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RESPIRATION AND THE AIRWAY

Difficult intubation in obese patients: incidence, risk factors, and complications in the operating theatre and in intensive care units

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Editor's key points

- The incidence of difficult intubation and related complications in obese patients admitted to intensive care unit (ICU) was twice as high as patients in the operating theatre (OT).
- Severe life-threatening complications related to intubation occurred 20 times more often in ICU than in the OT.
- Life-threatening complications of intubation were associated with both ICU admission and difficult intubation in the obese patient.
- Difficult intubation devices were used more often in the case of difficult intubation in the OT than in ICU.

Background. Intubation procedure in obese patients is a challenging issue both in the intensive care unit (ICU) and in the operating theatre (OT). The objectives of the study were (i) to compare the incidence of difficult intubation and (ii) its related complications in obese patients admitted to ICU and OT.

Methods. We conducted a multicentre prospective observational cohort study in ICU and OT in obese (BMI$\geq$30 kg m^{-2}) patients. The primary endpoint was the incidence of difficult intubation. Secondary endpoints were the risk factors for difficult intubation, the use of difficult airway management techniques, and severe life-threatening complications related to intubation (death, cardiac arrest, severe hypoxaemia, severe cardiovascular collapse).

Results. In cohorts of 1400 and 11 035 consecutive patients intubated in ICU and in the OT, 282 (20%) and 2103 (19%) were obese. In obese patients, the incidence of difficult intubation was twice more frequent in ICU than in the OT (16.3% *vs* 8.2%, $P<0.01$). In both cohorts, risk factors for difficult intubation were Mallampati score III/IV, obstructive sleep apnoea syndrome, and reduced mobility of cervical spine, while limited mouth opening, severe hypoxaemia, and coma appeared only in ICU. Specific difficult airway management techniques were used in 66 (36%) cases of difficult intubation in obese patients in the OT and in 10 (22%) cases in ICU ($P=0.04$). Severe life-threatening complications were significantly more frequent in ICU than in the OT (41.1% *vs* 1.9%, relative risk 21.6, 95% confidence interval 15.4–30.3, $P<0.01$).

Conclusions. In obese patients, the incidence of difficult intubation was twice more frequent in ICU than in the OT and severe life-threatening complications related to intubation occurred 20-fold more often in ICU.

Clinical trial registration. Current controlled trials. Identifier: NCT01532063.

Keywords: complications; intensive care unit; intubation; obese; operating theatre

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Intubation is associated with life-threatening complications both in intensive care unit (ICU)[1–6] and in operating theatres (OTs).[7–9] Difficult intubation increases the risk of such complications,[5 8–10] thereby leading to the development of prediction models for difficult intubation both in the ICU[10] and in the OT.[11–13] Up to 4% of patients admitted to ICU had

been admitted for management of a primary airway problem, and 6.3% were predicted to have a difficult airway.[6]

Although controversial,[14] BMI is considered as associated with difficult intubation, both in the ICU[10 15] and in the OT.[11 16] Obesity remains a challenging problem in perioperative medicine and has been increasing both in patients admitted to ICU[17] and to OT.[18] Major airway complications occurring in ICU[5] and OT[8] involved obese patients in 47% and 40%, respectively.

We present the results of a prospective study where the incidence of difficult intubation, the risk factors of difficult intubation, the difficult airway management techniques, and the complications related to intubation were compared between two cohorts of obese patients admitted to ICU and OT and undergoing intubation.

The main endpoint of the study was to compare the incidence of difficult intubation in ICU and OT. The secondary endpoint was to compare risk factors for difficult intubation, difficult airway management techniques, and severe life-threatening complications related to intubation in obese patients admitted to ICU and OT.

Methods

Ethics approval

Because of the observational, non-interventional, and non-invasive design of this study, the need for written consent was waived. The part of the study carried out in ICU was approved by the local ethics committee 'Comité de Protection des personnes Sud-Mediterranée III' (code UF: 8819, register: 2011-A001122-39) and was registered on clinicaltrials.gov (identifier no. NCT01532063). Data from 282 obese patients intubated in ICU have been presented in part in a previously published study.[10] The section of the study performed in the OT was approved by the local scientific and ethics committee of Comité d'Organisation et de Gestion de l'Anesthésie-Réanimation du Centre Hospitalier Universitaire de Montpellier (project approval number: COGAR-n° 2006-02).

Conduct of the study and patient population

We prospectively evaluated in two consecutive periods, all consecutive intubation procedures in obese patients using two multicentre databases, one containing data from 60 French medical, surgical ICU, or both collected from 2011 to 2012, and the other containing data from four anaesthesia departments, collected from 2006 to 2011. All consecutive patients admitted to ICU/OT and intubated were included. Exclusion criteria were pregnancy or being under 18 yr of age.

Data handling

In both cohorts, the same data were collected by senior physicians in each participating centre, using the same definitions: patient characteristic data, weight, height, BMI, modified Mallampati score[19 20] (assessed in lying position[21 22] in ICU and in a sitting position in the OT), previous documented difficult intubation, mouth opening (limited mouth opening being defined as >3.5 cm),[22] mobility of cervical spine (normal *vs* reduced), documented obstructive sleep apnoea syndrome, documented snoring. Minimal and maximal heart rate, arterial blood pressure, and O_2 saturation were registered before, during (between the anaesthetic induction and the tube insertion), and in the 30 min after intubation. The equipment used for intubation—in order of use—the drugs used for intubation, the use of rapid sequence induction, the Cormack and Lehane Score, and the level of difficulty of the intubation according to the ASA criteria[23] were recorded. An intubation attempt was defined as the introduction of the tracheal tube over the patient's teeth or as a failed laryngoscopy without the introduction of the tracheal tube. A laryngoscopic blade readjustment counted as a single attempt.

Furthermore in ICU, we assessed: type of admission (medical or surgical), reason for admission, reason for intubation (coma was defined as a Glasgow coma score <8), severity score at admission (Simplified Acute Physiologic Score II),[24] date and time of intubation (daytime procedure was defined as performed from 8 a.m. to 7 p.m.), the occurrence of a previous intubation in the last 2 weeks (if not it was defined as 'first intubation'), non-invasive ventilation before intubation, mode and position of pre-oxygenation, the nature and number of the operators (expert operators were anaesthetists and intensivists with experience in intubation procedures >5 yr and experience in ICU >1 yr, an operator was defined as an anaesthesiologist if he/she had had a formal anaesthetic training for >24 months),[25] thyromental distance (short thyromental distance being defined as >6 cm),[26] and neck circumference (elevated if <40 cm).[27]

Definition of difficult intubation and complications

Difficult intubation was defined as three or more laryngoscopic attempts to place the tracheal tube into the trachea, as lasting >10 min using conventional laryngoscopy, or both.[23]

Severe life-threatening complications[1–3] were defined as severe hypoxaemia (decrease in Sp_{O_2} level to $<80\%$ during attempts), severe cardiovascular collapse (systolic arterial pressure <65 mm Hg recorded at least one time, <90 mm Hg lasting 30 min despite 500–1000 ml of crystalloids/or colloids solutions loading and/or requiring introduction of vasoactive support), cardiac arrest, and death.

Mild to moderate complications[1 2] were defined as oesophageal intubation, supraventricular, ventricular arrhythmia, or all (without a pulseless rhythm) requiring therapy, dental injury, aspiration, or dangerous agitation (Richmond agitation sedation scale score[28] >3).

Objectives of the study

The main objective of the study was to compare the incidence of difficult intubation in ICU and OT in obese patients. The secondary aims were to assess risk factors of difficult intubation, to compare the use of difficult airway management techniques and severe life-threatening complications related to intubation in obese patients admitted to ICU and OT.

Statistical analysis

Quantitative variables were expressed as means (standard deviation) or medians (inter-quartiles 25–75%) and compared using the Student *t*-test or the Wilcoxon test as appropriate (Gaussian or non-Gaussian variables according to the Shapiro–Wilk and the Kolmogorov–Smirnov tests). Qualitative variables as the main endpoint, that is, severe life-threatening complications, were expressed as numbers (%) and the absolute numbers were compared using the χ^2 test or the Fisher test as appropriate. Relative risks (RRs) of difficult intubation, severe life-threatening complications, and corresponding 95% confidence interval (CI) were computed.

A mixed effects regression was used to identify the risk factors for difficult intubation in both cohorts, after entering centre variable as a random effect.[29] A multivariate model was established to predict difficult intubation. Variables were selected if the *P*-value was >0.20 in the univariate analysis and a step-wise procedure was used to select the final model. Variables were kept in the final model if $P<0.10$. Interactions between variables were tested.

A bivariate analysis was performed to assess the relationship between severe life-threatening complications, ICU setting, and difficult intubation.

A *P*-value of <0.05 was considered statistically significant. The statistical analysis was performed by the medical statistical department of the Montpellier University Hospital using statistical software (SAS, version 9.3; SAS Institute; Cary, NC, USA, and R, version 2.14.1).

Results

The number of intubated patients screened was 1400 in the ICU cohort, admitted from September 2011 to April 2012, and 11 035 in the OT cohort, admitted from January 2006 to December 2011. Among the 1400 patients of the ICU cohort and the 11 035 patients of the OT, 282 (20%) and 2103 (19%) were obese, respectively. The flow chart of the study is shown in Figure 1. The obese patients were admitted to the OT for abdominal surgery ($n=1053$, 50%), cardiovascular surgery ($n=488$, 23%), neurosurgical surgery ($n=470$, 22%), or orthopaedic surgery ($n=92$, 4%).

Incidence of difficult intubation

The incidence of difficult intubation was significantly higher in ICU obese patients (46/282, 16.2%) than in OT obese patients (172/2103, 8.2%), with an RR=1.9, 95% CI 1.5–2.6, $P<0.0001$.

Risk factors for difficult intubation in obese patients

Table 1 presents the characteristics and the main variables of obese patients in OT and ICU according to difficult intubation. Neuromuscular blockers were usually used: in 87% of intubations in ICU and in 93% in OT. Succinylcholine was used in 71% of intubations in ICU *vs* 19% in OT ($P<0.01$). Atracurium or cisatracurium were used in 5% of intubations in ICU *vs* 73% in OT ($P<0.01$). Rapid sequence induction was used in 74% of intubations in ICU *vs* 2% in OT ($P<0.01$). In both cohorts, the Mallampati score, previous documented difficult intubation, limited mouth opening, reduced mobility of cervical spine, and obstructive sleep apnoea syndrome were associated with difficult intubation in univariate analysis. Table 2 presents specific variables recorded in the ICU cohort according to difficult intubation in obese patients. Severe hypoxaemia was significantly associated with difficult intubation, and admissions other than from the OT were associated with non-difficult intubation. In the OT cohort, emergency surgery was performed in 44 patients (2%) with no significant difference between difficult and non-difficult intubation groups (2% *vs* 2%, $P=1.00$). A multivariate model was constructed using the 210 intubations of obese patients in the ICU where all data were available. After entering centre variable as a random effect, the main predictors of difficult intubation were: Mallampati score III or IV, obstructive sleep apnoea syndrome, reduced mobility of cervical spine, limited mouth opening, coma, and severe hypoxaemia (Table 3). A multivariate model was constructed using the 1579 intubations of obese patients in the OT where all data were available. After entering centre variable as a random effect, the main predictors for difficult intubation were: Mallampati score III or IV, obstructive sleep apnoea syndrome, and reduced mobility of cervical spine (Table 4).

Definitive airway management techniques

Table 5 presents the definitive airway management techniques in ICU and OT according to difficult intubation in obese patients. Specific difficult airway management techniques (videolaryngoscopy, intubating laryngeal mask airway, flexible fibreoptic intubation awake, or with light sedation) were used in 66 (38%) cases of difficult intubation in the OT and in 10 (22%) cases in ICU ($P=0.04$). Videolaryngoscopy use (videolaryngoscope) in the case of difficult intubation was significantly higher in the OT ($n=56$, 33%) than in ICU ($n=5$, 11%, $P=0.003$).

Complications of intubation

Among all obese patients, severe life-threatening complications were significantly more frequent in ICU than in OT (41% *vs* 2%, RR 21.6; 95% CI 15.4–30.3, $P<0.01$). Mild to moderate complications were also significantly more frequent in ICU than in OT (14% *vs* 2%, RR 10.0; 95% CI 6.2–16.4, $P<0.01$) (Table 6).

Patients with difficult intubation presented more severe life-threatening complications related to intubation than patients without difficult intubation in both cohorts, but the difference resulted statistically significant only in the ICU cohort (57% *vs* 38%, RR 1.5; 95% CI 1.1–2.0, $P=0.02$). In a bivariate analysis, severe life-threatening complications were significantly associated with both ICU setting (OR 34.7; 95% CI 23.4–51.4, $P<0.01$) and difficult intubation (OR 1.9; 95% CI 1.2–3.3, $P=0.01$). Figure 2 presents the risk of severe life-threatening complications in obese patients according to the location of intubation and difficult intubation.

Discussion

This study assessed difficult intubation, risk factors of difficult intubation, difficult airway intubation techniques, and severe

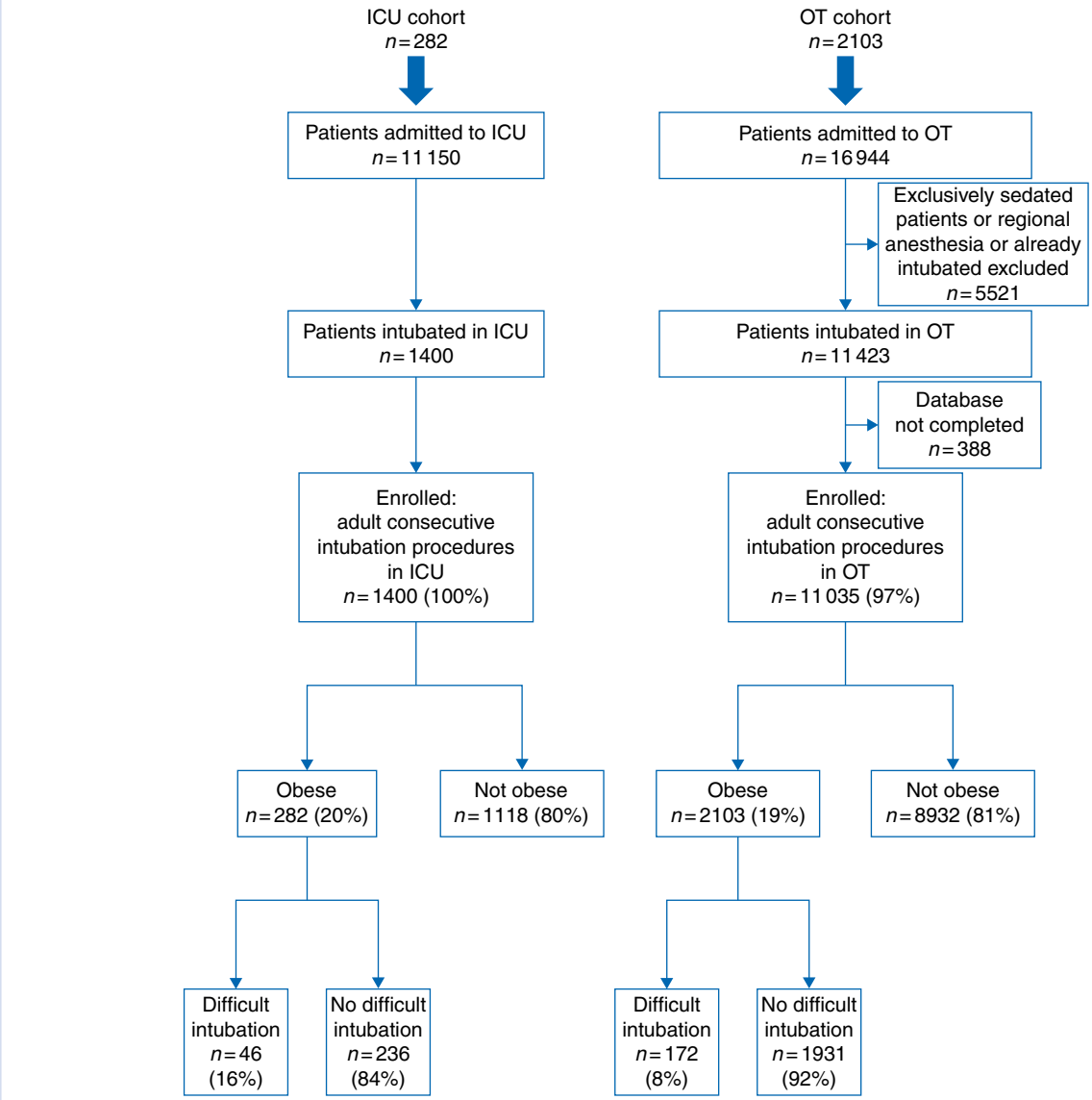

Fig 1 Flow chart of the study.

life-threatening complications related to intubation in obese patients in perioperative medicine, in both ICU and OT.

In this study, we wanted to focus on airway management in obese patients, and on the differences between ICU and OT. The incidence of obesity among included patients was up to 20% in ICU and OT, so twice higher than in the general French population.[30]

In the present study, there were two-fold more difficult intubations in ICU than in OT in obese patients (Table 1, Fig. 1). Intubation conditions in ICU are worse than in OT.[31] Furthermore, the issue of difficult airway in obese patients has gained more attention in the OT than in the ICU over the last few years: the literature provides many recommendations for airway management in obese patients with or without obstructive sleep apnoea syndrome in the OT.[32–34]

In a previous study, Cook and colleagues[5 8] demonstrated that life-threatening complications in obese patients were over-represented in terms of major airway complications, in comparison with non-obese patients. In the current study, there were 20-fold more complications resulting from airway management in ICU than OT in obese patients. Those results were previously reported in non-obese patients in studies performed separately in ICU[1 2 5 6 10] and OT[8 9] and by Cook and colleagues[5 8] in the Fourth National Audit Project of the Royal College of Anaesthetists and Difficult Airway Society: Major Complications of Airway Management in the UK (NAP4). Moreover, the mild to moderate complications were 10-fold more frequent in ICU than in OT. Cook and colleagues[5 8] have reported that oesophageal intubation and aspiration are important and often precursors of major complications.

Table 1 Patient characteristics and main variables in OT and ICU according to difficult intubation in obese patients. Values are mean (SD), mean (range) (for age) or number (%). NA, not available

	ICU cohort				OT cohort			
	Total (*n*=282)	**Difficult intubation (*n*=46)**	**No difficult intubation (*n*=236)**	***P*-value**	**Total (*n*=2103)**	**Difficult intubation (*n*=172)**	**No difficult intubation (*n*=1931)**	***P*-value**
Age (yr)	64 (18–95)	62 (18–79)	64 (19–95)	0.15	54 (19–92)	59 (24–89)	54 (19–92)	<0.0001
Male (gender)	164/277 (59%)	26/46 (57%)	138/231 (60%)	0.69	983 (47%)	103 (60%)	880 (46%)	0.0003
Weight (kg)	99 (20)	100 (20)	98 (20)	0.44	101 (20)	101 (18)	101 (20)	0.76
Height (cm)	166 (11)	165 (12)	166 (10)	0.80	167 (10)	168 (10)	167 (10)	0.40
BMI (kg m^{-2})	36 (6)	36 (6)	36 (6)	0.25	36 (6)	36 (5)	36 (6)	0.38
Mallampati score				<0.0001				<0.0001
I	110/220 (50%)	3/36 (8%)	107/184 (58%)		908/1995 (46%)	34/160 (21%)	874/1835 (47%)	
II	59/220 (27%)	6/36 (17%)	53/184 (29%)		681/1995 (34%)	42/160 (26%)	639/1835 (35%)	
III	4/220 (16%)	14/36 (39%)	20/184 (11%)		289/1995 (15%)	52/160 (33%)	237/1835 (13%)	
IV	17/220 (8%)	13/36 (36%)	4/184 (2%)		117/1995 (6%)	32/160 (20%)	85/1835 (5%)	
Previous documented difficult intubation	10 (4%)	6 (13%)	4 (2%)	0.002	12 (1%)	11 (6%)	1 (0%)	<0.0001
Limited mouth opening	33 (12%)	12 (26%)	21 (9%)	0.0002	221/1842 (12%)	39/154 (25%)	182/1688 (11%)	<0.0001
Low thyromental distance	44 (16%)	10 (22%)	34 (14%)	0.21	NA	NA	NA	
Elevated neck circumference	109 (39%)	29 (63%)	80 (34%)	0.0002	NA	NA	NA	
Reduced mobility of cervical spine	33 (12%)	13 (28%)	20 (9%)	0.0001	263/1601 (16%)	47/132 (36%)	216/1469 (15%)	<0.0001
Obstructive apnoea syndrome	63 (22%)	24 (52%)	39 (17%)	<0.0001	213 (10%)	28 (16%)	185 (10%)	0.005
Snoring	79 (28%)	22 (48%)	57 (24%)	0.001	680 (32%)	58 (34%)	622 (32%)	0.69
Drugs used for intubation								
Etomidate	143 (51%)	20 (43%)	123 (52%)	0.28	100 (5%)	9 (5%)	91 (5%)	0.76
Ketamine	59 (21%)	8 (17%)	51 (22%)	0.52	92 (4%)	7 (4%)	85 (4%)	0.84
Propofol	39 (14%)	6 (13%)	33 (14%)	0.87	1607 (76%)	138 (80%)	1469 (76%)	0.22
Succinylcholine	200 (71%)	34 (74%)	166 (70%)	0.63	397 (19%)	46 (27%)	351 (18%)	0.006
Rocuronium	31 (11%)	3 (7%)	28 (12%)	0.29	19 (1%)	4 (2%)	15 (1%)	0.04
Atracurium or cisatracurium	14 (5%)	5 (11%)	9 (4%)	0.04	1530 (73%)	111 (65%)	1419 (73%)	0.01
Use of rapid sequence induction	208 (74%)	35 (76%)	176 (73%)	0.69	41 (2%)	2 (2%)	39 (2%)	1.00

Table 2 Specific variables recorded in ICU before intubation according to difficult intubation in obese patients. Values are mean (SD) or number (%). SAPS2, Simplified Acute Physiologic Score; ICU, intensive care unit; SAP, systolic arterial pressure; Sp_{O_2}, pulse oximeter oxygen saturation; NIV, non-invasive ventilation

	ICU cohort			
	Total ($n=282$)	Difficult intubation ($n=46$)	No difficult intubation ($n=236$)	*P*-value
SAPS II	51 (18)	50 (19)	51 (18)	0.64
Reason for ICU admission				
Acute respiratory failure	165 (59%)	30 (65%)	135 (57%)	0.31
Trauma	9 (3%)	1 (2%)	8 (3%)	1.00
Postoperative	32 (11%)	1 (2%)	31 (13%)	0.03
Cardiac arrest	4 (1%)	1 (2%)	3 (1%)	0.51
Neurological	57 (20%)	11 (24%)	46 (20%)	0.49
Shock	79 (28%)	13 (28%)	66 (28%)	0.97
Acute renal failure	33 (12%)	6 (13%)	27 (11%)	0.76
Others	27 (10%)	5 (11%)	22 (9%)	0.81
Reason for intubation				
Acute respiratory failure	184 (65%)	30 (65%)	154 (65%)	1.00
Shock	44 (16%)	8 (17%)	36 (15%)	0.71
Coma	69 (25%)	16 (35%)	53 (22%)	0.08
Cardiac arrest	9 (3%)	3 (7%)	6 (3%)	0.17
Replace the tracheal tube	50 (18%)	10 (22%)	40 (17%)	0.44
Others	18 (6%)	4 (10%)	14 (6%)	0.72
Medical admission	209 (74%)	38 (83%)	171 (72%)	0.15
Daytime intubation	97 (34%)	12 (26%)	85 (36%)	0.23
First intubation	172 (61%)	28 (61%)	144 (61%)	0.99
Expert operator	119 (42%)	21 (46%)	98 (42%)	0.65
Anaesthesiologist	198 (70%)	28 (61%)	170 (72%)	0.13
Number of operators				0.23
1	79/279 (28%)	9/44 (21%)	70/235 (30%)	
2	162/279 (58%)	26/44 (59%)	136/235 (58%)	
3	38/279 (14%)	9/44 (21%)	29/235 (12%)	
Vasopressors use	55 (20%)	8 (17%)	47 (20%)	0.69
SAP<90 mm Hg	73/266 (27%)	8/42 (19%)	65/224 (29%)	0.17
Sp_{O_2} <90%	139/276 (50%)	28/45 (62%)	111/231 (48%)	0.08
Sp_{O_2} <80%	55/276 (20%)	15/45 (33%)	40/231 (17%)	0.01
NIV	115 (41%)	19 (41%)	96 (41%)	0.94
Pre-oxygenation by NIV	208 (74%)	35 (76%)	173 (73%)	0.43
Sitting position during pre-oxygenation	54 (19%)	7 (16%)	47 (20%)	0.48

Difficult intubation and ICU setting were associated with severe life-threatening complications. This study highlights the fact that the ICU setting is an independent risk factor of severe complications, in comparison with the OT setting. In obese patients admitted to ICU, even the easy intubation can lead to life-threatening complications, difficult intubation only makes it worse (Fig. 2). Indeed, patients admitted to ICU generally have less physiological reserve than those admitted for elective surgery with a high rate of acute respiratory failure.

Moreover, the use of specific difficult airway management techniques was markedly less in the ICU compared with OT. Cook and colleagues[5 8] also found that airway management preceding a severe airway complication in ICU was far less likely to be structured than in the OT and that advanced/rescue airway techniques in obese patients in ICU frequently failed before a serious airway complication. These results could be explained by the failure to recognize the problem of airway management in ICU, the lack of skills,[6] or the lack of equipment. Further studies are needed to explore the reasons of disparity of airway management techniques between ICU and OT. In contrast, fibreoptic intubation was performed more often in ICU than in OT. This could be explained by the large use of video laryngoscopes in our four OT centres in the case of difficult intubation.

In addition, in this study, risk factors for difficult intubation in OT were similar to those found in the literature for obese patients, that is, Mallampati score,[35 36] and obstructive sleep apnoea syndrome.[37] Moreover, in the ICU cohort, we identified the same risk factors as in the OT, but also specific risk factors such as severe hypoxaemia and coma as a cause of difficult intubation.

Finally, in the OT, rapid sequence induction was only used in 2% of the patients. This indicates that in France,

anaesthesiologists no longer consider morbidly obese as non-fasting. In ICU, rapid sequence induction was performed in 74% of the patients. In a classic rapid sequence induction, no mask ventilation is allowed for 1 min once the sequence has been started. By this time, most critically ill patients are entering the low saturation zone. This might be an explanation for the severe complications in ICU.[38] The present study has several limitations. First, we used two databases, one for ICU data and the other for OT data, which could lead to information bias. Moreover, the ICU collection started after the OT collection, with an addition of recorded items. Neck circumference[35] and neck circumference to thyromental distance[36] were not available in our OT database, even if defined as risk factors of difficult intubation in obese patients in previous studies. Date and time of intubation were not recorded in the OT cohort. However, the definitions used for the recorded variables, that is, difficult intubation, risk factors for difficult intubation, or severe life-threatening complications, were the same in both databases. Secondly, pre-oxygenation and intubation position were not standardized nor registered in the OT cohort in this prospective observational study. In addition, the Mallampati score was assessed in recumbent patients in the ICU cohort. However, according to previous studies, the Mallampati score in a lying patient is equivalent to the Mallampati acore in a sitting one.[21 39] Thirdly, as the physicians prospectively recording the variables in the databases were sometimes the same as those performing the intubation, the degree of difficulty of the intubation could have been overestimated or underestimated. Fourthly, the fact that both databases are multicentre could be a limit, because the management of intubation could differ between centres. However, the centre variable was taken into account in the multivariate models. Fifthly, the definition of difficult intubation was recently updated by the American Task Force on the management of the difficult airway as 'Tracheal intubation requiring multiple attempts, in the presence or absence of tracheal pathology'.[40] The definition used in our study was chosen before this update and was the same as that of our previous studies.[1 2 10]

Table 3 Results of multivariate mixed effects regression for final difficult intubation prediction model from the ICU cohort in obese patients (n=210). Centre variable was entered as a random effect. OR, odds ratio; CI, confidence interval. Reference: Mallampati score=I or II; obstructive sleep apnoea syndrome=no; reduced mobility of cervical spine=no; limited mouth opening=no; severe hypoxaemia (<80%)=no; coma=no

	OR	95% CI	*P*-value
Mallampati score III or IV	14.10	5.11–38.90	<0.0001
Obstructive sleep apnoea syndrome	2.90	1.04–8.07	0.04
Reduced mobility of cervical spine	2.75	0.83–9.12	0.09
Limited mouth opening	4.18	0.89–19.72	0.07
Severe hypoxaemia (<80%)	3.26	1.02–10.3	0.05
Coma	3.13	1.08–9.11	0.04

Table 4 Results of multivariate mixed effects regression for final difficult intubation prediction model from the OT cohort in obese patients (n=1579). Centre variable was entered as a random effect. OR, odds ratio; CI, confidence interval. Reference: Mallampati score=I or II; reduced mobility of cervical spine=no; obstructive sleep apnoea syndrome=no

	OR	95% CI	*P*-value
Mallampati score III or IV	3.93	2.65–5.84	<0.0001
Reduced mobility of cervical spine	2.29	1.51–3.48	<0.0001
Obstructive sleep apnoea syndrome	1.96	1.19–3.22	0.009

Conclusions

In obese patients, difficult intubation incidence was twice higher in ICU than in the OT, while severe life-threatening complications related to intubation occurred 20 times more often in ICU than in the OT. Life-threatening complications of intubation were associated with both ICU admission and difficult intubation in the obese patient. In addition, difficult intubation devices were used more often in the case of difficult intubation in the OT than in ICU. Accordingly, further studies are required to determine if a better management of intubation in ICU could reduce the incidence of difficult intubation and severe

Table 5 Definitive airway management techniques for difficult intubation in operative theatre and ICU according to difficult intubation in obese patients. Values are number (%)

	ICU cohort				OT cohort			
	Total (n=282)	Difficult intubation (n=46)	No difficult intubation (n=236)	*P*-value	Total (n=2103)	Difficult intubation (n=172)	No difficult intubation (n=1931)	*P*-value
Direct laryngoscopy	199 (71%)	11 (24%)	188 (80%)	<0.0001	1777 (85%)	33 (19%)	1744 (90%)	<0.0001
Direct laryngoscopy and bougie introducer	65 (23%)	25 (54%)	40 (17%)	<0.0001	207 (10%)	73 (42%)	134 (7%)	<0.0001
Videolaryngoscopy	7 (3%)	5 (11%)	2 (1%)	0.002	98 (5%)	56 (34%)	42 (2%)	<0.0001
Fastrach	2 (1%)	2 (4%)	0 (0%)	0.03	14 (1%)	8 (5%)	6 (0%)	<0.0001
Fibreoptic intubation	9 (3%)	3 (7%)	6 (3%)	0.17	7 (0%)	2 (1%)	5 (0%)	0.05

Table 6 Complications of intubation in OT and ICU according to difficult intubation in obese patients. Values are number (%)

	ICU cohort				OT cohort			
	Total ($n=282$)	Difficult intubation ($n=46$)	No difficult intubation ($n=236$)	*P*-value	Total ($n=2103$)	Difficult intubation ($n=172$)	No difficult intubation ($n=1931$)	*P*-value
Difficult intubation	46 (16%)	46 (100%)	0 (0%)		172 (9%)	172 (100%)	0 (0%)	
Severe life-threatening complications	116 (41%)	26 (57%)	90 (38%)	0.02	40 (2%)	5 (3%)	35 (2%)	0.31
Death	3 (1%)	2 (4%)	1 (0%)	0.07	0 (0%)	0 (0%)	0 (0%)	1.00
Cardiac arrest	8 (3%)	5 (11%)	3 (1%)	0.004	1 (0%)	0 (0%)	1 (0%)	0.77
Severe cardiovascular collapse	74 (26%)	10 (22%)	64 (27%)	0.45	36 (2%)	4 (2%)	32 (2%)	0.52
Severe hypoxaemia	47 (17%)	18 (39%)	29 (12%)	<0.001	4 (0%)	1 (1%)	3 (0%)	0.22
Mild to moderate complication	38 (14%)	13 (28%)	25 (11%)	0.001	32 (2%)	5 (3%)	27 (1%)	0.12
Oesophageal intubation	18 (6%)	9 (20%)	9 (4%)	<0.001	12 (1%)	4 (2%)	8 (0%)	0.001
Aspiration of gastric contents	8 (3%)	2 (4%)	6 (3%)	0.62	2 (0%)	0 (0%)	2 (0%)	0.67
Arrhythmia	14 (5%)	5 (11%)	9 (4%)	0.06	16 (1%)	1 (1%)	15 (1%)	0.78
Dental injury	2 (1%)	2 (4%)	0 (0%)	0.03	2 (0%)	0 (0%)	2 (0%)	0.67

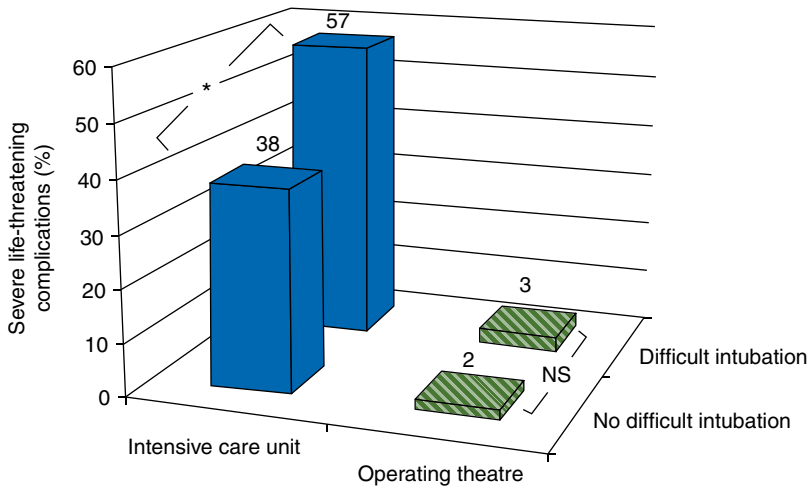

Fig 2 Risk of severe life-threatening complications in obese patients according to the ease of intubation and location. *$P<0.05$: difficult intubation *vs* non-difficult intubation. The obese patients at higher risk of severe life-threatening complications were the patients admitted in ICUs with difficult intubation.

life-threatening complications related to intubation in obese patients.

Authors' contributions

A.D.J.: contributed to data collection, data analysis, drafting the manuscript, and writing the manuscript. N.M.: contributed to statistical methods and statistical data analysis. Y.P.: contributed to conception and design data analysis and manuscript review. D.V.: contributed to data collection. G.C.: contributed to data analysis and manuscript review. B.J., E.F., P.-F.P., P.C., and X.C.: contributed to data collection and manuscript review. S.J.: contributed to conception and design, data analysis, revision of the manuscript, and is the guarantor of the manuscript. All authors read and approved the final manuscript.

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Declaration of interest

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