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Effect of intravenous and intra-cuff magnesium sulphate on post-extubation tracheal morbidity: a randomised single-blind study

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Abstract

Background Post-extubation sore throat (PEST), cough, and hoarseness are common complications of tracheal intubation. Several agents and techniques have been postulated to reduce their occurrence.

Aim This study sought to compare the effects of intravenous and intra-cuff magnesium sulphate on the incidence and severity of PEST, cough and hoarseness of voice.

Materials and methods This was a randomised single-blind study involving 90 surgical patients requiring endotracheal intubation. Patients were randomised into 3 groups: A (control), B (intra-cuff magnesium sulphate) and C (intravenous magnesium sulphate). Participants in Group A had the endotracheal tube cuff (ETTc) inflated with air to a pressure of 25 cmH_2O whilst those in Group B had the ETTc inflated with 2 g of magnesium sulphate solution and the pressure adjusted to 25 cmH_2O with top-ups of 0.9% normal saline. Participants in Group C had the ETTc filled with air to a pressure of 25 cmH_2O and received 2 g of intravenous magnesium sulphate in 20 ml of 0.9% normal saline perfused over 10 min immediately prior to the induction of general anaesthesia. The occurrence of PEST, cough and hoarseness of voice were recorded at 0, 4, 8, 12 and 24 h after surgery.

Results The incidence of PEST on swallowing in the intra-cuff magnesium sulphate group compared to the intravenous magnesium sulphate group at 4, 8, and 12 h post-operatively were 51.7% vs 12.5%, 51.7% vs 18.8% and 51.7% vs 21.9% respectively. Compared to intra-cuff magnesium sulphate, intravenous magnesium sulphate significantly reduced the incidence and severity of PEST during swallowing at 4, 8, and 12 h. The incidence of PEST at rest in the intra-cuff magnesium sulphate group compared to the intravenous magnesium sulphate group at 0, 4, 8, 12 and 24 h post-operatively were 13.8% vs 9.4%, 20.7% vs 6.3%, 17.2% vs 6.3%, 13.8% vs 3.1% and 13.8% vs 3.1% respectively. Compared to intra-cuff magnesium sulphate, intravenous magnesium sulphate reduced the incidence of PEST at rest, though this was not statistically significant over first 24 h postoperative period. Intravenous magnesium sulphate had significantly lower PEST severity scores at rest at 12 h only compared to intra-cuff magnesium sulphate. There was no statistically significant difference in the incidence and severity of cough and hoarseness between the study groups.

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Conclusion Intravenous magnesium sulphate given at induction was found to be better compared to intra-cuff magnesium sulphate in lowering the incidence and severity of post-extubation sore throat on swallowing but not at rest. However, it does not significantly reduce the incidence or severity of post-extubation cough or hoarseness.

Trial registration PACTR202211634990263.

Keywords Magnesium sulphate, Intravenous, Extubation, Tracheal, Postoperative, Morbidity

Introduction

Post-extubation laryngotracheal morbidities (sore throat, cough and hoarseness) are common complications that are often overlooked clinically [1, 2]. The incidence of these morbidities following endotracheal intubation is reported to be between 14 and 90% [3, 4]. Endotracheal tube size, trauma during laryngoscopy and insertion of endotracheal tubes (ETTs), difficult intubations, high endotracheal tube cuff (ETTc) pressures and prolonged intubation, among other factors, have been identified as causes of post-extubation laryngotracheal morbidity [5–9].

Laryngotracheal morbidities have been associated with patient dissatisfaction with their anaesthetic experience, increased duration of hospital stay, especially for day surgery, reduced bed turnover and increased hospital cost. This makes it imperative to identify avenues for reducing the incidence of these morbidities.

Various strategies for reducing the occurrence of laryngotracheal morbidities have been identified [10, 11]. These include improvements in the technique of laryngoscopy and endotracheal tube properties [12]. Other pharmacological strategies employed involve the administration of intra-cuff and intravenous lidocaine, topical airway and intravenous steroids, gargled NSAID, nebulised and intravenous ketamine [13–16].

Recent modalities targeted at mitigating the occurrence of post-extubation laryngotracheal morbidities have focused on the role of magnesium sulphate, particularly when used as a lubricant or agent for inflating the endotracheal tube cuff. Magnesium, an N-methyl-D-aspartate (NMDA) receptor antagonist, has antinociceptive and anti-inflammatory properties [17, 18] and thus has the potential to reduce post-extubation laryngotracheal morbidities. It is therefore not surprising to see the use of magnesium sulphate in preventing post-extubation laryngotracheal morbidities in literature [16, 18–24]. The application of magnesium sulphate to the endotracheal tube cuff either by lubricating the external surface or inflating the cuff with magnesium sulphate instead of air or saline, has been shown to reduce the incidence and severity of post-extubation laryngotracheal morbidity through its local anti-inflammatory action and possible peripheral nerve blocking effect at the mucosal level [25]. Additionally, magnesium osmotic properties may aid in reducing local tracheal mucosa oedema, further minimizing discomfort with an added advantage of longer duration and minimal systemic absorption when used topically [26]. Few studies have supported the effectiveness of intra-cuff magnesium sulphate in reducing the incidence and severity of post-extubation laryngotracheal morbidity [27, 28]. These findings underscore the potential of endotracheal tube cuff magnesium sulphate as a simple, safe and cost-effective strategy to enhance postoperative comfort.

We hypothesised that magnesium sulphate administered intra-cuff will diffuse across the cuff membrane into the tracheal mucosa where its anti-inflammatory action will attenuate the incidence and severity of post-extubation laryngotracheal morbidity. This study therefore sought to determine the effect of intravenous and intra-cuff magnesium sulphate on the incidence and severity of PEST, cough and hoarseness of voice compared to control.

Materials and methods

Study design and site

This was a prospective, randomised, single-blind study (trial registration number: PACTR202211634990263) conducted among 90 patients who underwent general anaesthesia with endotracheal intubation at the Korle-Bu Teaching Hospital (KBTH). KBTH is a tertiary health facility and the largest teaching hospital in Ghana, with over 2000 bed capacity and 23 theatres.

The study involved ASA I and II elective general surgical patients aged 18 years and above who required general anaesthesia with endotracheal intubation. Patients with a history of asthma, active upper respiratory tract infection, known anatomical laryngotracheal abnormalities, abnormal serum magnesium levels, history of difficult intubations, anticipated difficult intubations, multiple attempts at intubation, a BMI > 35 kg/m^2, scheduled for head and neck surgeries or surgeries in the prone position were excluded from the study.

Sample size

Sheikh et al. [19] reported the incidence of sore throat 24 h post-extubation in patients receiving intravenous magnesium sulphate compared to placebo as 12% and 46%, respectively. At a power of 80% and 95% confidence level,

the minimum sample size of 28 in each group was found to be adequate using the formula by Hajian-Tilaki [29].

Procedure

Ethical clearance for the study was obtained from the KBTH Institutional Review Board (KBTH-IRB/000116/2021), and the study was registered with the Pan African Clinical Trials Registry (PACTR202211634990263). All patients presenting for elective surgeries undergo a preoperative anaesthesia assessment at the Anaesthesia Clinic of KBTH about a week prior to surgery. Patients for the study were recruited, and informed consent was obtained at the Anaesthesia Clinic. Preoperative anaesthesia assessment included a detailed history and clinical examination with the request of relevant investigations. Recruited patients were randomised into 3 groups by balloting without replacement by the principal investigator (anaesthesia provider) on admission to the surgical ward, a day prior to surgery. Ninety-six ballots consisting of 32 ballots each of A, B and C were placed in an envelope. An eligible patient who consented to the study was made to pick a ballot without replacement. The ballot thus picked was the group to which the patient was assigned. This process was replicated until all the ballots were exhausted. The anaesthesia provider was not blinded but the patients were blinded to the study treatment. Patients in Group A (control) had their ETTc inflated with air to a pressure of 25 cmH_2O after intubation. Patients in Group B (intra cuff magnesium sulphate) had their ETTc inflated with 2 g of magnesium sulphate solution (4 mls of 50% magnesium sulphate solution). The ETTc pressure was then adjusted to 25 cmH_2O using 0.9% normal saline top-ups. Patients in Group C (intravenous magnesium sulphate) had their ETTc inflated with air to a pressure of 25 cmH_2O and received 2 g of intravenous magnesium sulphate in 20 ml of 0.9% normal saline perfused over 10 min immediately prior to induction of general anaesthesia.

After preoxygenation for 5 min, patients were induced with midazolam (0.03 mg/kg), fentanyl (1 µg/kg) and propofol (2 mg/kg) and intubated using vecuronium (0.1 mg/kg). Direct laryngoscopy was performed and all patients were intubated with a Blue Arrow® endotracheal tube (Dasn Medical International Limited, China). Males were intubated with an 8.0 mm while female patients were intubated with a 7.0mm internal diameter endotracheal tube. Anaesthesia was maintained with isoflurane in an oxygen/air mixture without the use of nitrous oxide.

Electrocardiography (ECG), non-invasive blood pressure, pulse oximetry, continuous wave capnography and temperature were used for intraoperative monitoring.

Immediately after intubation and inflation of the ETTc, the ETTc pressures of all patients were measured and optimised to 25 cmH_2O. The ETTc pressures were measured at the end of expiration after ensuring patients were adequately paralysed. The ETTc of patients in groups A and C were inflated with air and an aneroid manometer (Rusch Endotest Cuff Pressure Manometer) was used to measure and optimise the ETTc pressures. The ETTc of patients in group B were inflated with 2 g of magnesium sulphate and the pressure optimised to 25 cmH_2O using normal saline. The pressure transducer of a Drager® Vista 120 patient monitor (Drager, Germany, 2015) connected through a three-way tap system was used to measure and optimise the ETTc pressure of patients in group B.

All patients received intravenous paracetamol 1 g, morphine 0.1 mg/kg and granisetron 1 mg intraoperatively.

At the end of the surgical procedure, neuromuscular blockade was reversed with a combination of intravenous atropine 0.02 mg/kg and neostigmine 0.05 mg/kg. Patients were extubated awake and transferred to the recovery ward. On arrival at the recovery ward, patients receive 6 L/min of oxygen via a simple face mask, standard postoperative monitoring and later discharged per the hospital's protocol.

The age, weight, height, body mass index (BMI) of patients and duration of anaesthesia were recorded.

Assessment of sore throat, cough and hoarseness was done by a different anaesthesia provider who was blinded to the groups patients were assigned using a modification of the scoring system utilised by Bagchi et al. [30] (Table 1).

Incidence and severity of PEST, cough and hoarseness were assessed immediately prior to discharge from the recovery ward (time zero) and at 4, 8, 12 and 24

Table 1 Scoring assessment of sore throat, cough, and hoarseness

Sore throat
0—No sore throat anytime since the operation
1—Minimal sore throat (a complaint of sore throat on request)
2—Moderate sore throat (complain of sore throat on his/her own)
3—Severe sore throat (change in voice associated with throat pain)
Hoarseness
0—No complaint of hoarseness
1—Minimal change
2—Moderate change (noticed by patient)
3—Severe change (easily recognised by others)
Cough
0—No cough at any time since the operation
1—Light or single episode of cough
2—More than one episode of non-sustained cough
3—Sustained and repetitive cough

postoperative hours. The incidence and severity of PEST were assessed both at rest and on swallowing.

The primary outcome measure of the study was the incidence of PEST during the first 24 postoperative hours. The secondary outcome measures were the severity of PEST, and incidence and severity of cough and hoarseness during the first 24 postoperative hours.

Statistical analysis

Data was analysed using International Business Machines Corporation (IBM)® Statistical Product and Service Solution (SPSS)® version 25. Age, weight, height, BMI, duration of anaesthesia and surgery were compared between the groups using a one-way analysis of variance (ANOVA). Gender was summarised as frequency (percentage). Chi-squared test and Fisher's exact test were used to compare the incidence and severity of PEST, cough and hoarseness between the groups. Where there was any overall statistical significance in the incidence and severity between the groups, an adjusted *Z*-score was used to determine which group was significant in comparison to other groups. The adjusted *Z*-score within each cell was deemed significant if it exceeded the critical Z-score value of 1.96 at 95% confidence level. A p-value < 0.05 was considered statistically significant.

Results

A total of 96 patients were enrolled in the study. Six patients did not complete the study. Twenty-nine patients in Group A, 29 in Group B and 32 in Group C completed the study and their data was included in the analysis as shown in the consort diagram (Fig. 1).

There was no statistically significant difference in the sex, age, BMI, mean duration of anaesthesia and surgery of patients between the groups (Table 2).

The incidence of PEST at rest, cough and hoarseness were comparable among patients in the three study groups during the first 24 postoperative hours. Compared to control and intra-cuff magnesium sulphate, patients who received intravenous magnesium sulphate recorded significantly lower incidence of sore throat on swallowing at 4, 8 and 12 h post-extubation (Table 3).

Patients in the intravenous magnesium sulphate group generally recorded the lowest sore throat severity scores at rest compared to the intra-cuff magnesium group. The differences in the sore throat severity scores at rest were, however, only statistically significant at 12 h post-operative period. A follow-up test revealed the intra-cuff magnesium sulphate group had significantly higher severity score compared to the intravenous magnesium group and the control group (Table 4).

The sore throat severity score on swallowing was highest among patients in the intra-cuff magnesium sulphate group and generally lower among patients in the intravenous magnesium sulphate group. The observed differences in the severity of sore throat on swallowing among the study groups was found to be statistically significant at 4-, 12- and 24-h postoperative period. A follow-up analysis revealed the intra-cuff magnesium sulphate group had a significantly higher severity score compared to the intravenous magnesium group and the control group at 4-, 12- and 24-h postoperative period (Table 4).

Discussion

Compared with intra-cuff magnesium sulphate, intravenous magnesium sulphate significantly reduced the incidence and severity of PEST during swallowing at 4, 8 and 12 h post-operatively. Compared with intra-cuff magnesium sulphate, intravenous magnesium sulphate reduced the incidence of PEST at rest, although not statistically significant over the first 24 h postoperative period. Intravenous magnesium sulphate had significantly lower PEST severity scores at rest only at the 12 post-operative hour compared to intra-cuff magnesium sulphate. Intravenous magnesium sulphate and intra-cuff magnesium sulphate did not influence the incidence and severity of cough and hoarseness.

Patients in the three study groups had similar sociodemographic and health characteristics (Table 2); therefore, differences in observed outcomes can be attributed to the different interventions applied.

Postoperative sore throat, cough and hoarseness are common distressing sequelae after intubation, especially in the presence of poorly managed surgical site pain. Postoperative sore throat starts within the first 24 h after extubation [10] and is known to take up to 2 days to resolve [31, 32].

There was no statistically significant difference in the incidence of sore throat at rest among the three study groups at any of the measured time points. However, intravenous magnesium sulphate significantly reduced the incidence of sore throat during swallowing at 4, 12 and 24 h post-extubation. This finding is similar to that of Sheikh et al. [19] and Park et al. [16], who reported that intravenous magnesium sulphate, with its anti-inflammatory [33] and antinociceptive properties [34], was able to significantly reduce sore throat during the 24-h post-extubation period. Sheikh et al.[19] and Park et al. [16], however, reported a reduction in the incidence and severity of sore throat at rest in contrast to the findings of this study. This might be because Park et al. and Sheikh et al. used higher doses of magnesium than that used in this study. Also, Park et al. [16] after the initial intravenous bolus, administered continuous intravenous

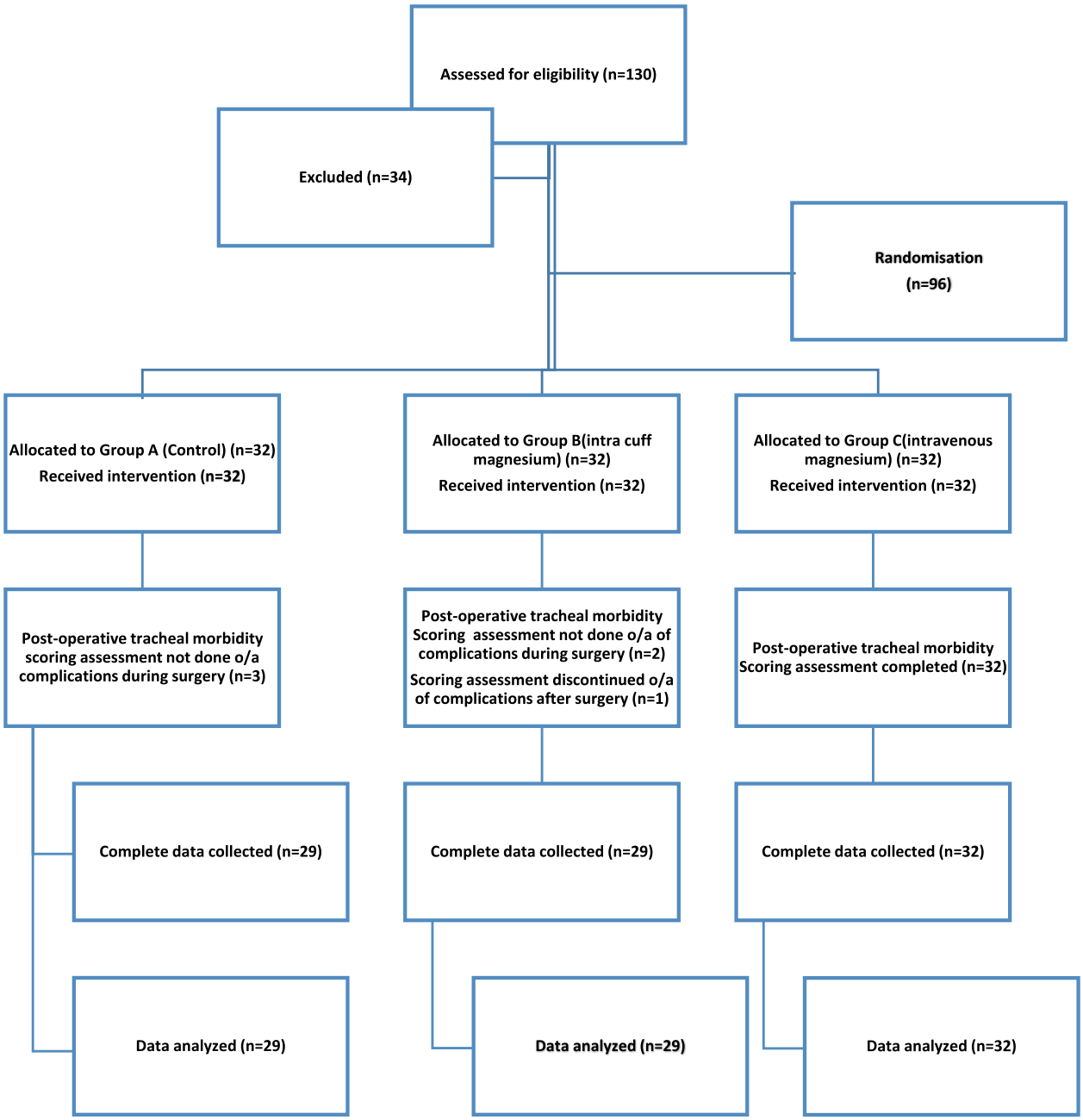

Fig. 1 Consort diagram

infusion of magnesium sulphate until the end of surgery which may have resulted in higher immediate postoperative serum magnesium concentrations accounting for the longer period of reduction in the severity of PEST they observed.

Several studies have reported that magnesium sulphate works topically to reduce the incidence of PEST [17, 18, 21, 23, 34, 35]. Ansari et al. [24], who used 50 mg/kg magnesium sulphate to inflate the endotracheal tube cuff, however, reported no significant reduction in the incidence or severity of 24-h postoperative sore throat. In this study, intra-cuff magnesium sulphate significantly increased the incidence and severity of post-extubation sore throat on swallowing at all measured time points compared to the control and intravenous magnesium sulphate (Tables 3 and 4). Magnesium is most pharmacologically active in its ionised form [18]. Our findings might be due to the fact that there was inadequate diffusion

Table 2 Demographic characteristics and durations of anaesthesia and surgery between groups

Variable	Study groups			*p*-value
	Group A (*n* = 29)	Group B (*n* = 29)	Group C (*n* = 32)	
Gender				0.264
Male[a]	4(13.8)	6(20.7)	2(6.2)	
Female[a]	25(86.2)	23(79.3)	30 (93.8)	
Age (years)[b]	43.8 (11.3)	44.2(11.8)	45.8(9.3)	0.760
Weight (kg)[b]	69.3(12.7)	74.3(15.9)	73.9(11.6)	0.282
Height (m)[b]	1.61(0.08)	1.63(0.07)	1.62(0.05)	0.537
BMI (kg/m^2)[b]	26.8 (4.4)	28.1(5.6)	28.3(4.5)	0.439
Duration of anaesthesia[b]	2.7 (0.9)	2.6(0.7)	2.9(1.1)	0.239
Duration of surgery(h)[b]	2.0(0.9)	2.0(0.9)	2.3(1.1)	0.393

Group A control, *Group B* intra-cuff magnesium sulphate, *Group C* intravenous magnesium sulphate

[a] *n* (%)

[b] Mean(SD)

Table 3 Incidence of PEST, cough and hoarseness between groups

Variable		Group; *n* (%)			*p*-value
	Time	Group A	Group B	Group C	
Sore throat at rest	0 h	0 (0.0)	4 (13.8)	3(9.4)	0.149
	4 h	6(20.7)	6(20.7)	2(6.3)	0.172
	8 h	6(20.7)	5(17.2)	2(6.3)	0.218
	12 h	5(17.2)	4(13.8)	1(3.1)	0.145
	24 h	1(3.4)	4(13.8)	1(3.1)	0.309
Sore throat on swallowing	0 h	0(0.0)	7(24.1)	4(12.5)	0.013*
	4 h	7(24.1)	15(51.7)	4(12.5)	0.003*
	8 h	9(31.0)	15(51.7)	6(18.8)	0.023*
	12 h	9(31.0)	15(51.7)	7(21.9)	0.045*
	24 h	5(17.2)	12(41.4)	6(18.8)	0.059
Cough	0 h	1(3.4)	1(3.4)	2(6.3)	1.000
	4 h	2(6.9)	3(10.3)	0(0.0)	0.189
	8 h	4(13.8)	3(10.3)	0(0.0)	0.087
	12 h	6(20.7)	2(6.9)	1(3.1)	0.096
	24 h	4(13.8)	1(3.4)	2(6.3)	0.389
Hoarseness	0 h	9(31.0))	7(24.1)	8(25.0)	0.873
	4 h	12(41.4)	17(58.6)	10(31.3)	0.098
	8 h	13(44.8)	17(58.6)	10(31.3)	0.099
	12 h	12(14.4)	11(37.9)	8(25.0)	0.361
	24 h	8(27.6)	11(37.9)	6(18.8)	0.244

* *p*-value < 0.05 (statistically significant), *Group A* control, *Group B* intra-cuff magnesium sulphate, *Group C* intravenous magnesium sulphate

of the ionised magnesium across the membrane of the endotracheal tube cuff to reach the laryngeal mucosa and exert its effect. When intra-cuff lidocaine was studied, it was found that alkalised lidocaine was more effective at reducing the incidence of PEST than lidocaine alone [36–38]. Perhaps an additive may also have been needed to enhance the effectiveness of intra-cuff magnesium sulphate.

Studies that have reported topical magnesium to be effective against PEST have used lower doses of magnesium compared to that used in our study [17, 18, 21, 23, 34, 35]. Magnesium sulphate at high concentrations (> 20%) is known to cause irritation upon intravenous injection [39]. Less than 6 mls of normal saline was required to optimise the cuff pressures in the intra-cuff magnesium sulphate group. The concentration of magnesium sulphate in the cuffs were thus greater than 20%. It is thus also possible that there was diffusion of significant amounts of magnesium across the endotracheal tube cuff that might have caused irritation of the tracheal mucosa. This may account for the higher incidence and severity of PEST experienced by patients in the intra-cuff magnesium sulphate group.

Among the three groups, the control group had a significantly lower incidence of sore throat during swallowing in the immediate postoperative period (0 h). The maintenance of ideal cuff pressure may have contributed to the reduction in the incidence of immediate post-extubation sore throat, as evident in other studies [40]. Hence, in the absence of pharmacological agents, optimising the endotracheal tube cuff pressure within the ideal range may offer some benefit in reducing postoperative sore throat in the immediate postoperative period.

Studies have shown that the incidence and severity of post-extubation cough are mainly reduced by optimising endotracheal tube cuff pressures rather than by the use of topical magnesium, either gargle or nebulised [23, 40, 41]. The ETTc pressures were optimised in all patients and it is thus not surprising that there was no significant difference in the incidence of post-extubation cough among the study groups.

In the current study, compared to the control, administration of intravenous magnesium sulphate resulted in a non-significant reduction in the incidence of post-extubation cough. Similarly, intravenous magnesium sulphate resulted in a non-significant reduction in the incidence of hoarseness within the first 24 h post-extubation, compared with intra-cuff magnesium sulphate and the control. These findings are similar to those reported by Sheik et al. [19], Raghavendra et al. [36] and Park et al. [16].

Limitations

Though endotracheal tube cuff pressures were optimised at induction, continuous cuff pressure monitoring was not done. Therefore, changes in cuff pressures after induction of anaesthesia could have influenced the

Table 4 Severity of PEST, cough and hoarseness between groups

Time (h)	Variable		Group A	Group B	Group C	*p*-value
Sore throat at rest			***n* (%)**	***n* (%)**	***n* (%)**	
0	No		29(100)	25(86.2)	29(90.6)	0.259
	Minimal		0(0.0)	3(10.3)	3(9.4)	
	Moderate		0(0.0)	1(3.4)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
4	No		23(79.3)	23(79.3)	30(93.8)	0.438
	Minimal		4(13.8)	4(13.8)	2(6.2)	
	Moderate		2(6.9)	2(6.9)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
8	No		23(79.3)	24(82.8)	30(93.8)	0.480
	Minimal		4(13.8)	3(10.3)	2(6.2)	
	Moderate		2(6.9)	2(6.9)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
12	No		24(82.8)	25(86.2)	31(96.9)	0.020*
		Adjusted *Z*-score	− 1.3	− 0.6	1.8	
	Minimal		5(17.2)	1(3.4)	1(3.1)	
		Adjusted *Z*-score	2.3**	− 1.1	− 1.2	
	Moderate		0(0.0)	3(10.3)	0(0.0)	
		Adjusted *Z*-score	− 1.2	2.6**	− 1.3	
	Severe		0(0.0)	0(0.0)	0(0.0)	
24	No		28(96.6)	25(86.2)	31(96.9)	0.162
	Minimal		1(3.4)	1(3.4)	1(3.1)	
	Moderate		0(0.0)	3(10.3)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
Sore throat on swallowing						
0	No		29(100)	22(75.9)	28(87.5)	0.068
	Minimal		0(0.0)	6(20.7)	4(12.5)	
	Moderate		0(0.0)	1(3.4)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
4	No		22(75.9)	14(48.3)	28(87.5)	0.011*
		Adjusted *Z*-score	0.7	− 3.3	2.5	
	Minimal		5(17.2)	10(34.5)	4(12.5)	
		Adjusted *Z*-score	− 0.6	2.1**	− 1.5	
	Moderate		2(6.9)	5(17.2)	0(0.0)	
		Adjusted *Z*-score	− 0.2	2.3**	− 2.0	
	Severe		0(0.0)	0(0.0)	0(0.0)	
8	No		20(69.0)	14(48.3)	26(81.2)	0.057
	Minimal		6(20.7)	11(37.9)	6(18.8)	
	Moderate		3(10.3)	4(13.8)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
12	No		20(69.0)	14(48.3)	3(78.1)	0.047*
		Adjusted *Z*-score	0.5	− 2.4**	1.9	
	Minimal		9(31.0)	11(37.9)	6(18.8)	
		Adjusted *Z*-score	0.3	1.3	− 1.6	
	Moderate		0(0.0)	4(13.8)	1(3.1)	
		Adjusted *Z*-score	− 1.6	2.4**	− 0.7	
	Severe		0(0.0)	0(0.0)	0(0.0)	

Table 4 (continued)

Time (h)	Variable		Group A	Group B	Group C	*p*-value
Sore throat at rest			***n* (%)**	***n* (%)**	***n* (%)**	
24	No		24(82.8)	17(58.6)	26(81.2)	0.007*
		Adjusted *Z*-score	1.2	− 2.4**	1.1	
	Minimal		5(17.2)	6(20.7)	6(18.8)	
		Adjusted *Z*-score	− 0.3	0.3	0.0	
	Moderate		0(0.0)	6(20.7)	0(0.0)	
		Adjusted *Z*-score	− 1.7	4.7**	− 1.9	
	Severe		0(0.0)	0(0.0)	0(0.0)	
Cough						
0	No		28(96.6)	28(96.6)	30(93.8)	0.826
	Minimal		1(3.4)	1(3.4)	2(6.2)	
	Moderate		0(0.0)	0(0.0)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
4	No		27(93.1)	26(89.7)	32(100)	0.197
	Minimal		2(6.9)	3(10.3)	0(0.0)	
	Moderate		0(0.0)	0(0.0)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
8	No		25(86.2)	26(89.7)	32(100)	0.109
	Minimal		4(13.8)	3(10.3)	0(0.0)	
	Moderate		0(0.0)	0(0.0)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
12	No		23(79.3)	27(93.1)	31(96.9)	0.059
	Minimal		6(20.7)	2(6.9)	1(3.1)	
	Moderate		0(0.0)	0(0.0)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
24	No		25(86.2)	28(96.6)	30(93.8)	0.504
	Minimal		3(10.3)	1(3.4)	2(6.2)	
	Moderate		1(3.4)	0(0.0)	0(0.0)	
	Severe		0(0.0)	0(0.0)	0(0.0)	
Hoarseness						
0	No		20(69.0)	22(75.9)	24(75.0)	0.782
	Minimal		6(20.7)	5(17.2)	6(18.8)	
	Moderate		3(10.3)	2(6.9)	1(3.1)	
	Severe		0(0.0)	0(0.0)	1(3.1)	
4	No		17(58.6)	12(41.4)	22(68.8)	0.148
	Minimal		7(24.1)	12(41.4)	7(21.9)	
	Moderate		3(10.3)	5(17.2)	3(9.4)	
	Severe		2(6.9)	0(0.0)	0(0.0)	
8	No		16(55.2)	12(41.4)	22(68.8)	0.310
	Minimal		9(31.0)	12(41.4)	8(25.0)	
	Moderate		3(10.3)	5(17.2)	2(6.2)	
	Severe		1(3.4)	0(0.0)	0(0.0)	
12	No		17(58.6)	18(62.1)	24(75.0)	0.679
	Minimal		9(31.0)	9(31.0)	6(18.8)	
	Moderate		2(6.9)	2(6.9)	2(6.2)	
	Severe		1(3.4)	0(0.0)	0(0.0)	

Table 4 (continued)

Time (h)	Variable	Group A	Group B	Group C	*p*-value
Sore throat at rest		***n*** **(%)**	***n*** **(%)**	***n*** **(%)**	
24	No	21(72.4)	18(62.1)	26(81.2)	0.209
	Minimal	4(13.8)	10(34.5)	4(12.5)	
	Moderate	3(10.3)	1(3.4)	2(6.2)	
	Severe	1(3.4)	0(0.0)	0(0.0)	

* $p < 0.05$ (statistically significant)

** Adjusted *Z*-score > 1.96 (statistically significant) for follow-up analysis

results of the study. The volume of the saline injected with magnesium sulphate into the ETT cuff to optimise the cuff pressure to 25 cmH_2O varied among patients. This could have greatly altered the concentration of intra-cuff magnesium sulphate and thus its effects on post-extubation tracheal morbidity. Due to paucity of literature on the use of intra-cuff magnesium sulphate in preventing post-extubation laryngotracheal morbidity, the incidence of sore throat following the use of intravenous magnesium sulphate in prevention of post-extubation laryngotracheal morbidity was used in calculating the sample size for the study. Though intravenous magnesium was an intervention in this study, immediate postoperative serum levels of magnesium was not determined. The study was a single centre trial, used a relatively small sample size and this might affect the external validity of our results.

Conclusion

Intravenous magnesium sulphate given immediately prior to induction is found better compared to intra-cuff magnesium sulphate but not the control group in lowering the incidence and severity of post-extubation sore throat on swallowing but not at rest. However, it does not significantly reduce the incidence or severity of post-extubation cough or hoarseness.

Supplementary Information

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Supplementary Material 1.

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Authors' contribution
EOD, NMV and RD developed the concept and writing of the manuscript. RE and GA analysed the data. BA and LBA contributed to the writing and review of different sections of the manuscript. Prior to submission, all the authors were involved in the review of the final manuscript. EOD and RD contributed equally to the writing of the manuscript.

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Data availability
The datasets used and analysed in this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and ethics committee approval. Ethics approval was obtained from the Institutional Review Board of the Korle-Bu Teaching Hospital (KBTH-IRB/000116/2021). This trial was registered with the Pan African Clinical Trial Registry (trial registration number: PACTR202211634990263, on 18 th November 2022).
The study was thoroughly explained to all eligible participants in the language they understood via the study participant information leaflet. Written consent was obtained by signing or thumb-printing the consent form. Patients were informed of the voluntary nature of their participation in the study and their rights to withdraw from the study at any point, should they wish to do so without it affecting their subsequent management.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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