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SCIENTIFIC ARTICLE

Simulation of difficult airway management for residents: prospective comparative study☆

Marc Lilot [a,b,c,*], **Jean-Noel Evain** [d], **Alban Vincent** [a], **Guillain Gaillard** [a], **Dominique Chassard** [a,c], **Laurent Mattatia** [d], **Jacques Ripart** [d], **Lucas Denoyel** [c], **Christian Bauer** [a,c], **Philip Robinson** [e], **Antoine Duclos** [b,f], **Jean-Jacques Lehot** [a,b,c], **Thomas Rimmelé** [a,c,g]

[a] *Hospices Civils de Lyon, Département d'Anesthésie-Réanimation, Lyon, France*
[b] *Université Claude Bernard Lyon 1, Health Services and Performance Research Lab, Lyon, France*
[c] *Université Claude Bernard Lyon 1, Centre Lyonnais d'Enseignement par Simulation en Santé, SAMSEI, Lyon, France*
[d] *Groupe Hospitalo-Universitaire Carémeau, Division Anesthésie Réanimation Urgences Douleur, Simulation Médicale Hospitalo-Universitaire (SIMHU), Nîmes, França*
[e] *Hospices Civils de Lyon, Direction de la Recherche Clinique et de l'Innovation, Lyon, France*
[f] *Hospices Civils de Lyon, Pôle Information Médicale Evaluation Recherche, Lyon, France*
[g] *Université Claude Bernard Lyon 1, Pathophysiology of Injury Induced Immunosuppression, Lyon, França*

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Abstract
Background and objectives: Procedural simulation training for difficult airway management offers acquisition opportunities. The hypothesis was that 3 hours of procedural simulation training for difficult airway management improves: acquisition, behavior, and patient outcomes as reported 6 months later.
Methods: This prospective comparative study took place in two medical universities. Second-year residents of anesthesiology and intensive care from one region participated in 3 h procedural simulation (intervention group). No intervention was scheduled for their peers from the other region (control). Prior to simulation and 6 months later, residents filled-out the same self-assessment form collecting experience with different devices. The control group filled-out the same forms simultaneously. The primary endpoint was the frequency of use of each difficult airway management device within groups at 6 months. Secondary endpoints included modifications of knowledge, skills, and patient outcomes with each device at 6 months. Intervention cost assessment was provided.

☆ First results of this study were presented at the 2016 annual meeting of the French Society of Anesthesiology and Critical Care Medicine (SFAR), Paris, September 2016.

* Corresponding author.
E-mail: marclilot@hotmail.com (M. Lilot).

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Results: 44 residents were included in the intervention group and 16 in the control group. No significant difference was observed for the primary endpoint. In the intervention group, improvement of knowledge and skills was observed at 6 months for each device, and improvement of patient outcomes was observed with the use of malleable intubation stylet and Eschmann introducer. No such improvement was observed in the control group. Estimated intervention cost was 406€ per resident.
Conclusions: A 3 h procedural simulation training for difficult airway management did not improve the frequency of use of devices at 6 months by residents. However, other positive effects suggest exploring the best ratio of time/acquisition efficiency with difficult airway management simulation.
ClinicalTrials.gov Identifier: NCT02470195.

PALAVRAS-CHAVE
Manejo de vias aéreas;
Educação;
Aquisição de aprendizagem;
Simulação processual

Simulação de manejo de via aérea difícil para residentes: estudo comparativo prospectivo

Resumo
Justificativa e objetivos: O treinamento em simulação para o manejo de via aérea difícil oferece oportunidades de aprendizagem. A hipótese foi que um treinamento em simulação de procedimentos de três horas, para o manejo de via aérea difícil, melhoraria o aprendizado, o comportamento e os resultados dos pacientes, conforme relatado seis meses após o treinamento.
Métodos: Este estudo comparativo prospectivo foi realizado em duas universidades médicas. Residentes do segundo ano de anestesiologia e terapia intensiva de uma região participaram de um curso de três horas em simulação de procedimentos (grupo intervenção). Nenhuma intervenção foi programada para seus pares da outra região (grupo controle). Antes da simulação e seis meses após, os residentes preencheram a mesma ficha de autoavaliação sobre sua experiência com diferentes dispositivos. O grupo controle preencheu os mesmos formulários simultaneamente. O desfecho primário foi a frequência de uso de cada dispositivo para o manejo de via aérea difícil dentro dos grupos aos seis meses. Os pontos de corte secundários incluíram modificações em relação ao conhecimento, às habilidades e aos resultados dos pacientes com cada dispositivo aos seis meses. A avaliação do custo da intervenção foi registrada.
Resultados: Foram incluídos no grupo intervenção 44 residentes e 16 no grupo controle. Nenhuma diferença significativa foi observada para o ponto de corte primário. No grupo intervenção, a melhoria do conhecimento e das habilidades foi observada aos seis meses para cada dispositivo e a melhoria dos desfechos dos pacientes foi analisada com o uso de estilete maleável e do introdutor de Eschmann para intubação. Nenhuma melhoria foi observada no grupo controle. O custo da intervenção estimado foi de 406€ por residente.
Conclusões: Um treinamento simulado de três horas para o manejo de via aérea difícil não melhorou a frequência do uso de dispositivos pelos residentes aos seis meses. No entanto, outros efeitos positivos sugerem a exploração da melhor relação tempo/eficiência de aquisição de conhecimento com a simulação do manejo de via aérea difícil.
ClinicalTrials.gov Identifier: NCT02470195.

Introduction

Unanticipated Difficult Airway Management (DAM) may be a stressful challenge with life-threatening risks for the patient. Residents in anesthesiology and intensive care are expected to master the technical skills required for DAM as much as decision making ability.[1] However, this event occurrence is rare, limiting real-life daily practice exposition to this situation and therefore limiting experience.[2] In the context of rare but critical events, simulation is of particular value, providing practical learning of both technical and non-technical skills. This is underlined by the global trend toward simulation in the educational curriculum of anesthesiology and intensive care residents.[3,4] DAM

simulation-based learning has been reported to improve knowledge acquisition, professional behavior and patient-related outcomes with durations of training ranging from one day to one year.[5,6] However, despite benefits transposed to patients,[7] simulation-based education programs are time and resource consuming. Optimizing education in DAM is a challenge requesting more exploration for specific efficient training methods.[1,8] The objective of the present study was therefore to investigate whether a 3 h procedural simulation training for DAM would be associated with effects on knowledge acquisition, behavior, and patient outcomes as reported by participants 6 months later.

Methods

Design

The study protocol was registered on clinicaltrial.gov (Protocol ID: NCT02470195) and obtained the approval from Hospices Civils de Lyon institutional ethics committee. This prospective and comparative study with concurrent controls in two parallel arms was conducted among residents of two distinct French medical interregional universities. The intervention took place at the Lyon teaching center for simulation in healthcare (*Centre Lyonnais d'Enseignement par Simulation en Santé*, CLESS, Claude Bernard Lyon 1 University) that included residents from Auvergne-Rhône-Alpes Universities while the control group included residents from Montpellier-Nîmes Universities. Enrolled residents gave their individual consent after receiving general information about the study. This study followed the recommendations of the International Committee of Medical Journal Editors (ICMJE).

Population and setting

All second year anesthesiology and intensive care residents from the mentioned universities were included during the 2015–2016 academic year. No exclusion criterion was applied. Each resident of the intervention group participated in a 3 h procedural simulation session on DAM. Residents of the control group had no specific intervention planned during the study period. All residents worked in their respective hospitals under seniors' responsibility.

Intervention: simulation session

The total training time was scheduled for a 3 h in total for the procedural simulation session at the CLESS for each resident included in the intervention group. It started with a standardized 15 min computerized lecture provided by an instructor to all participants. This lecture was a reminder of the importance of the topic and the current existing national guidelines for DAM.[9] Residents participated in three different workshops. Each workshop was supervised by one or two instructors. Instructors were local experts who had prepared the workshop before the session. Instructors explained and showed the practical use of each airway management device, sharing their experience and giving specific tips. Each resident was also encouraged to practice individually while listening to the instructors' advice until they felt comfortable with the devices.

The first workshop was set up for ventilation and supraglottic devices for intubation. Intubation blades, malleable intubation stylet (Portex™, Smiths Medical ASD, Inc. Norwell, MA, USA), Eschmann introducer, Airtraq blade® (Prodol Meditec S.A., Vizcaya, Spain), video laryngoscope McGrath MAC® (Aircraft Medical Ltd., Scotland) and intubation laryngeal mask (LMA® Fastrach™, Teleflex Medical, Athlone, Ireland) were available. A mannequin head (Airway Management Trainer®, Laerdal Medical AS, Stavanger, Norway) was used for this workshop.

The second workshop was set up for fiberoptic intubation. Two disposable fiberscopes with the dedicated screen were available with accessories: intranasal, pharyngeal, supraglottic, intra-tracheal and/or laryngeal block with local anesthetics, intravenous sedation for awake anesthesia, nasopharyngeal canulae, lubricant and two mannequin heads (Airway Management Trainer®, Laerdal Medical AS).

The third workshop was set up for cricothyrotomy and tracheotomy. Surgical kit, scalpel, antiseptics, sterile drapes, fixation strings, filters, self-inflating bag, adult and pediatric sets for cricothyrotomy, and percutaneous and surgical set for tracheotomy were available. Three cricothyrotomy necks (Crico Trainer®, Laerdal Medical AS) were used for this workshop.

Evaluation

To assess the impact of the simulation program, the Kirkpatrick evaluation framework has been transposed to healthcare.[10] This classification describes a traditional hierarchy of four levels (KL): participant reaction (KL1), knowledge acquisition (KL2), change of participant behavior (KL3) and results on patient outcomes (KL4).[11]

Initial evaluation survey form

Residents of the intervention group were asked to fill out an initial self-assessment paper survey form upon arrival at the simulation center (Appendix). Residents of the control group were asked to fill out the same initial survey form received by email. Questions explored the different KL assessment dimensions for each device presented during the DAM simulation and required binary and numerical answers on a scale from 0 to 10. Each resident in the intervention group were asked to fill-out a specific independent ''satisfaction'' form (i.e., KL1) on a 10 points Likert scales, at the end of the simulation. However, the survey form did not explore the KL1 dimension. Questions from the ''ACQUISITION'', ''USE'', and ''RESULT'' sections of the survey forms explored, respectively, the KL2, KL3, and KL4 dimensions.

Final evaluation survey form

Six months after the initial survey form, all residents were contacted by email to fill out the same self-assessment survey form. The timeline of the study protocol is provided in Fig. 1.

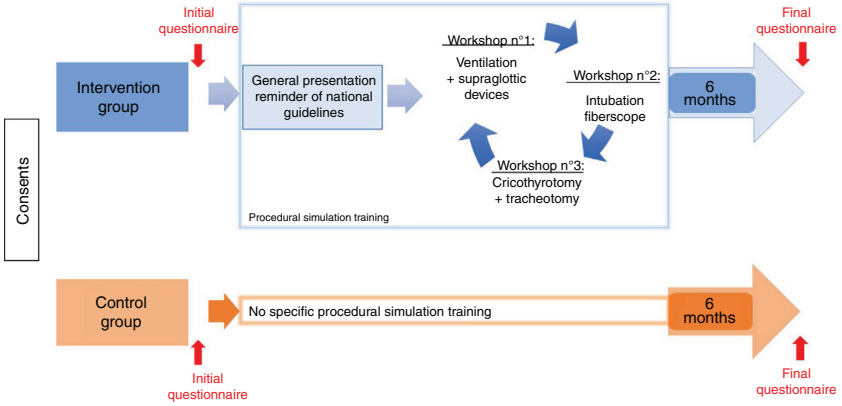

Figure 1 Protocol timeline. Residents of the intervention group participated in a procedural simulation session of 3 h in groups of 6 to 8 residents. Self-assessment forms were completed just before simulation formation and 6 months later.

Endpoints

The primary endpoint was the increase in the self-reported frequency of use of devices for DAM at 6 months as compared with prior use of the same devices within groups. The frequency was quoted by residents as a numerical value from 0 to 10 (0: never, the highest value being ''as much as possible'' i.e., a hundred per cent of situations of DAM'').

The secondary endpoints were the changes between initial and final survey forms for each device. Self-reported theoretical knowledge and practical skills (from 0 to 10), clinical use, difficulties using these devices, success or failure with their use, estimated positive and negative patient outcomes with the use reported from 0 to 10 (every time). Comparison between groups was not performed because the study design planned comparison of change within groups, which were composed of different populations of residents.

Economic cost of the simulation program

All costs for the simulation program of the intervention group are reported with the cost expected for the simulation. The two intubation fiberscope screens were offered by the manufacturer (Aview™, Ambu, Ballerup, Denmark), the video laryngoscope was borrowed from the hospital department of anesthesia, and all other devices and single use devices or expendables were out-of-date stock obtained free-of-charge from the hospital department of anesthesia. The costs associated with the latter materials were therefore not taken into account in the economic analysis. The costs for instructors were estimated according to current university salaries.

Statistical analysis

Categorical variables were expressed using absolute and relative frequencies and were compared using the χ^2 test, Fisher's exact test or McNemar test (for the primary endpoint), as appropriate. Continuous variables were described using median [25th–75th percentile] and compared using Mann–Whitney *U* or Wilcoxon tests as appropriate. All tests were two-tailed, and $p < 0.05$ was considered statistically significant. Statistical analysis was performed in a *per protocol* basis using MedCalc software version 9.6.4.0 (MedCalc, Mariakerke, Belgium).

Results

Study population

A total of 60 residents were included from February 2015 to December 2015; all completed the initial survey form. In the intervention group, all 44 residents were included, and 34 (77%) filled out the survey form at 6 months. In the control group, all 16 residents were included, and all (100%) filled out the survey form at 6 months. With the exception of gender (female sex: 48% in the intervention group vs. 13% in the control; $p = 0.029$), there was no significant difference in demographics and previous clinical or simulation experience (Table 1). In the intervention group, the satisfaction forms provided excellent mean scores: the mean score for responding to learner expectations of procedural simulation was 9 (SD = 1) and the mean score for the practical organization of the training was 9 (SD = 1).

Endpoints

''ACQUISITION'' questions (exploring the KL2 dimension)
In the intervention group, there was a significant increase in both theoretical knowledge and practical skills between the initial and final survey forms for each airway management device individually. In the control group, there were significant increases in both theoretical knowledge and practical skills between initial and final survey forms only for malleable intubation stylet and Eschmann introducer, and in practical skills for cricothyrotomy (Tables 2 and 3).

''USE'' questions (exploring the KL3 dimension)
There was no significant difference in the frequency of use of any devices between initial and final survey forms in intervention and control groups (primary endpoint; Tables 2 and 3).

In the intervention group, there was a significant decrease in the proportion of residents reporting clinical

Table 1 Demographic and experience at baseline (initial survey form) in groups. Values are expressed as number (proportion) or median (25th–75th).

	Intervention ($n = 44$)	Control ($n = 16$)	p-value
Female	21 (48%)	2 (13%)	0.029
Age, years	27 (26–27)	26 (26–27)	0.155
Prior experience of difficult ventilation	31 (70%)	9 (56%)	0.584
Prior experience of difficult intubation	42 (95%)	14 (88%)	0.999
Prior airway management training on LFS	35 (80%)	8 (50%)	0.073

LFS, Low-Fidelity Simulation (manikin).

use of the malleable intubation stylet and a decrease in the proportion reporting failure of use of the Eschmann introducer between initial and final survey forms. In the control group, there was a significant decrease in the proportion of residents reporting clinical use of Airtraq blade, intubation laryngeal mask, and tracheotomy between initial and final survey forms (Tables 2 and 3).

''RESULTS'' questions (exploring the KL4 dimension)
In the intervention group, there was a significant increase in the frequency of positive outcomes related to the use of malleable intubation stylet and Eschmann introducer between initial and final survey forms. In the control group, there was no significant difference in the frequency of positive outcomes related to the use of any of the airway management devices between initial and final survey forms (Tables 2 and 3).

The significant changes at 6 months according to the different airway devices are summarized in Table 4.

Cost of simulation program

The expected global cost for simulation program implementation was 17,892€ which represents approximately 406€ *per* resident (Table 5).

Discussion

A significant improvement at 6 months of theoretical knowledge and practical skill acquisition (*i.e.*; KL2 dimension) was observed in the intervention group for each device presented during the procedural simulation session. Except for the clinical use of the malleable intubation stylet, no significant decrease in any KL dimension for any device was found in the procedural simulation group. However, there was no significant difference in the frequency of use of any of the devices at 6 months within groups (primary endpoint). A decrease in clinical use (*i.e.*, KL3 dimension) was reported in the control group at 6 months with less clinical use for Airtraq blade, intubation laryngeal mask, and tracheotomy. Finally, there was an improvement in estimated patient outcomes (*i.e.*, KL4 dimension) related to the use of malleable intubation stylet and Eschmann introducer in the procedural simulation group, with no change in the control group for any of the devices.

Previous reports underlined the clinical value of procedural simulation programs to enhance knowledge acquisition for DAM.[5,6] However, a recent systematic review and meta-analyses of 17 studies found improvement with simulation based training for DAM in behavior performance but not in time-skill, written examination score or success rate of procedure on real patient.[8] Procedural simulation offers opportunities to experts and trainees to meet in a favorable learning environment. The small number of learners coached by experts providing device demonstrations, general information and corrective personal advices might have enhanced acquisitions at 6 months.[12] This might partially explain why both theoretical knowledge and practical skills improved in the simulation group.[13,14] Conversely, real-life DAM experience may lead to anxiety which may affect the behavior of healthcare providers. Moreover, the scarcity of such situations could lead more experienced physicians to act during DAM rather than residents. The lost opportunity for acquisition from this real-life learning situation is further compounded by the usual absence of specific debriefing with residents. The differences related to KL3 and KL4 dimensions implicated devices that are usually involved early in the DAM strategy. On the contrary, one can suspect that the rare occurrence of tracheotomy, cricothyrotomy, intubation fiberscope, intubation with laryngeal mask in real patients might explain the lack of modification reported on KL3 and KL4 dimensions while reported modifications of KL2 dimension was constantly observed in the intervention group.

Several reports exploring low or high-fidelity simulation for DAM are associated with better skill retention.[15,16] However, comparisons of efficacy between procedural and high-fidelity simulation are not univocal.[17,18] High-fidelity simulation for DAM explores the whole procedure including anticipation, team resource management and time-pressure management. Technical skills are correlated with non-technical skills so that experience of a mastered technical procedure will be associated with the enhancement of the overall non-technical skills of participants.[19] Therefore, technical performance acquisition is required to benefit from expensive high-fidelity simulation programs for DAM.

The costs associated with different simulation modalities vary greatly, inviting to a rational, structured and progressive educational simulation curriculum.[20,21] The information reported here might help to approach the global cost of such a simulation program which had apparently never been reported.

A limitation of this study is that intervention and control groups were included in two different universities with no shared educational program. While no specific teaching for DAM had been provided before or during the study period in the control group, differences observed at 6 months might have been influenced by local educational factors. Data

Table 2 Comparisons within groups between initial and final survey for malleable intubation stylet, Eschmann introducer®, Airtraq blade® and video laryngoscope.

	Malleable intubation stylet		Eschmann tube®		Airtraq blade®		Video laryngoscope	
	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)
Theoretical knowledge								
Initial	7 (5–8)	8 (7–8.5)	7 (6–8)	8 (7–8)	7 (5.5–8)	6.5 (5.5–7.5)	6 (5–7)	8 (7–8)
Final	8 (7–8)	9 (8–9.5)	8 (8–9)	8.5 (8–9)	8 (7–8)	6 (5–8)	8 (6–8)	8 (7.5–9)
p-value (intra-group)	<0.001	0.005	<0.001	0.002	<0.001	0.652	<0.001	0.700
Practical skills								
Initial	7 (5–8)	7 (6.5–8)	7 (7–8)	7 (6–8)	6 (4.5–7.5)	4 (0–6)	5 (3.3–7)	7 (6–8)
Final	8 (7–9)	8 (8–9)	8 (8–9)	8 (8–8)	7.5 (6–8)	5 (3–6)	7 (6–8)	8 (7–8)
p-value (intra-group)	<0.001	0.001	<0.001	0.014	<0.001	0.413	0.004	0.135
Clinical use, n (%)								
Initial	40 (90%)	15 (94%)	40 (91%)	16 (100%)	36 (81%)	10 (63%)	25 (58%)	14 (88%)
Final	23 (68%)	15 (100%)	30 (88%)	15 (100%)	21 (62%)	2 (13%)	16 (47%)	11 (73%)
p-value (intra-group)	0.039	>0.999	0.688	NA	0.146	0.022	0.629	0.375
Frequency of use								
Initial	5 (2–7)	5.5 (4–8)	5.5 (3–8)	5 (2–5.75)	3 (1–6)	1.5 (1–2)	5 (2.3–6.8)	3 (1.8–6.3)
Final	4.5 (3–6)	6 (5–8)	5 (4–7)	6 (3.5–7)	4.5 (3.5–6)	2 (NA)	7 (3.3–8)	6 (5.3–7.8)
p-value (intra-group)	0.194	0.625	0.592	0.240	0.359	NA	0.383	0.195
Difficulty during use, n (%)								
Initial	6 (16%)	2 (17%)	6 (15%)	1 (6%)	11 (31%)	9 (90%)	7 (28%)	5 (38%)
Final	1 (4%)	1 (6%)	5 (16%)	1 (6%)	3 (14%)	1 (33%)	1 (7%)	2 (18%)
p-value (intra-group)	0.250	0.500	>0.999	>0.999	0.125	NA	>0.999	0.625
Successful use, n (%)								
Initial	34 (87%)	13 (87%)	39 (96%)	16 (100%)	29 (81%)	6 (60%)	16 (67%)	12 (87%)
Final	19 (79%)	12 (75%)	29 (94%)	15 (94%)	17 (81%)	1 (33%)	12 (75%)	11 (92%)
p-value (intra-group)	0.625	0.625	0.5	>0.999	>0.999	NA	0.25	>0.999

Table 2 (*Continued*)

	Malleable intubation stylet		Eschmann tube®		Airtraq blade®		Video laryngoscope	
	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)
Frequency of positive outcome								
Initial	7 (5–8)	8 (5.25–8)	8 (6.3–8)	8 (7–9)	8 (6.5–8.8)	7 (4.3–7.3)	8 (7–8)	9 (8–9)
Final	8 (6–9)	7.5 (5–8)	10 (8–10)	8 (8–9)	9 (7.5–10)	7 (NA)	9.5 (8–10)	9 (8.3–10)
p-value (intra-group)	0.019	0.875	0.009	0.203	0.067	NA	0.063	0.383
Failure of the use, n (%)								
Initial	25 (63%)	12 (80%)	25 (63%)	10 (63%)	15 (42%)	9 (90%)	3 (12%)	5 (38%)
Final	11 (46%)	12 (75%)	11 (35%)	16 (50%)	6 (29%)	0 (0%)	1 (6%)	2 (17%)
p-value (intra-group)	0.754	>0.999	0.039	0.754	>0.999	NA	NA	0.625
Frequency of negative outcome								
Initial	4 (2–5)	1 (0–3)	2.5 (2–3.5)	1 (0–2)	4 (3–4)	2.5 (1.5–4)	3 (2.8–3.3)	1.5 (0.5–3.4)
Final	2 (0.5–5)	1.5 (1–5)	1.5 (1–2)	1 (1–1.5)	2 (2–3)	NA	NA	NA
p-value (intra-group)	>0.999	0.461	NA	NA	NA	NA	NA	NA

NA, not applicable (sample too small); initial, initial form of the survey filled out by resident at the beginning of the training session in the intervention group and sent by email in the control group; final, final form of the survey sent by email 6 months after the initial survey form in both groups. Results are presented as median (25th–75th) or *n* (%) where % is the percentage of residents who answered the question.

Table 3 Comparisons within groups between initial and final survey for intubation laryngeal mask, intubation fiberscope, cricothyrotomy and tracheotomy.

	Intubation laryngeal mask		Intubation fiberscope		Cricothyrotomy		Tracheotomy	
	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)
Theoretical knowledge								
Initial	5 (3–6)	5.5 (5–7)	5 (3–6)	7.5 (6–8)	3 (0–5)	5 (4.5–7)	3.5 (1–5)	7 (6–8)
Final	7 (6–8)	6 (4.5–7.5)	7 (6–8)	7 (6–8)	6 (5–7)	5.5 (5–7)	6 (5–7)	7 (6.5–8)
p-value (intra-group)	<0.001	0.733	<0.001	0.820	<0.001	0.850	<0.001	0.634
Practical skills								
Initial	3.5 (0–5.5)	1.5 (0–5.5)	3 (1–5)	4.5 (0.5–6)	0 (0–2.5)	0 (0–2)	1 (0–4)	6 (5–7)
Final	6 (5–7)	4 (1.5–6)	6 (4–7)	5 (3.5–6.5)	4 (2–5)	2 (0–4.5)	4 (2–5)	7 (5.5–8)
p-value (intra-group)	0.001	0.064	<0.001	0.123	<0.001	0.014	<0.001	0.217
Clinical use, n (%)								
Initial	9 (20%)	8 (50%)	17 (39%)	10 (63%)	NA	NA	10 (23%)	14 (88%)
Final	5 (15%)	2 (13%)	12 (35%)	5 (36%)	NA	NA	8 (24%)	6 (40%)
p-value (intra-group)	0.688	0.031	>0.999	0.219	NA	NA	0.754	0.039
Frequency of use								
Initial	1.5 (1–4)	1 (1–4.3)	2 (2–3.5)	2 (0.78–4.3)	NA	NA	1 (1–2)	1 (0.5–5)
Final	3 (1–5.8)	2 (NA)	3 (1.5–8)	2 (1–4.3)	NA	NA	1.5 (1–2)	2 (1.8–3.3)
p-value (Intra-group)	NA	NA	0.250	0.875	NA	NA	NA	NA
Difficulty during the use, n (%)								
Initial	3 (33%)	2 (29%)	8 (53%)	7 (70%)	NA	NA	1 (11%)	5 (37%)
Final	2 (40%)	3 (100%)	2 (18%)	1 (20%)	NA	NA	2 (25%)	1 (14%)
p-value (intra-group)	>0.999	0.5	0.25	0.5	NA	NA	NA	>0.999

Table 3 (*Continued*)

	Intubation laryngeal mask		Intubation fiberscope		Cricothyrotomy		Tracheotomy	
	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)	Intervention group ($n = 44$)	Control group ($n = 16$)
Successful use, n (%)								
Initial	4 (50%)	3 (38%)	14 (90%)	9 (82%)	NA	NA	1 (14%)	4 (27%)
Final	3 (60%)	0 (0%)	9 (82%)	4 (67%)	NA	NA	5 (63%)	2 (29%)
p-value (intra-group)	0.5	>0.999	>0.999	NA	NA	NA	NA	>0.999
Frequency of positive outcome								
Initial	8 (8–10)	5 (NA)	8 (5.5–8.3)	9 (8–9)	NA	NA	5 (NA)	7 (NA)
Final	7 (3.3–9.3)	NA	9 (8–10)	9 (8.5–9)	NA	NA	8.5 (6.5–10)	5 (NA)
p-value (intra-group)	NA	NA	0.625	NA	NA	NA	NA	NA
Failure of the use, n (%)								
Initial	3 (33%)	3 (38%)	6 (100%)	0 (0%)	NA	NA	0 (0%)	3 (23%)
Final	NA	NA	NA	NA	NA	NA	1 (12.5%)	0 (0%)
p-value (intra-group)	0.5	0.5	0.5	0.5	NA	NA	NA	0.5
Frequency of negative outcome								
Initial	1.5 (1–2)	3 (NA)	1 (0.75–2)	1.5 (0–3)	NA	NA	NA	NA
Final	NA	NA	NA	NA	NA	NA	NA	NA
p-value (intra-group)	NA	NA	NA	NA	NA	NA	NA	NA

NA, not applicable (sample too small); initial, initial form of the survey filled out by resident at the beginning of the training session in the intervention group and sent by email in the control group; final, final form of the survey sent by email 6 months after the initial survey forms in both groups. Results are presented as median (25th–75th) or *n* (%) where % is the percentage of residents who answered the question.

Table 4 Statistically significant modifications within groups at 6 months of at least 1 question exploring Kirkpatrick level (KL) dimensions.

	Malleable intubation stylet				Eschmann introducer				Airtraq blade				Video laryngoscope				Intubation laryngeal mask				Intubation fiberscope				Cricothyrotomy				Tracheotomy			
KL	2		3	4	2		3	4	2		3	4	2		3	4	2		3	4	2		3	4	2		3	4	2		3	4
	a	b	c	d e	a	b	c	d e	a	b	c	d e	a	b	c	d e	a	b	c	d e	a	b	c	d e	a	b	c	d e	a	b	c	d e
Intervention group	+	+	−	0 +	+	+	0	+ +	+	+	0	0 0	+	+	0	0 0	+	+	0	0 NA	+	+	0	NA 0	+	+	NA	NA NA	+	+	0	NA NA
Control group	+	+	0	0 0	+	+	NA	0 0	0	0	−	0 NA	0	0	0	0 0	0	0	−	0 NA	0	0	0	NA NA	0	+	NA	NA NA	0	0	−	0 NA

+, group experiencing a positive effect with the device at 6 months as compared with initial; −, group experiencing a negative effect with the device at 6 months as compared with initial; 0, no significant modification at 6 months compared to initial survey. $p < 0.05$ was considered as statistically significant; NA, no result available; KL 2, acquisition: (a) theoretical knowledge, (b) practical skills; KL 3, use: (c) number of residents with less clinical use, (d) number of residents with less failure of the use; KL 4, results: (e) frequency of positive outcomes related to the use.

Table 5 Detailed financial plan of the procedural simulation for difficult airway management. Values are cost in Euros.

	Cost expected per unit	Cost expected per session	Cost expected per simulation program	Cost expected per resident
Simulation room[a]	444	444	3108	71
Instructors[b]	58	699	4890	111
Three cricothyrotomy neck[c]	704	302	2112	48
Cricothyroid membrane tape	32	4.5	32	0.7
Three intubation heads	2570	1102	7710	175
Tracheal lubricating gel	40	6	40	1
Total[c]	NA	2552	17,892	406

NA, not applicable. Each cost is reported in Euros in accordance with the financial bill contracted by the health simulation center of Lyon, France (CLESS). Cost per session is based on a 3-hour program. Cost per simulation program is based on a 7-session program.

[a] A total of 4 simulation rooms were used per session during a half-day (one room for reception and theoretical recall and 3 rooms for simultaneous workshop). This cost might decrease a lot if non-simulation rooms are used for the training.

[b] Wages per hour, all taxes included, calculated according to the scale provided by the Claude Bernard Lyon 1 University. Four instructors were scheduled per session.

[c] Airway devices and expendables were borrowed or given free of charge by the hospital medical center. Best-before use dates of given products were expired.

were declarative and were not objective clinical observations. Moreover, the absence of randomization due to the different pedagogical programs and training planning constraints prevents comparing groups. Therefore, while these results highlight the enhancement of DAM acquisition by procedural simulation, no extrapolation should be made concerning patient benefit. The differences observed could not be extrapolated to the expertise that residents will acquire by the end of their 5 year residency. Further studies are needed to explore the remnant effect of early, late, or repeated procedural simulation sessions by the end of their curriculum. The study did not compare procedural simulation to a standardized theoretical teaching. Therefore, one cannot presume yet that a unique short procedural simulation alone for DAM learning is the best strategy to reach educational objectives for residents.[22] At last, the total training time divided into three different workshops to practice with the large number of devices available might have influenced the results regarding the acquisition of knowledge, behavior change and outcomes related to the patients. More focused and specific device training for individual student centered-learning will probably helps to reach competency-based learning for DAM. Further studies are warranted to define the optimal strategy of procedural simulations included in a global educational process for the best cost-effectiveness ratio with a curriculum that ensures DAM acquisitions.[23]

Conclusions

No significant increase in the use of devices for DAM was reported at 6 months. However, residents who attended a 3 h procedural simulation session for DAM reported 6 months later an overall improvement for all devices in terms of theoretical knowledge and practical skills, and an increase in positive outcomes related to the use of malleable intubation stylet and the Eschmann introducer.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.bjane.2019.03.004.

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