STORZ, Tuttlingen, Germany), and an area for drug preparation.

Both scenarios were short (approximately 10 min each), standardized, repeatable, and planned to immediately expose the participants to high-stress levels. Briefly, Scenario 1 was an introperative case, where the participants were faced with a dislocated laryngeal mask and ongoing desaturation shortly after induction of anesthesia. In Scenario 2, set in a post anesthesia care unit (PACU), a patient was apneic with increasing hypoxemia after a tonic–clonic seizure episode. Both scenarios were constructed to allow attempts at the four principally different ways of achieving a free airway (intubation, oxygenation via a supraglottic airway device, facemask ventilation, emergency invasive airway access), and ultimately resulted in cannot ventilate, cannot intubate (CICO) situations, with ensuing front-of-neck-access (FONA).

2.4 | Difficult airway trolleys

Prior to initiation of Scenario 1, a brief demonstration (~5 min) of the two different trolleys was given to the participants. Participants also had an opportunity to acquaint themselves with the DATs and ask questions related to design and organization of equipment (~5 min). When the demonstration was completed, participants left the simulation room and awaited further instructions. The order in which the DATs were used was randomized; participants were just aware that they would be working with one of the DATs per scenario. Randomization was performed through a digital random number generator (www.randomizer.org), to determine the order in which DATs were used for each team. The result of randomization was revealed to the study team immediately prior to the start of each simulation session. Given the study design, and nature of the randomization (crossover), no allocation concealment mechanism was applicable.

We have previously provided detailed information about the airway algorithm-based DAT with integrated cognitive aids.[14] Principally, the algorithm-based DAT is subdivided to accommodate sequential progression through a four-step difficult airway algorithm: A = intubation, B = oxygenation via a supraglottic airway device, C = facemask ventilation, D = emergency invasive airway access.[12] The layout is structured with integrated color-coded cognitive aids (Figure 1A; further figures in reference 14). Content has strategically been limited ("less is more" approach), to reduce the risk of decision-delay.[22] Some of the included cognitive aids were partially adopted from DAT designs suggested by the Difficult Airway Society (although modified and translated to Swedish language)[23] and drawer front images were copied from the Vortex difficult airway cart.[10] All utilized cognitive aids are described in detail in reference 14 and also briefly outlined in Appendix A(1). Briefly, four relatively large figures, each linking one airway management strategy (A, B, C, D) according to the four-step difficult airway algorithm, to the content of a drawer (A, B, C, D), is provided on a vertical, clearly visible surface of the DAT. Additionally, on top of the DAT, two text boxes are integrated to increase situational awareness and promote adherence to the difficult airway algorithm. Contents of these boxes include instructions to summon help, limit number of attempts per airway management technique, keep flowing O_2 during attempts, be vigilant about ensuring adequate muscle relaxation and depth of anesthesia, as well as hypoxia and the potential possibility to wake up the patient. In Drawer 1, cognitive aids are included to promote use of a videolaryngoscope and continuous waveform capnography.

The standard trolley was reconstructed to reflect the exact layout, organization and content of a DAT currently used at a county hospital (with emergency department and ICU) in the southern part of Sweden (Figure 1B).

A complete list of included equipment is provided in Appendix A.

2.5 | Outcome measures

All outcome measures were determined prior to commencement of study activities.

2.5.1 | Efficiency

Objective efficiency measures were obtained through assessment of video recordings by two expert clinical observers (experienced anesthetists). Efficiency measures are described in Table 1.

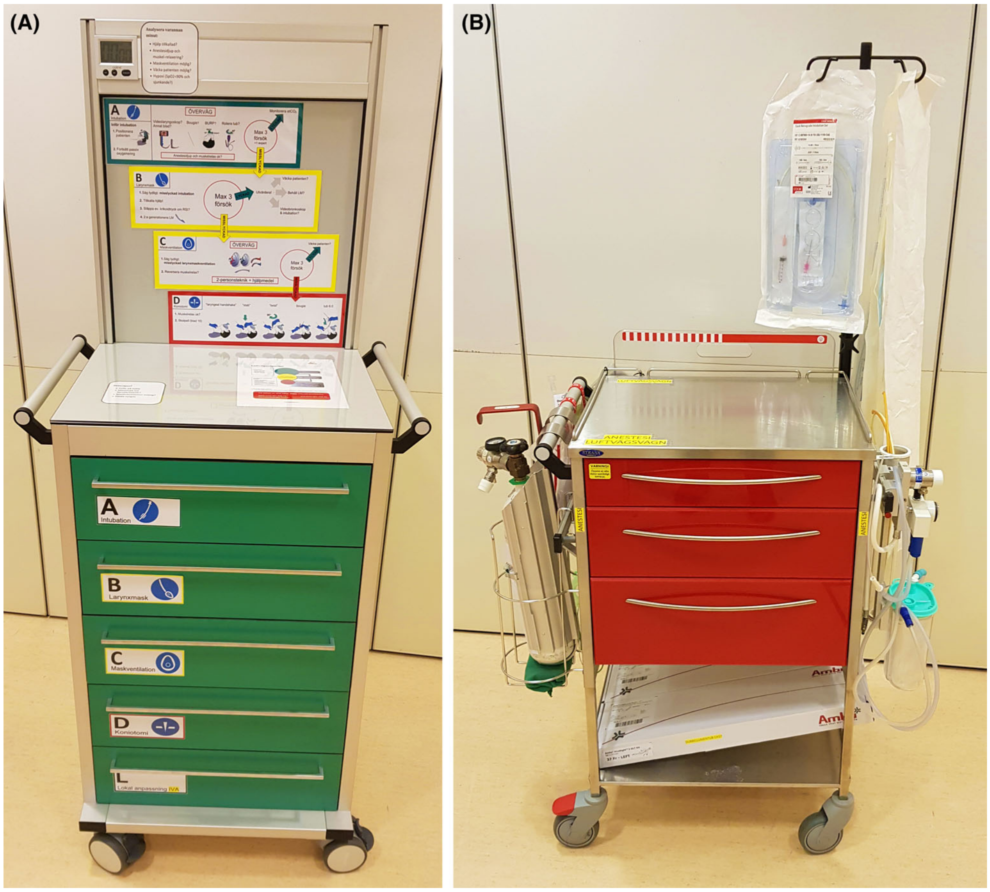

FIGURE 1 Design and layout of the (A) algorithm-based difficult airway trolley with integrated cognitive aids, and the (B) standard difficult airway trolley

2.5.2 | Team performance

Team performance was graded through assessment of video recordings by two expert clinical observers (anesthetist, nurse anesthetist) using the Team Emergency Assessment Measure (TEAM) instrument. In addition to a global rating of the team performance, the TEAM instrument generates three subscale-scores: leadership, teamwork and task management. The TEAM instrument was selected based on data indicating higher validity and reliability compared to 12 other tools for assessing teamwork in crisis situations.[24] Previous studies have demonstrated high internal consistency (Cronbach's alpha 0.78–0.95), high total content validity, strong correlation between total item score and global rating score (i.e., concurrent validity), adequate inter-rater reliability, as well as test–retest reliability.[25–29]

2.5.3 | Opinions about the DATs

Upon completion of both scenarios, participants were asked to complete questionnaires regarding their opinions about the two different DATs (Swedish version Appendix B; English translation Appendix C). Participants responded how strongly they agreed or disagreed to statements about the DATs on a scale 1–7 (ordinal scale 1 to 7, where 1 indicates "completely disagree" and 7 indicates "completely agree," as previously used in a simulation study comparing resuscitation trolleys).[30]

2.6 | Statistical analyses

The statistical analysis plan was approved by the authors before analyses began. All measures were assessed at the team level. Chi-squared analyses were used to compare categorical variables. Linear mixed models analysis of variance (ANOVA) was utilized for the primary analyses of the team results. The main factors were Trolley Type (within factor) and Order of condition (between factor); the interaction term was also included in the model. Compound symmetry was assumed for the within factor. Additionally, the main effects of two covariates were included in the model: the weighted average of the experience level across members of the team and the percentage of female members of the team (given sample size limitations, factor interactions with the covariates were not included in the model). Model derived estimated means and standard errors were generated for the Trolley Type × Order conditions and the covariates. One-way ANOVA was used to compare user-rated measures between occupational categories (post hoc test LSD). Sample size (16 teams) was determined by the number of teams which could be spared from clinical anesthesia work for 2 h/team during 1 week; given the repeated measures design, the study was sufficiently powered to detect large effects ($d = 0.80$) at 84.8% power. Post hoc power calculations were predicated on the main effects of the trolley condition. A p-value <.05 was considered significant. Data management and analyses were conducted utilizing SPSS version 27.0 (IBM Corp., Armonk, NY).

TABLE 1 Objective efficiency outcome measures

Outcome measure	Definition
Number of departures from difficult airway algorithm	Quantification of failures to adhere to the difficult airway algorithm. Eight possible departures were defined: 1. No intubation attempt 2. No attempt to oxygenate via a supraglottic airway device 3. No/suboptimal facemask ventilation attempt 4. No FONA attempt 5. No attempt to oxygenate during FONA procedure 6. No call for help 7. Incorrect usage of equipment (e.g., during FONA procedure) 8. No administration of muscle relaxants or deepening of anesthesia
Unnecessary drawer openings	Quantification of occasions when a drawer is opened without extraction of the desired equipment
Time to retrieval of airway device	Time from command until receipt of requested device (oropharyngeal airway, nasopharyngeal airway, laryngeal mask airway, endotracheal tube, bougie, scalpel)
Time to FONA decision	Time from start of simulation until verbal declaration that FONA shall be established
Maximum sound-level	Sound-level (decibel, dB) measurements were obtained through a digital sound meter (range 30–130 dB, accuracy ±1.5 dB; UNI-T 48880, UNI-TREND Technology, Dongguan City, China) placed approximately 3 m from the head of the SimMan 3G Patient Simulator

Abbreviation: FONA, front-of-neck-access.

3 | RESULTS

3.1 | Study participants

Out of 48 invited participants, one assistant nurse was not able to take part due to acute illness, resulting in a total of 47 study participants. Thirteen teams consisted of anesthetist, nurse anesthetist and nurse assistant, two teams were composed of anesthetist and two nurse anesthetists, and one team consisted of anesthetist and nurse anesthetist. One assistant nurse was not willing to complete questionnaires, which resulted in complete background data for 46 participants (Table 2). Frequency of simulation training has been significantly reduced due to the ongoing COVID-19 pandemic; most participants reported having undergone no such training the past year. There were no differences in anesthesiology or simulation experience related to profession (χ^2 (6) = 5.98, p = .426 and χ^2 (4) = 6.49, p = .166, respectively). In all analyses, the interaction term for Trolley Type × Order was not significant (all p's > .25) and thus will not be presented or discussed.

TABLE 2 Basic characteristics of the study participants (n = 46)

Characteristic	*n* (%)
Sex (male:female)	16:30 (34.8:65.2)
Profession	
Anesthetist	16 (34.8)
Nurse anesthetist	18 (39.1)
Assistant nurse	12 (26.1)
Experience anesthesiology	
<5 years	17 (37.0)
5–10 years	11 (23.9)
10–15 years	8 (17.4)
>15 years	10 (21.7)
Experience simulation-based training past 3 years	
0–1 times/year	39 (84.8)
2–3 times/year	6 (13.0)
≥4 times/year	1 (2.2)

3.2 | Efficiency measures

Usage of the algorithm-based DAT was associated with lower number of departures from the difficult airway algorithm, compared to the standard DAT (Table 3). Although usage of the algorithm-based DAT was associated with fewer unnecessary drawer openings, there were no significant differences in time to retrieval of airway devices, time to FONA decision or time to first effective ventilation (Table 3). Time to retrieval of nasopharyngeal airway and time to retrieval of laryngeal mask airway variables were excluded from analyses due to significant proportions of missing data (78.1% and 34.4%, respectively). There were no significant differences between the DATs related to maximum sound-level during the scenarios (Table 3). Interestingly, higher percentage of female members of the team improved adherence to the difficult airway algorithm (p = .043), whereas there was a trend toward poorer adherence to the difficult airway algorithm for teams with higher weighted average of experience level (Table 3).

3.3 | Team performance

The TEAM instrument global score and subscores were similar for both DATs (Table 3).

3.4 | Opinions about the DATs: user ratings

Participants expressed strong preference for the algorithm-based DAT, compared to the standard DAT (all eight measures p < .0001,

TABLE 3 Objective efficiency and team performance measures: algorithm-based DAT vs standard DAT

	Algorithm-based DAT		Standard DAT					
	First	Second	First	Second	$p^{Trolley}$	p^{Order}	Expertise Est (SE); *p*	% Female Est (SE); *p*
Number of departures from difficult airway algorithm	0.66 (0.26)	1.21 (0.26)	1.71 (0.26)	1.29 (0.26)	.010	.16	0.15 (0.07); .053	−1.68 (0.74); .043
Number of unnecessary drawer openings	2.98 (1.00)	2.53 (1.00)	6.15 (1.00)	7.23 (1.00)	.002	.45	−.027 (0.21); .23	0.37 (2.28); .88
Time to (s)								
Oropharyngeal airway	13.1 (3.33)	12.1 (3.33)	7.83 (3.31)	8.11 (3.10)	.20	.85	0.22 (0.68); .75	1.44 (7.36); .85
Endotracheal tube	61.7 (14.1)	51.8 (14.1)	64.3 (14.1)	67.8 (14.1)	.48	.68	−2.11 (3.36); .55	3.67 (36.1); .11
Bougie	57.5 (9.12)	40.0 (9.14)	49.6 (9.14)	59.3 (9.08)	.50	.21	−6.08 (2.27); .020	15.5 (22.5); .51
Scalpel	29.3 (7.80)	24.1 (7.80)	30.6 (7.80)	38.5 (7.80)	.32	.44	−1.08 (1.76); .56	7.02 (18.9); .72
FONA decision	283 (25.9)	265 (25.9)	253 (25.9)	240 (25.9)	.19	.94	−10.8 (6.70); .14	31.2 (72.0); .68
First effective ventilation	399 (27.5)	382 (27.5)	379 (27.5)	375 (27.5)	.61	.82	−12.4 (6.14); .067	−35.1 (66.0); .61
Team performance								
Leadership (0–8)	7.55 (0.59)	5.70 (0.59)	5.33 (0.59)	7.42 (0.59)	.41	.027	0.01 (0.17); .95	2.53 (1.82); .19
Team work (0–28)	24.0 (1.68)	18.5 (1.68)	17.8 (1.68)	24.3 (1.68)	.82	.022	0.26 (0.49); .61	8.76 (530); .13
Task management (0–8)	7.32 (0.56)	6.06 (0.56)	5.93 (0.56)	7.44 (0.56)	.99	.090	0.19 (0.16); .28	0.39 (1.76); .83
Global score (1–10)	7.28 (0.50)	6.09 (0.50)	5.84 (0.50)	7.53 (0.50)	.99	.053	0.10 (0.15); .50	3.25 (1.156); .060
Sound-level								
Maximum sound-level (dB)	81.9 (1.19)	81.3 (1.19)	80.9 (1.19)	80.5 (1.19)	.42	.94	−0.53 (0.29); .098	3.88 (3.16); .25

Note: Results are presented as model-derived estimated means and standard errors from linear mixed models ANOVA, including two factors (Trolley Type [$p^{Trolley}$] and Order of condition [p^{Order}]) and main effects of two covariates (weighted average of the experience level across members of the team [Expertise], and percentage of female members of the team [%Female]).
Abbreviations: DAT, difficult airway trolley; FONA, front-of-neck-access.

TABLE 4 Opinions about the DATs: user-ratings

Statement	Algorithm-based DAT	Standard DAT	*p*
Overall this is an excellent trolley	6.0 (1.0)	3.5 (3.0)	<.0001
The design of this trolley simplifies my work in a difficult airway situation	6.0 (1.0)	4.0 (3.0)	<.0001
It is easy to the find the equipment in this trolley	6.0 (1.0)	3.0 (2.0)	<.0001
All equipment which is needed for management of a difficult airway is included in the trolley	6.0 (2.0)	4.5 (3.0)	<.0001
This trolley improves teamwork in a difficult airway situation	6.0 (1.0)	4.0 (2.0)	<.0001
The design of this trolley is intuitive and I could use it without specific instructions	6.0 (1.0)	3.0 (2.0)	<.0001
I prefer this trolley compared to the one I usually work with	6.0 (3.0)	2.0 (2.0)	<.0001
The design of this trolley needs to be changed	2.0 (2.0)	6.0 (2.0)	<.0001
The cognitive aids facilitate my work in a difficult airway situation	6.0 (1.0)	NA	NA

Note: Data are median (interquartile range), ordinal scale 1 to 7, where 1 indicates "completely disagree" and 7 indicates "completely agree." Between-group comparison *p*-value Wilcoxon signed-rank test.
Abbreviation: DAT, difficult airway trolley.

Table 4). For example, most participants expressed that, in a difficult airway situation, the design of the algorithm-based DAT would simplify work and improve teamwork. The utility of cognitive aids was only assessed for the algorithm-based DAT, since no aids were included in the standard DAT: the statement "the cognitive aids facilitate my work in a difficult airway situation" received high ratings (median 6.0; interquartile range [IQR] 1.0; ordinal scale 1 to 7). Overall, the standard trolley received average ratings on most outcomes. There were no significant differences in ratings for the different occupational categories (one-way ANOVA, all p's > .11).

4 | DISCUSSION

4.1 | Main findings

In the current, randomized, crossover simulation study we found that usage of an algorithm-based DAT with integrated cognitive aids improved efficiency (better adherence to difficult airway algorithms and reduced number of unnecessary drawer openings) in unanticipated difficult airway scenarios, compared to a standard DAT. Although there were no significant differences between the DATs related to objective team performance measures, participants showed strong favorability toward the algorithm-based DAT.

4.2 | The importance of easily accessible, optimized DATs in difficult airway situations

Airway emergencies are often unanticipated. Hence, multiple national and international difficult airway guidelines promote readily available DATs in all areas airway management occurs.[14] Unfortunately, availability has been shown to differ significantly between hospital locations: whereas surveys show relatively high prevalence of DATs in operating departments (64%–95%),[16,17,19,21,31] availability in remote anesthetizing locations is far lower (~20%).[16] Delayed access to DATs in emergency departments and ICUs may adversely impact risk of airway complications.[4,32,33]

Over recent years, increased attention has been directed toward optimization of the layout of DATs, to improve clinical performance.[14,34] One key element in this effort is to organize equipment and integrate cognitive aids to enhance decision-making and prompt users to sequentially execute airway management strategies according to difficult airway algorithms. This type of algorithm-based design has potential to create a clearer link between equipment and airway strategy, compared to traditional DAT designs. Another important element is inclusion of a limited range of airway devices—a "less-is-more" approach—to simplify decision-making, facilitate rapid access, and ensure clinicians are proficient in the use of every device.[22] In the current study, user ratings showed participants strongly preferred the algorithm-based DAT, compared to the standard DAT. Interestingly, although most participants agreed to a high extent that the algorithm-based design with integrated cognitive aids could improve performance and team work in difficult airway situations, objective observer assessments of team performance did not differ for the two DATs. One factor possibly explaining this discrepancy between subjective and objective team performance outcomes might be the relatively short introduction time given for each DAT. Nevertheless, usage of the algorithm-based DAT was associated with objectively assessed increases in efficiency, compared to the standard DAT.

Recurrent training to maintain and develop preparedness and nontechnical skills is essential for successful emergency airway management.[11] Although NAP4 has led to increases in the frequency of human factors training and multidisciplinary team training,[35] national surveys commonly show low rates of airway simulation training.[16,19] Simulation-based airway training may improve adherence to difficult airway algorithms, and increase proficiency in rarely used technical skills.[36] To maximize the effects of an optimized DAT, it is essential that all staff are well-acquainted not only with the location of the nearest DAT, but also with all included equipment, the layout and integrated cognitive aids. However, previous studies have shown that in most ICUs in the United States, staff were not trained in the use of the DAT,[20] and an international survey showed that less than 60% of pediatric anesthetists were confident that they knew the contents of their DAT.[21] To our knowledge, this is the first simulation-based team study to compare effects of different DATs in difficult airway situations. We strongly encourage integration of DATs as essential components of difficult airway simulation training and research.

4.3 | Methodological considerations and future directions

This study has a number of limitations that should be considered. First, the study design only permitted a brief introduction of the different DATs. To yield maximum impact of a DAT, it is important to be familiar with all contents and layout details. Hence, future studies should evaluate the effect of more comprehensive DAT introduction and education prior to simulation-based team training. Although we believe that our choice of standard trolley is adequate and enables comparison of principally different types of trolley designs, we acknowledge that it is challenging to select an ideal comparison trolley. Moreover, evidence derived from simulation studies does not necessarily translate into the clinical setting. Although there are theoretical benefits associated with the use of algorithm-based DATs, it remains to be seen whether these effects are seen in clinical, real-life difficult airway situations. Previous meta-analytic data regarding potential clinical benefits of simulation-based team airway training are inconclusive.[37] Given the low frequency and nature of unanticipated difficult airway situations, prospective randomized controlled studies evaluating effects of different DATs are complicated to perform. Although the algorithm-based DAT used in the current study has potential to improve execution of airway management strategies, the ideal layout is not known. Based on user-feedback, alterations to the algorithm-based DAT have been made post-study (e.g., removal of translucent lids placed in the top part of each drawer; these lids were originally positioned to promote easier stocking of drawers, but found to impede retrieval of devices under high-stress simulation conditions). Future simulation studies may guide further optimization and calibration of DAT layout. Another possible limitation is that randomization did not apply to group composition; future studies could evaluate possible outcome differences related to profession and clinical experience more closely. Finally, our results indicate that higher percentage of female team members may improve efficiency, and possibly also global team performance, in simulated difficult airway situations. These findings contrast and extend previous reports, and motivate further efforts to evaluate sex effects in anesthesia simulation studies.[38–41]

5 | CONCLUSIONS

To our knowledge, this is the first study to compare the effects of conceptually different types of DATs in simulated difficult airway scenarios. Our findings indicate that algorithm-based DATs with integrated cognitive aids may convey benefits in difficult airway situations, compared to traditional DATs. These findings have implications for improvement of anesthetic practice. Future simulation studies investigating the influence of DAT design and layout on efficiency and teamwork in unanticipated difficult airway scenarios are strongly encouraged.

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CONFLICT OF INTEREST

No external funding and no competing interests declared.

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APPENDIX A

(1) An overview of the organization and contents of the algorithm-based DAT:

Part of the DAT	Contents	
On top	Difficult airway algorithm flow-chart Direct access phone numbers to ENT and anesthesiology/intensive care physician resources Stop-watch	Cognitive aids: × Principles: “summon help, maximally three attempts/technique, flow O2” × Analyze every 2 min: “help summoned? Anesthesia depth? muscle relaxation? Facemask ventilation possible? Possible to wake up patient? Hypoxia (SpO2 < 90% and decreasing?)”
On the side + posterior part	Introducers × 2 (angled tip; soft, flexible bougie) Airway exchange catheter	
Drawer 1	Laryngoscope handles: standard, short Laryngoscope blades: Macintosh 3, 4; Miller 2, 3 Cognitive aid: retrieve and use videolaryngoscope Endotracheal tubes 5.0, 6.0, 7.0, 8.0 Extra-long endotracheal tubes 4.0, 5.0, 6.0 Nasal endotracheal tubes 6.0. 7.0 Stylet Lubrication gel	Syringe 5, 10 ml Magill forceps Adhesive tape, wide and narrow Bite block Aspiration cannula Rocuronium 10 mg/mL Preprinted labels “Rocuronium” Cognitive aid: continuous waveform capnography
Drawer 2	Two different types of 2nd generation SADs size 3, 4, 5 Lubrication gel Syringe 20 ml Orogastric tube size 12, 14	Adjuvants for flexible videobronchoscopic-guided intubation: endoscopy mask, breakaway oropharyngeal airway, swivel connector, spray solution lidocaine 40 mg/mL and 100 mg/mL, anti-fog solution, tongue depressor
Drawer 3	Facemask size 3, 4 Neonatal facemask size 0 Oropharyngeal airways (7, 9, 10, 11 cm) Nasopharyngeal airway 6.0, 7.0, 8.0	Sugammadex 100 mg/mL, 2 ml/vial, 8 vials Syringe 10 ml Aspiration cannula Preprinted labels “Sugammadex”
Drawer 4	Endotracheal tube 6.0 Scalpel blade 10	Frova introducer
Drawer 5	Optional, customized equipment (e.g., left-hand laryngoscope blades, equipment for management of tracheostomies, etc.)	

(2) An overview of the organization and contents of the standard DAT:

Part of the DAT	Contents	
Stand	Retrograde intubation set Airway exchange catheter Staged extubation set Introducers × 2 (angled tip)	
On the side	Introducers × 3 (soft, flexible bougie) Oxygen cylinder Suction incl. catheters	
Drawer 1	Oropharyngeal airway (7, 9, 10, 11 cm) Nasopharyngeal airway 6.0 × 2, 7.0 × 2, 8.0 × 2 Bite block × 2 Tooth protection (adhesive, for laryngoscope blade) Syringe 10 mL Magill forceps Regular forceps	Scissors × 2 Scalpel blade 10 × 2 Endoscopy mask Breakaway oropharyngeal airway Adhesive tape, wide Tongue depressor Throat gasket
Drawer 2	Two different types of 2nd generation SADs size 3, 4, 5 Emergency cricothyrotomy catheter set (for surgical and Seldinger technique) × 2	
Drawer 3	Endotracheal tubes 6.0, 7.0, 8.0 Extra-long endotracheal tubes 4.0, 5.0, 6.0 Nasal endotracheal tubes 6.5, 7.0	Orogastric tube size 12, 14, 16 Swivel connector
On lower shelf	Double-lumen endotracheal tube 35 F, 37 F	

Abbreviations: DAT, difficult airway trolley; ENT, ear, nose and throat; SAD, supraglottic airway device.

APPENDIX B

FRÅGOR OM LUFTVÄGSVAGNARNA

Tänk på den luftvägsvagn som är organiserad enligt en svår luftvägsalgoritm, med kognitiva hjälpmedel.

Läs nedanstående påståenden om luftvägsvagnen och gradera ditt svar efter hur starkt du håller med eller inte håller med om varje påstående.

	Håller inte alls med		Varken eller			Håller med helt	
Överlag är detta en utmärkt vagn	1	2	3	4	5	6	7
Luftvägsvagnens design förenklar mitt arbete vid en svår luftvägssituation	1	2	3	4	5	6	7
Det är lätt att hitta utrustningen i denna vagn	1	2	3	4	5	6	7
All utrustning som behövs för hantering av en oväntad svår luftväg är inkluderad i vagnen	1	2	3	4	5	6	7
Den här vagnen förbättrar teamarbetet vid en svår luftvägssituation	1	2	3	4	5	6	7
Den här vagnens design är intuitiv och jag skulle kunna använda den utan specifika instruktioner	1	2	3	4	5	6	7
De kognitiva hjälpmedlen underlättar mitt arbete vid en svår luftvägssituation	1	2	3	4	5	6	7
Den här vagnens design skulle behöva ändras	1	2	3	4	5	6	7
Jag föredrar denna vagn jämfört med den/de luftvägsvagnar som jag i vanliga fall arbetar med	1	2	3	4	5	6	7

Tänk på standard-luftvägsvagnen. Läs nedanstående påståenden om luftvägsvagnen och gradera ditt svar efter hur starkt du håller med eller inte håller med om varje påstående.

	Håller inte alls med		Varken eller			Håller med helt	
Överlag är detta en utmärkt vagn	1	2	3	4	5	6	7
Luftvägsvagnens design förenklar mitt arbete vid en svår luftvägssituation	1	2	3	4	5	6	7
Det är lätt att hitta utrustningen i denna vagn	1	2	3	4	5	6	7
All utrustning som behövs för hantering av en oväntad svår luftväg är inkluderad i vagnen	1	2	3	4	5	6	7
Den här vagnen förbättrar teamarbetet vid en svår luftvägssituation	1	2	3	4	5	6	7
Den här vagnens design är intuitiv och jag skulle kunna använda den utan specifika instruktioner	1	2	3	4	5	6	7
Den här vagnens design skulle behöva ändras	1	2	3	4	5	6	7
Jag föredrar denna vagn jämfört med den/de luftvägsvagnar som jag i vanliga fall arbetar med	1	2	3	4	5	6	7

APPENDIX C

DIFFICULT AIRWAY TROLLEY QUESTIONNAIRE

Think about the Difficult Airway Trolley, referred to below as the DAT, organized according to an airway management algorithm, with cognitive aids.

Read the following statements about the DAT and rate your response by how strongly you agree or disagree with each statement.

	Completely disagree		Neither agree nor disagree			Completely agree	
This is in general an excellent DAT	1	2	3	4	5	6	7
The DAT design facilitates my work in a difficult airway situation	1	2	3	4	5	6	7
It is easy to find the equipment in the DAT	1	2	3	4	5	6	7
All equipment needed to handle an unanticipated difficult airway is included in the DAT	1	2	3	4	5	6	7
The DAT improves team work in a difficult airway situation	1	2	3	4	5	6	7
The DAT design is intuitive and I could use it without specific instructions	1	2	3	4	5	6	7
The cognitive aids facilitate my work in a difficult airway situation	1	2	3	4	5	6	7
The design of the DAT needs to be changed	1	2	3	4	5	6	7
I prefer this DAT to the DAT/DATs I normally work with	1	2	3	4	5	6	7

Think of the standard difficult airway trolley, referred to below as the DAT.

Read the following statements about the DAT and rate your response by how strongly you agree or disagree with each statement.

	Completely disagree		Neither agree nor disagree			Completely agree	
This is in general an excellent DAT	1	2	3	4	5	6	7
The DAT design facilitates my work in a difficult airway situation	1	2	3	4	5	6	7
It is easy to find the equipment in the DAT	1	2	3	4	5	6	7
All equipment needed to handle an unanticipated difficult airway is included in the DAT	1	2	3	4	5	6	7
The DAT improves team work in a difficult airway situation	1	2	3	4	5	6	7
The DAT design is intuitive and I could use it without specific instructions	1	2	3	4	5	6	7
The design of the DAT needs to be changed	1	2	3	4	5	6	7
I prefer this DAT to the DAT/DATs I normally work with	1	2	3	4	5	6	7