

# A cross-sectional observational study of endotracheal intubation and extubation practices among doctors treating adult COVID-19 and suspected COVID-19 patients in South Africa

K Naidoo,<sup>1</sup> MB ChB, DA (SA); S Spijkerman,<sup>1</sup> MB ChB, MMed (Anaes); J Wyngaard,<sup>1</sup> MB ChB, MMed (Anaes); H de Menezes-Williams,<sup>1</sup> MB ChB, MMed (Anaes); C Janse van Rensburg,<sup>2</sup> MSc (Math Stats)

<sup>1</sup> Department of Anaesthesiology, School of Medicine, Faculty of Health Sciences, University of Pretoria, South Africa

<sup>2</sup> Biostatistics Unit, South African Medical Research Council, Pretoria, South Africa

**Corresponding author:** K Naidoo (karshn9@gmail.com)

**Background.** Patients with severe COVID-19 may require endotracheal intubation. Unique adjustments to endotracheal intubation and extubation practices are necessary to decrease the risk of SARS-CoV-2 transmission to healthcare workers (HCWs) while avoiding complications of airway management.

**Objectives.** To investigate the practice of endotracheal intubation and extubation, resources available and complications encountered by clinicians performing endotracheal intubation and extubation of COVID-19 and suspected COVID-19 patients in South Africa (SA).

**Method.** A cross-sectional observational study was conducted during the initial surge of COVID-19 cases in SA. Data were collected by means of a self-administered questionnaire completed by clinicians in the private and public healthcare sectors after performing an endotracheal intubation and/or extubation of a patient with confirmed or suspected COVID-19.

**Results.** Data from 135 endotracheal intubations and 45 extubations were collected. Anaesthetists accounted for 87.0% ( $n=120$ ) of the study participants, specialist clinicians in their respective fields for 59.4% ( $n=82$ ), and public HCWs for 71.0% ( $n=98$ ). Cases from Gauteng Province made up 76.8% ( $n=106$ ) of the database. Haemoglobin desaturation was the most frequent complication encountered during endotracheal intubation (40.0%;  $n=54$ ). Endotracheal intubations performed at private healthcare institutions were associated with a significantly lower complication rate of 17.5% ( $n=7$ ) compared with 52.6% ( $n=50$ ) in the public healthcare sector ( $p<0.001$ ). Endotracheal intubations performed in theatre had the lowest complication rate of 10.4% ( $n=5$ ;  $p<0.001$ ). Propofol was used in 90 endotracheal intubations (66.7%), and its use was associated with fewer complications relative to other induction agents. Minimising the number of intubation attempts ( $p=0.009$ ) and the use of checklists ( $p=0.013$ ) significantly reduced the frequency of complications encountered during endotracheal intubation. Intravenous induction technique, neuromuscular blocking agent used, intubating device used and time at which intubation was performed did not affect the incidence of complications. The majority of endotracheal extubations were uncomplicated (88.9%).

**Conclusions.** The study provides valuable insight into the resources used by clinicians and complications encountered when endotracheal intubations and/or extubations were performed. Data from this study may be used to guide future clinical practice and research, especially in resource-limited settings.

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COVID-19 was declared a global pandemic on 11 March 2020 and continues to spread across the world as new variants of the novel coronavirus emerge. At the time of writing, South Africa (SA) was in its third wave of the disease and had surpassed two million COVID-19 infections since the country's first case was diagnosed on 5 March 2020.<sup>[1,2]</sup>

A significant proportion of cases of severe COVID-19 require endotracheal intubation and ventilatory support for respiratory failure.<sup>[3,4]</sup> Other frequent indications for endotracheal intubation in COVID-19 patients include general anaesthesia for surgery and endotracheal tube exchange.<sup>[5]</sup> Endotracheal intubation and extubation are aerosol-generating procedures that pose the greatest risk of SARS-CoV-2 exposure and transmission to healthcare workers (HCWs).<sup>[4-6]</sup> Data from the SARS-CoV-1 outbreak revealed that HCWs who performed endotracheal intubation of SARS-CoV-1-infected patients were 6.6 times more likely to contract SARS-CoV-1 compared with unexposed HCWs.<sup>[7]</sup> Furthermore, endotracheal intubation poses a considerable risk for complications

in the physiologically compromised COVID-19 patient.<sup>[8-10]</sup> Most COVID-19 patients requiring endotracheal intubation are likely to be tachypnoeic, tachycardic, hypotensive and of altered mentation, with 75.2% being hypoxaemic (peripheral pulse oximetry  $<90\%$ ) before intubation.<sup>[11]</sup> Because of the risks to patient and healthcare provider, various airway management guidelines have been developed to manage COVID-19 patients safely.<sup>[9,10,12-16]</sup> However, adherence to these guidelines may be challenging in resource-poor healthcare settings. At the time of writing, the practice of endotracheal intubation and/or extubation of COVID-19 patients in SA had not been evaluated.

## Objectives

To investigate the performance of endotracheal intubation and extubation among clinicians in SA who managed patients considered to have a highly infectious airway. The study further aimed to assess the resources available to perform endotracheal intubation and/or extubation and the complications encountered in this setting.

## Methods

This cross-sectional observational study was conducted during the initial wave of the COVID-19 pandemic in SA. Data were collected using a self-administered, online questionnaire that was completed by clinicians working in SA public and private healthcare facilities after performing endotracheal intubations and/or extubations of suspected or confirmed COVID-19 patients.

The questionnaire used was developed from local and international COVID-19 guidelines available at the outset of the pandemic for endotracheal intubation and extubation practices. The questions were also aligned with established airway management practices used regularly in the disciplines of anaesthesia, critical care and emergency medicine. Participants completed a maximum of 40 closed-ended questions that required either single or multiple responses to be selected. The number of questions completed by participants varied according to whether endotracheal intubation, extubation or both were performed. Fixed-choice questions were used to minimise the inherent pitfalls associated with self-reported data. The questionnaire was designed to be as comprehensive as possible while remaining brief and easy to administer. It was expected to take 3 - 7 minutes to complete. The brevity and design of the questionnaire allowed its use to be feasible in busy clinical environments. Every endotracheal intubation and/or extubation was considered as a new case for which a questionnaire was completed. Prior to its distribution, the questionnaire was reviewed by a number of specialist anaesthesiologists affiliated to the University of Pretoria. Permission to collect data was granted by the University of Pretoria's Faculty of Health Sciences Research Ethics Committee (ref. no. 245/2020).

All clinicians in SA who performed endotracheal intubations and/or extubations of patients aged >12 years who tested positive for COVID-19 or were highly suspicious for COVID-19 based on clinical assessment were potential participants in this study. The questionnaire was distributed to members of the South African Society of Anaesthesiologists (SASA) and shared with representatives of other front-line disciplines for further distribution.

Consent was obtained electronically prior to completion of the questionnaire. Questionnaires for which demographic data were captured without completion of the respective endotracheal intubation and/or extubation sections of the questionnaire were considered to be incomplete.

Data were collected between March and September 2020 using REDCap 10.3.4 (Vanderbilt University, USA) and exported to Excel 365 (Microsoft, USA) using a password-protected laptop. Statistical analysis was conducted using Stata 16 software (StataCorp, USA). A sample size of 150 participants was used. Categorical variables were described using frequencies and proportions. Associations between categorical variables were tested for using the  $\chi^2$  test. Tests were evaluated at a 5% level of significance. Incomplete questionnaires and those for which consent was denied were excluded from the statistical analysis. Data were reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.<sup>[17]</sup>

## Results

### Study participants

A total of 174 responses were collected between March and September 2020. Thirty-six responses were excluded from statistical analysis. Data describing 135 endotracheal intubations and 45 endotracheal extubations of COVID-19 patients were analysed (Fig. 1). We were unable to determine an exact participation rate for our study, as it was not possible to determine the total number of potential participants. SASA has 2 200 members, but not all SASA members would have managed COVID-19 patients. Furthermore, it was not possible to determine how many participants from disciplines outside of anaesthesia had access to our study.

A description of the study participants is summarised in Table 1.

### Endotracheal intubation

Data pertaining to 135 endotracheal intubations were collected. Patients had confirmed COVID-19 (as determined by SARS-CoV-2

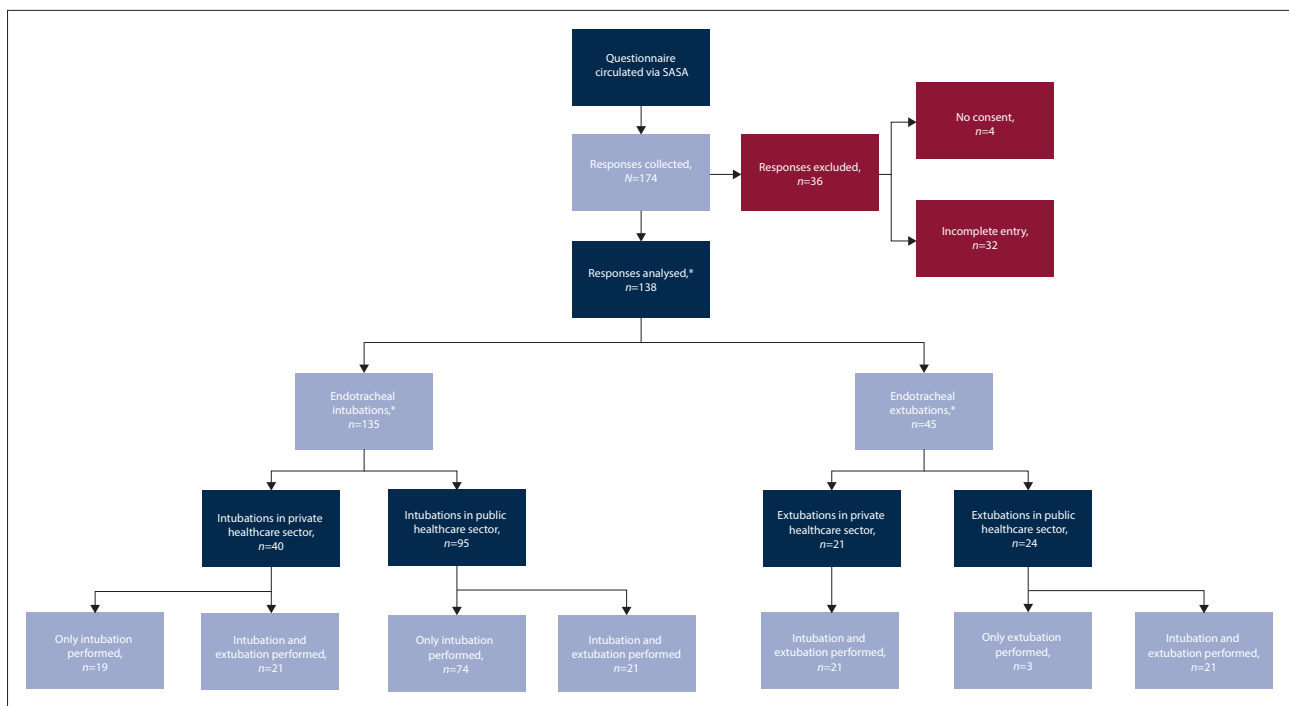


Fig. 1. Recruitment and responses analysed. (SASA = South African Society of Anaesthesiologists. \*Note that some endotracheal intubations and extubations were performed on the same patient during one case entry. The number of cases reported may therefore differ from the number of participants in the study.)

**Table 1. Summary of study participants (N=138)**

	n (%)
Specialty	
Anaesthesiology	120 (87.0)*
Critical care	7 (5.1)
Internal medicine	4 (2.9)
Family medicine	3 (2.2)
Emergency medicine	3 (2.2)
Other	1 (0.7)
Designation	
Specialist	82 (59.4)
Registrar	42 (30.4)
Medical officer	12 (8.7)
Medical intern	2 (1.4)
Clinical experience (years)	
>10	54 (39.1)
5 - 10	35 (25.4)
2 - 5	44 (31.9)
<2	5 (3.6)
Province	
Gauteng	106 (76.8)
KwaZulu-Natal	14 (10.1)
Western Cape	8 (5.8)
Eastern Cape	4 (2.9)
North West	3 (2.2)
Free State	2 (1.5)
Mpumalanga	1 (0.7)
Northern Cape	0
Limpopo	0
Healthcare sector	
Public	98 (71.0)
Private	40 (29.0)

\*Specialist anaesthesiologists accounted for 77/120 respondents. Non-specialist clinicians accounted for 43/120 respondents from the field of anaesthesiology.

polymerase chain reaction (PCR) testing) in 59.3% (n=80) of intubations performed, while the remaining 40.7% of intubations (n=55) were performed on patients who were highly suspicious for COVID-19 based on the clinical judgement of the attending clinician. Their SARS-CoV-2 PCR result was not followed up as part of the study. Endotracheal intubation of patients who were highly suspicious for COVID-19 was conducted in the same way as for those with confirmed COVID-19. First-pass successful endotracheal intubation was achieved in 88.1% of cases (n=119). Most endotracheal intubations were performed in theatre (35.6%; n=48), dedicated COVID-19 wards (34.1%; n=46) and intensive care or high-care units (24.4%; n=33). The majority of endotracheal intubations (63.0%; n=85) were performed outside of core hours, which were considered to be 08h00 - 16h00 from Monday to Friday. Ninety-three (68.9%) of the tracheal intubations reported were performed at academic institutions.

Complications of endotracheal intubation occurred in 42.2% of cases (n=57) (Fig. 2). The associations between the overall incidence of complications experienced during endotracheal intubation and various healthcare factors are summarised in Table 2. A sub-analysis of factors influencing the complications encountered during endotracheal intubations performed in confirmed COVID-19 patients is summarised in Table 3. Five cases of endotracheal intubations were recorded as reintubations for patients whose endotracheal tube had dislodged or migrated. All reintubations were conducted

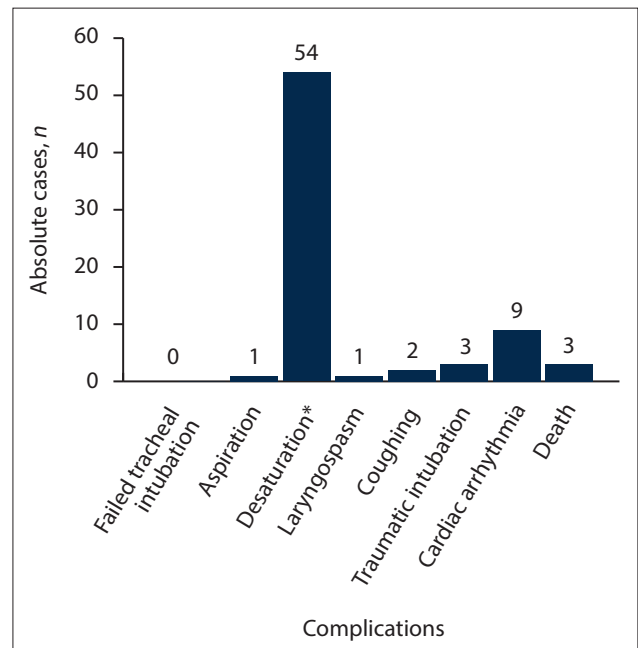


Fig. 2. Frequency of complications encountered during endotracheal intubation (N=57 intubations). Note that more than one complication may have occurred during the same endotracheal intubation. (\*Desaturation >10% from baseline.)

while patients continued to receive cisatracurium infusions, and no additional neuromuscular blocking agent (NMBA) was administered. During all reintubations patients desaturated >10% from baseline, but no other significant complications were encountered. Endotracheal intubations performed at public healthcare facilities were associated with a significantly higher complication rate of 52.6% (n=50) compared with 17.5% (n=7) of intubations performed at private healthcare facilities (p<0.001). Table 4 summarises the differences in endotracheal intubation performance between the public and private healthcare sectors.

Modifications to a classic rapid-sequence induction and intubation were applied to 90 endotracheal intubations performed (66.7%) (Fig. 3). The most common complication encountered when modifications were applied was desaturation >10% from baseline, occurring in 47.8% of cases (n=43). Checklists were used in 38.5% of cases (n=52) (Fig. 4).

Fig. 5 depicts the frequency with which various items of PPE were used by clinicians performing endotracheal intubations throughout this study. Twenty clinicians reported the use of N95/FFP2 respirators in conjunction with surgical masks during endotracheal intubation.

### Endotracheal extubation

Forty-five endotracheal extubations were captured during the study. Endotracheal extubations performed in theatre accounted for 84.4% of extubations (n=38). Four extubations were performed in the intensive care unit (8.9%) and 3 in COVID-19 wards (6.7%). Deep extubation was performed in 7 patients (15.6%), 1 patient's endotracheal tube was exchanged for a laryngeal mask airway device prior to extubation, and 37 patients (82.2%) were extubated when fully awake. The majority of endotracheal extubations were uncomplicated (88.9%; n=40). Four patients (8.9%) coughed during extubation, and 1 patient desaturated >10% from baseline. Equipment necessary for reintubation was readily available in 93.3% of cases (n=42). No failed extubations were reported. Endotracheal extubations were performed during core hours in 51.1% of cases (n=23). No significant

**Table 2. Association between various healthcare factors investigated and the overall incidence of complications encountered during endotracheal intubations in the study**

Variable	Complication rate, <i>n</i> complicated intubations/ N intubations performed (%)	<i>p</i> -value
Designation		0.825
Specialist	32/80 (40.0)	
Registrar	18/42 (42.9)	
Medical officer	6/11 (54.5)	
Medical intern	1/2 (50.0)	
Clinical experience (years)		0.238
>10	19/54 (35.2)	
5 - 10	15/34 (44.1)	
2 - 5	19/42 (45.2)	
<2	4/5 (80.0)	
Healthcare sector		<0.001*
Public	50/95 (52.6)	
Private	7/40 (17.5)	
SARS-CoV-2 PCR test		<0.001*
Positive	46/80 (57.5)	
Unknown but highly suspicious for COVID-19	11/55 (20.0)	
Site of intubation		<0.001*
Dedicated COVID-19 ward	29/46 (63)	
ICU	16/33 (48.5)	
Theatre	5/48 (10.4)	
Emergency department	4/4 (100)	
Non-COVID-19 ward	2/2 (100)	
Other	1/2 (50.0)	
IV induction technique		0.416
RSII	50/116 (43.1)	
ESII	4/14 (28.6)	
No drugs used	3/5 (60.0)	
Modifications used		0.003*
Yes	46/90 (51.1)	
No	11/45 (24.4)	
Intubating device		0.411
Videolaryngoscope	40/100 (40.0)	
Macintosh direct laryngoscope	17/35 (48.6)	
Use of checklists		0.013*
Yes	15/52 (28.8)	
No	42/83 (50.6)	
Intubation attempts		0.009*
1	44/119 (37)	
2	10/13 (76.9)	
3	1/1 (100)	
>3	2/2 (100)	
IV induction agent		0.032*
Propofol	32/90 (35.6)	
Etomidate	13/29 (44.8)	
Ketamine	6/8 (75.0)	
Benzodiazepine only	1/3 (33.3)	
Other	1/1 (100)	
No induction agent	4/4 (100)	
NMBA used		0.135
Suxamethonium	33/79 (41.8)	
Rocuronium (1.2 mg/kg IBW)	17/45 (37.8)	
Atracurium	0/2 (0)	
Other	5/7 (71.4)	
No NMBA	2/2 (100)	
Time of intubation		0.079
After hours	41/85 (48.2)	
Core hours	16/50 (32.0)	

PCR = polymerase chain reaction; ICU = intensive care unit; IV = intravenous; RSII = rapid-sequence induction and intubation; ESII = elective-sequence induction and intubation; NMBA = neuromuscular blocking agent; IBW = ideal body weight.  
\*Significant at *p*<0.05.

**Table 3. Sub-analysis of factors influencing the complications encountered during endotracheal intubation of confirmed COVID-19 patients**

Variable	Complication rate, <i>n</i> complicated intubations/ <i>N</i> intubations performed (%)	<i>p</i> -value
Designation		0.43
Specialist	28/44 (63.6)	
Registrar	14/29 (48.3)	
Medical officer	4/7 (57.1)	
Clinical experience (years)		0.74
>10	17/28 (60.7)	
5 - 10	13/22 (59.1)	
2 - 5	13/26 (50.0)	
<2	3/4 (75.0)	
Healthcare sector		0.13
Public	40/65 (61.5)	
Private	6/15 (40.0)	
Site of intubation		0.01*
Dedicated COVID-19 ward	27/40 (67.5)	
ICU	15/29 (51.7)	
Theatre	1/8 (12.5)	
Emergency department	1/1 (100)	
Non-COVID-19 ward	1/1 (100)	
Other	1/1 (100)	
IV induction technique		0.68
RSII	40/68 (58.8)	
ESII	4/9 (44.4)	
No drugs used	2/3 (66.7)	
Modifications used		0.10
Yes	35/55 (63.6)	
No	11/25 (44.0)	
Intubating device		0.37
Videolaryngoscope	34/56 (60.7)	
Macintosh direct laryngoscope	12/24 (50.0)	
Use of checklists		0.37
Yes	12/24 (50.0)	
No	34/56 (60.7)	
Intubation attempts		0.10
1	35/67 (52.2)	
2	8/10 (80.0)	
3	1/1 (100)	
>3	2/2 (100)	
IV induction agent		0.89
Propofol	27/49 (55.1)	
Etomidate	12/22 (54.5)	
Ketamine	3/4 (75.0)	
Benzodiazepine only	1/2 (50.0)	
Other	1/1 (100)	
No induction agent	2/2 (100)	
NMBA used		0.80
Suxamethonium	27/50 (54)	
Rocuronium (1.2 mg/kg IBW)	13/21 (61.9)	
Atracurium	0/2 (0)	
Other	5/6 (83.3)	
No NMBA	1/1 (100)	
Time of intubation		0.35
After hours	33/54 (61.1)	
Core hours	13/26 (50.0)	

ICU = intensive care unit; IV = intravenous; RSII = rapid-sequence induction and intubation; ESII = elective-sequence induction and intubation; NMBA = neuromuscular blocking agent; IBW = ideal body weight.

\*Significant at *p*<0.05.

**Table 4. Differences in performance of endotracheal intubation between the public and private healthcare sectors**

Variable	Public healthcare cases (N=95), n (%)	Private healthcare cases (N=40), n (%)	p-value
Designation			<0.001*
Specialist	42 (44.2)	38 (95.0)	
Registrar	42 (44.2)	0	
Medical officer	9 (9.5)	2 (5.0)	
Medical intern	2 (2.1)	0	
Site of intubation			0.004*
COVID-19 ward	40 (42.1)	6 (15.0)	
Theatre	25 (26.3)	23 (57.5)	
ICU	22 (23.2)	11 (27.5)	
Emergency department	4 (4.2)	0	
Non-COVID-19 ward	2 (2.1)	0	
Other	2 (2.1)	0	
IV induction technique			0.047*
RSII	86 (90.5)	32 (80.0)	
ESII	6 (6.3)	8 (20.0)	
No drugs used	3 (3.2)	0	
IV induction agent			0.220
Propofol	59 (62.1)	31 (77.5)	
Etomidate	25 (26.3)	4 (10.0)	
Ketamine	6 (6.3)	2 (5.0)	
Benzodiazepine only	1 (1.1)	2 (5.0)	
No induction agent	3 (3.2)	1 (2.5)	
Other	1 (1.1)	0	
NMBA used			<0.001*
Suxamethonium	67 (70.5)	12 (30.0)	
Rocuronium (1.2 mg/kg IBW)	19 (20.0)	26 (65.0)	
Atracurium	1 (1.1)	1 (2.5)	
Other	6 (6.3)	1 (2.5)	
No NMBA	2 (2.1)	0	
Intubating device			0.159
Videolaryngoscope <sup>†</sup>	66 (69.5)	34 (85.0)	
Macintosh direct laryngoscope	29 (30.5)	6 (15.0)	
Time of intubation			0.002*
After hours	68 (71.6)	17 (42.5)	
Core hours	27 (28.4)	23 (57.5)	

ICU = intensive care unit; IV = intravenous; RSII = rapid-sequence induction and intubation; ESII = elective-sequence induction and intubation; NMBA = neuromuscular blocking agent; IBW = ideal body weight.

\*Significant at  $p < 0.05$ .

<sup>†</sup>Videolaryngoscopes were readily available for 85% and 87% of endotracheal intubations in the public and private healthcare sectors, respectively.

associations between complications encountered during endotracheal extubation and any of the variables measured were found.

## Discussion

Endotracheal intubation and extubation are aerosol-generating procedures that risk HCW exposure to SARS-CoV-2.<sup>[4,5]</sup> Unique airway management guidelines were therefore developed to protect HCWs from SARS-CoV-2 infection while aiming to prevent deterioration of the critically ill COVID-19 patient. This study aimed to investigate the complications encountered, techniques employed and resources utilised when clinicians performed endotracheal intubations and extubations of adult COVID-19 and suspected COVID-19 patients in SA.

Airway management guidelines recommend that the most experienced anaesthetist should intubate COVID-19 patients.<sup>[9,10,12-16]</sup> In our study, anaesthetists performed 87.0% of endotracheal intubations;

however, anaesthetists were probably over-represented in the study population because participants were primarily recruited through SASA. The respondents may therefore have represented a small subset of clinicians with specific performance characteristics that were not representative of all SA HCWs. In comparison, all endotracheal intubations were performed by experienced anaesthesiologists in Wuhan, China.<sup>[11]</sup> Despite the recommendation that the most experienced clinicians should intubate COVID-19 and suspected COVID-19 patients, complication rates were not significantly reduced when experienced clinicians performed endotracheal intubations in our study. This finding is consistent with results of similar studies.<sup>[18]</sup>

First-pass successful endotracheal intubation was achieved in 88.1% of cases in our study ( $n=119$ ). This figure is on par with similar first-pass success rates demonstrated in other studies.<sup>[8,11,19]</sup> As was also demonstrated by Ono *et al.*,<sup>[20]</sup> fewer endotracheal intubation attempts were associated with a lower complication rate in our study.

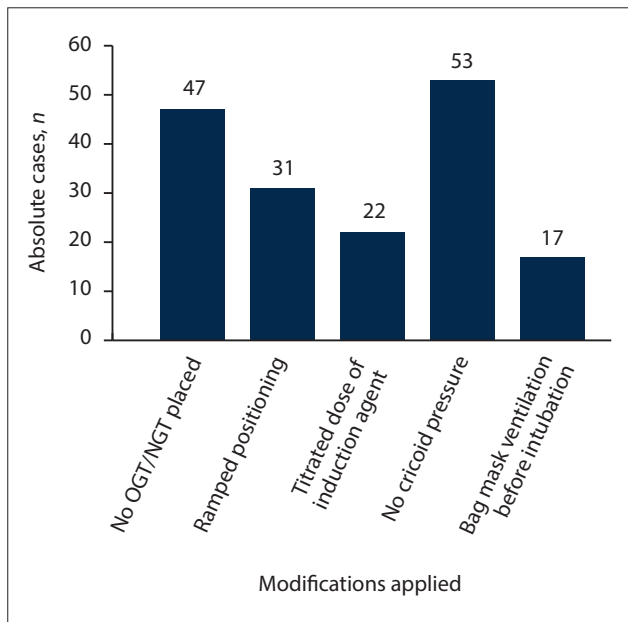


Fig. 3. Frequency of modifications applied to endotracheal intubations performed (N=90 intubations). Note that more than one modification may have been applied during the same endotracheal intubation. (OGT = orogastric tube; NGT = nasogastric tube.)

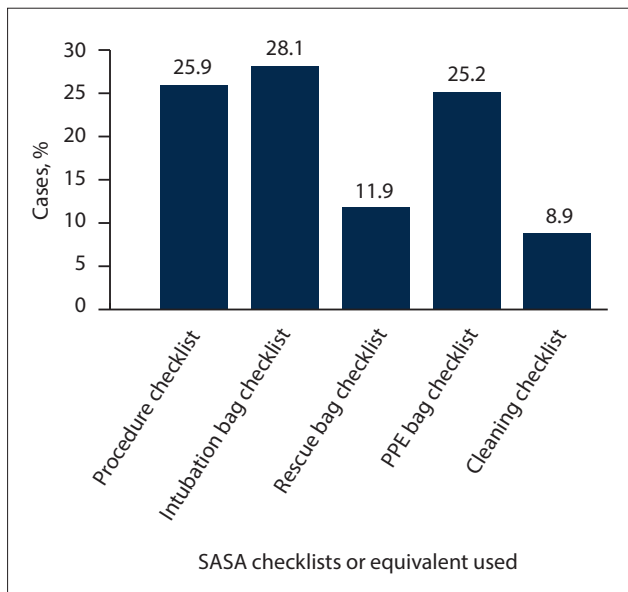


Fig. 4. Checklists used in preparation for endotracheal intubation (N=52 intubations). (PPE = personal protective equipment; SASA = South African Society of Anaesthesiologists.)

Complications during endotracheal intubation occurred in 42.2% of cases in our study. As seen in other studies, the most frequent complication experienced during endotracheal intubation was desaturation >10% from baseline pulse oximetry readings.<sup>[8,11,19]</sup> Significant factors that influenced the overall endotracheal intubation complication rate in our study are summarised in Table 2.

The highest number of endotracheal intubations with complications were performed in COVID-19 wards, while intubations conducted in theatre environments had the lowest complication rate relative to other sites. Theatres are environments that are well suited to manage the critically ill patient, as essential equipment, drugs and

skilled support staff are more readily available than in other settings throughout the hospital. Endotracheal intubations are routinely performed by anaesthesiologists in theatre during their daily practice, lending a sense of familiarity to the task at hand when intubating a COVID-19 patient. Additionally, staff in theatres often work together regularly, allowing for better team dynamics. The resulting familiarity of tasks and cohesiveness between staff members may contribute to better outcomes in the theatre environment compared with other sites of airway management. Sub-analysis of our data indicated that only the site of intubation significantly influenced the complication rate among confirmed COVID-19 patients (Table 3); however, this finding is more likely to reflect the possibility that patients managed in theatre environments were not as critically ill as those requiring endotracheal intubation at other sites, as the primary indication for intubation would be likely not to have been respiratory failure due to COVID-19, but rather a surgical procedure in a COVID-19-positive patient.

One of the strengths of this study was that data were collected from the public and private healthcare sectors. Significantly fewer complications during endotracheal intubation occurred in the private healthcare sector compared with the public healthcare sector. Table 4 summarises the differences in endotracheal intubation performance between the two sectors. The lower complication rate recorded in the private healthcare sector may be due to multiple factors.

Rocuronium was the NMBA of choice in the private healthcare sector. This practice was consistent with recommendations from the initial experiences in China.<sup>[11]</sup> Rocuronium has the advantage of producing neuromuscular blockade and improved intubating conditions rapidly, and for longer than suxamethonium. Additionally, high-dose rocuronium produces a similar first-pass success rate in emergency endotracheal intubations to the conventional use of suxamethonium.<sup>[21]</sup> At the time of writing, no outcome studies have been conducted to determine whether rocuronium is superior to suxamethonium when intubating COVID-19 patients. Many airway management guidelines recommend the use of either NMBA.<sup>[9,22,23]</sup> Sugammadex is not widely available in SA public healthcare facilities, and its availability may also influence the choice of NMBA used during emergency endotracheal intubations.<sup>[24]</sup> In our study, the choice of NMBA used did not significantly affect the overall incidence of endotracheal intubation complications.

Significantly more endotracheal intubations were performed after hours at public healthcare facilities compared with private healthcare facilities. This may be due to multiple factors. Logistical challenges at public healthcare facilities may have delayed critically ill patients' referral to high-dependency units where endotracheal intubations were performed. Furthermore, heavy workloads experienced by theatre staff at public healthcare facilities during core hours may have resulted in more COVID-19 patients receiving surgical procedures after hours. Logistical delays in transporting COVID-19 patients requiring surgery to dedicated COVID-19 theatre facilities may have also contributed to more endotracheal intubations in theatres after hours. Working conditions after hours in the public healthcare system differ significantly from conditions during core hours. Staff members available after core hours are often more junior, with less supervision and support available to them. Timeous access to essential equipment is also compromised, as equipment is often locked away after hours, and the staff on duty may not know where it is. Additionally, staff members working after hours may be working through long clinical shifts and can be hampered by fatigue when they are required to perform critical tasks such as endotracheal intubation.<sup>[25]</sup> These differences in working conditions may contribute to more

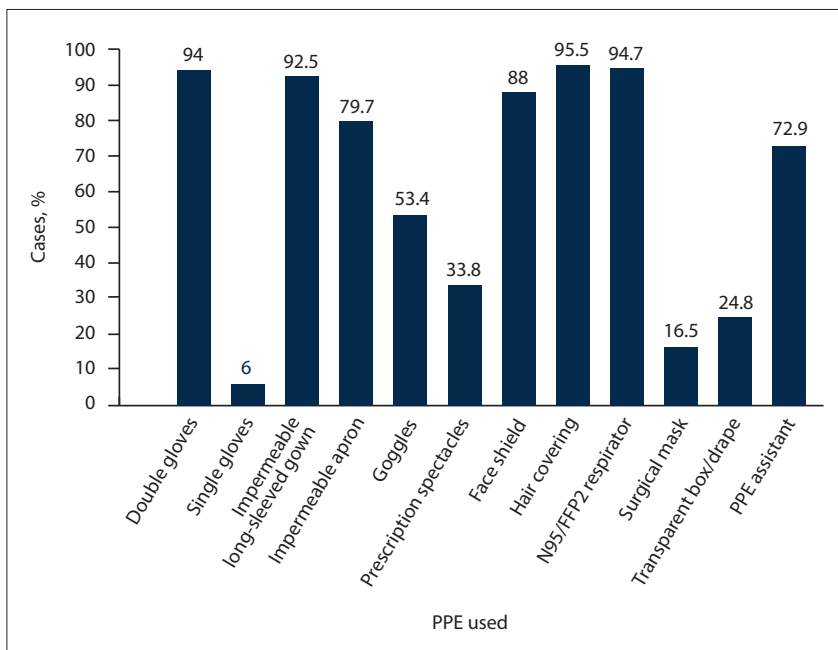


Fig. 5. PPE used by the intubating clinician during endotracheal intubation (N=135 intubations). (PPE = personal protective equipment.)

endotracheal intubation complications occurring after core hours. However, there was no significant association between the overall incidence of complications and the time at which endotracheal intubations were performed in our study.

Specialist doctors performed 95.0% ( $n=38$ ) of endotracheal intubations at private healthcare facilities compared with 44.2% ( $n=42$ ) of those in the public healthcare sector. Although clinician experience and designation did not independently contribute to the overall complication rate in our study, increased supervision of endotracheal intubation by a more experienced or qualified clinician has been shown to decrease complication rates.<sup>[26]</sup> Varying intubation criteria used in the public and private healthcare sectors may have also influenced the baseline characteristics of COVID-19 patients who were intubated.

COVID-19 results in diffuse alveolar destruction, leading to an acute respiratory distress syndrome (ARDS).<sup>[27]</sup> The impact of alveolar destruction on respiratory reserve in COVID-19 is more significant than that seen in other disease processes resulting in ARDS. This finding was illustrated by the significant difference in haemoglobin desaturation during endotracheal intubation of confirmed COVID-19 patients relative to suspected COVID-19 patients in our study. Furthermore, fewer endotracheal intubation complications were encountered in the private healthcare sector, in which most intubations were performed for suspected COVID-19 patients.

The classic rapid-sequence induction and intubation (RSII) technique intends to minimise the risk of aspiration during airway management, but aspiration may still occur when an RSII technique is applied.<sup>[26,28]</sup> Dullemond *et al.*<sup>[19]</sup> reported an aspiration rate of up to 3.1% in their study. In our study, one patient had already aspirated before endotracheal intubation was performed. No other aspirations during endotracheal intubation were recorded. Clinicians performing endotracheal intubations for these patients may have applied modifications to the classic RSII technique to improve their first-pass endotracheal intubation success rate or optimise apnoeic oxygenation time. In our study, haemoglobin desaturation occurred more frequently in cases in which modifications to the classic RSII were applied. The severity of a patient's clinical condition possibly prompted clinicians to use RSII modifications, and haemoglobin desaturation is likely to have resulted from the severity of the underlying pulmonary pathology rather than the modifications used during endotracheal intubation. Meng *et al.*<sup>[23]</sup> noted that some clinicians may criticise the use of RSII in the COVID-19 population, as they may prefer to maximise a patient's oxygen reserve with a slow and controlled induction if there is no immediate aspiration risk. Various techniques such as high-flow nasal oxygen (HFNO), supraglottic jet oxygenation and ventilation and low-flow nasal oxygen (LFNO) have been shown to effectively maximise a patient's apnoeic oxygenation

time during airway management.<sup>[29]</sup> However, concerns regarding the risk of SARS-CoV-2 aerosolisation by these apnoeic oxygenation techniques preclude their routine use in practice. In view of this controversy, Yao *et al.*<sup>[11]</sup> recommended that the use of HFNO or LFNO during airway management should be based on an individual's risk/benefit analysis. In view of the low aspiration rate and the frequency of haemoglobin desaturation during endotracheal intubation in our study, the use of a modified RSII technique was probably justified to optimise a patient's oxygen reserve. Use of a controlled induction technique with/without the application of an apnoeic oxygenation technique could have also been considered on a case-by-case basis.

Propofol use had the lowest incidence of complications relative to other induction agents used. Ketamine and etomidate were recommended alternatives to propofol in haemodynamically unstable patients.<sup>[8,11,19]</sup> Complications encountered when using induction agents other than propofol may have been associated with the severity of the patient's clinical condition rather than the use of a specific induction agent. This was also suggested by our finding that etomidate and ketamine were used more frequently at public healthcare facilities, in which more patients were likely to have required endotracheal intubation because of severe COVID-19, as opposed to the private healthcare sector, in which a greater proportion of patients were probably intubated as part of a general anaesthetic for surgery.

The use of videolaryngoscopes for endotracheal intubation of COVID-19 patients has been widely advocated, as it allows for greater distance between the intubating clinician and the patient. Additionally, videolaryngoscopy facilitates better assistance during intubation, as other team members are also able to visualise the airway.<sup>[11,23]</sup> Videolaryngoscopy was used more frequently in the private healthcare sector, yet was readily available in both healthcare sectors. It is the authors' opinion that practitioners in the private healthcare sector may be more familiar with or better trained in the use of videolaryngoscopy, and may have favoured its use more than their counterparts in the public healthcare sector. The use of videolaryngoscopy in our study was comparable with that in other studies, but was not associated with a lower incidence of complications during endotracheal intubation.<sup>[8,11,19]</sup>

The use of checklists in preparation for endotracheal intubation was associated with fewer complications in our study. While checklist use was recommended in many



guidelines, studies have not demonstrated an improvement in clinical outcomes associated with the use of checklists.<sup>[30,31]</sup>

Our study was unable to demonstrate any significant associations relevant to the practice of tracheal extubation among COVID-19 patients. We believe that this is because of the small number of tracheal extubations sampled in our study. Further studies focusing on this aspect of care are warranted.

PPE was available to and universally used by clinicians performing endotracheal intubation (Fig. 5). This finding was consistent with the findings of the IntubateCOVID trial.<sup>[5]</sup> No relationship between PPE used and performance of endotracheal intubation and extubation was established, although the wide range of PPE used may have hindered the ability to deduct any associations in this regard.

Our study sampled a small subset of endotracheal intubations and extubations performed in SA. Participant recruitment was limited by the distribution and voluntary nature of the study. Although the majority of our participants were anaesthetists, COVID-19 intubations in SA are performed regularly by clinicians in other fields, and the principles and practices employed to safely manage a COVID-19 patient's airway remain the same. Furthermore, survey request fatigue posed a significant challenge to the study. As a result, data collection was terminated before the onset of the second wave of COVID-19 cases in SA to limit over-surveying of the participants. Our study did not evaluate the indications for intubation, baseline characteristics of patients, clinical parameters, or the use of apnoeic oxygenation techniques during endotracheal intubations and extubations. Further studies are warranted, as these factors are likely to influence the complication rates encountered during endotracheal intubation and extubation of COVID-19 patients.

## Conclusions and recommendations

Despite its limitations, our study provided valuable insights into COVID-19 airway management practices in SA and may guide future research. The study showed that the intravenous induction technique, intubating device and NMBA used did not influence the complications encountered during endotracheal intubation of confirmed and suspected COVID-19 patients. Based on our findings, we recommend that clinicians aim to minimise the number of endotracheal intubation attempts, use checklists to prepare for confirmed and suspected COVID-19 intubations, and perform endotracheal intubations in an environment that is well equipped to manage difficult airways, such as theatre, to prevent complications. Endotracheal intubations of confirmed and suspected COVID-19 patients should be supervised by specialist clinicians to further reduce complication rates. Larger studies are needed to confirm the results of this study and evaluate the associations between specific variables and the complication rates described.

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