



Comparison of intubating conditions during rapid sequence induction between rocuronium with magnesium sulphate pretreatment and succinylcholine in patients undergoing elective surgery under general anaesthesia - prospective randomized study

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ABSTRACT

INTRODUCTION: Rapid sequence induction is a conventional method used for airway management during anesthesia. Succinylcholine is considered standard neuromuscular blocking agent in rapid sequence induction but avoid the side effects of succinylcholine, rocuronium used as an alternative. Magnesium given as pretreatment before standard dose of rocuronium shortens the duration of onset of action of rocuronium and improve the intubating conditions. Aim of the study was to compare intubating conditions during rapid sequence induction between rocuronium with magnesium sulphate pretreatment, and succinylcholine in patients undergoing elective surgery under general anaesthesia.

MATERIALS AND METHODS: In this Prospective comparative study, 150 patients were divided into 2 groups of 75 each. Group 1 patients were pretreated with magnesium sulphate 50 mg/kg in 100 ml 0.9% normal saline before induction and administration of rocuronium 0.6 mg/kg for intubation. Group 2 patients were given 100ml 0.9% normal saline before induction and succinylcholine 1.5 mg/kg was given for intubation. Intubating conditions were graded as excellent (score 8-9), good (score 6-7), fair (3-5), poor (0-2) according to Cooper's criteria.

RESULTS: In 74 patients in each group, jaw relaxation was easy and in 1 patient in each group, it was fair ($p=1$). Vocal cords were found to be abducted in 70 patients (93.3%) in group 1 and 74 patients (98.7%) in group 2. Vocal cords were moving in 5 patients (6.6%) and 1 patient (1.3%) in group 1 and 2 respectively ($p=0.209$). There was no response to intubation in 67 patients (89.3%) and 73 patients (97.3%) in group 1 and 2 respectively. 8 patients (10.6%) in group 1 and 2 patients (2.7%) in group 2 had slight diaphragmatic movement. ($p=0.097$). 71 patients (94.6%) in group 1 and 74 patients (98.7%) in group 2 had excellent intubating conditions. 4 patients in group 1 and 1 patient in group 2 had good intubating conditions. Intubating conditions were comparable between both the groups ($p=0.366$).

CONCLUSIONS: The study concluded that magnesium pretreatment before 0.6 mg/kg rocuronium provides clinically acceptable intubating conditions similar to succinylcholine making it suitable for rapid sequence induction with mild adverse effects which resolve spontaneously without any treatment.

KEY WORDS: Magnesium sulphate, rocuronium, succinylcholine, intubation, rapid sequence induction.

INTRODUCTION

Rapid sequence induction (RSI) is a standard technique for airway management under anaesthesia. During rapid sequence induction technique, the trachea is intubated within one minute after a predetermined dose of hypnotic agent and muscle relaxant is administered. Characteristics of neuromuscular blockade needed for rapid sequence induction are immediate onset of action, short duration of effect and excellent intubating conditions. In the event of a "*Cannot Intubate Cannot Ventilate*" situation, for rapid returning of spontaneous breathing, these characteristics are essential for rapid endotracheal intubation without bag-mask ventilation. Unfavourable intubating conditions include inability to visualize the vocal cord and patient reaction like coughing and diaphragmatic contractions. Therefore, it requires the use of rapid onset neuromuscular blockers to avoid complications like hypoxic damage and risk of pulmonary aspiration due to delay in tracheal intubation [1,2].

Earlier, succinylcholine was considered the gold standard neuromuscular blocking agent in rapid sequence induction and intubation by providing intense and short latency muscle relaxation. After administration, it becomes effective within 60 seconds and duration of action is 3 to 10 minutes until neuromuscular function recovers to normal within 15 minutes [3,4]. But the various side effects of succinylcholine like hyperkalemia, arrhythmia, increased intraocular, intra gastric and intracranial pressures and its potential to cause malignant hyperthermia has led to the search for alternate neuromuscular blocking agents for rapid sequence intubation. Additionally, repeated or prolonged use may increase the drug's effects at the sympathetic or vagal ganglia, which can cause bradycardia and hypotension, which are particularly severe in children and necessitates premedication with atropine [5-7].

To avoid these side effects of succinylcholine, the use of other neuromuscular blocking agents has been explored for rapid sequence intubation. Non-depolarizing muscle relaxants such as vecuronium and atracurium cannot be used for rapid sequence intubation as suitable intubating conditions are achieved only after 2-3 minutes, which is much later than that with succinylcholine. Rocuronium and mivacurium were found to have effects similar to those of succinylcholine. Although mivacurium has a shorter onset of action, the intubating conditions are unsatisfactory and unexpected delay in recovery occurs in patients with butyrylcholinesterase deficiency [8,9].

Rocuronium, a structural analog of vecuronium, is an amino steroid non-depolarising neuromuscular blocking agent that has been demonstrated to have dose dependent fast onset of action and produces rapid paralysis. It is not associated with complications like muscle fasciculations, hyperkalemia, postoperative myalgias, exhibits low systemic histamine release as are seen with succinylcholine. The only absolute contraindication to rocuronium is allergy and it should be used with care in cases where the duration of action may be prolonged, such as in myasthenia gravis, hepatic disease, neuromuscular disease, or severe cachexia [2,4,10].

Thus, rocuronium can act as an alternative to succinylcholine for rapid sequence intubation. It produces clinically acceptable intubating conditions within 1-2 minutes with a dose of 0.6 to 1.2 mg/kg with duration of action of 30-40 minutes. As the dose increases, there is faster onset of action. Hence 0.9-1.2 mg/kg dose of rocuronium can provide the same onset time and intubating conditions as succinylcholine [11,12]. Various methods have been studied which would accelerate the onset of neuromuscular blockade with a standard intubating dose of rocuronium. The first is the priming principle, which is administering a small dose of a muscle relaxant three to six minutes before induction to give the relaxant enough time to reach the receptors. A larger dose is subsequently given to facilitate rapid intubation following induction. Another method is the use of magnesium sulphate [8]. Magnesium sulfate is being widely used for anesthesia as an adjuvant. It causes inhibition of presynaptic release of acetylcholine at the neuromuscular junction and decreases the sensitivity of postsynaptic nicotinic acetylcholine receptor to acetylcholine. Magnesium also antagonizes the P-type calcium channel at the motor nerve terminal [6]. It helps to reduce onset time of neuromuscular blocking agents by improving hemodynamics and allowing a greater amount of drug to reach the motor end plate [8,13,14].

In paralysed muscles, the inhibitory effect of magnesium on acetylcholine release is seen within the physiological concentration of magnesium. Hence, magnesium when given as pretreatment before standard dose of rocuronium shortens the duration of onset of action of rocuronium and is suggested to improve the intubating conditions [15,16]. Hence, aim of the study was to compare intubating conditions during rapid sequence induction between rocuronium with magnesium sulphate pretreatment, and succinylcholine in patients undergoing elective surgery under general anaesthesia.

MATERIALS AND METHODS

This prospective randomized study was conducted after approval from the institutional ethical committee [TP(MD/MS)66/2022]/IEC/ABVIMS/RMLH/909] and registration with clinical trial registry of India (CTRI/2022/11/046959). The study was conducted at the Department of Anaesthesia, Atal Bihari Vajpayee Institute of Medical Sciences, Dr. Ram Manohar Lohia Hospital, New Delhi, from August 2022 to February 2024. Patients involved in this study were informed about the study and written consent was taken. The sample size calculation was based on a study conducted by Park SJ et al. [17] At 95% confidence level and 80% power, taking the percentage of subjects with excellent intubating conditions after rocuronium+ magnesium sulphate in 80% and expecting excellent intubating conditions after succinyl choline in 95% subjects, sample size was calculated as 75 per group. So, the total sample size we have taken 150 patients. 150 American society of anesthesiologists (ASA) grade I and II patients, in the age group of 18-60 years, body mass index 18.5–24.9 kg/m², mallampati grade 1 & 2, undergoing elective surgery under general anesthesia were included in the study. Exclusion criteria included refusal of consent, emergency surgery, anticipated difficult airway, pregnant patients or breastfeeding women, patients with hepatic, renal, metabolic or neuromuscular disorders, allergy to study drugs and patients receiving drugs that influence neuro muscular functions such as (aminoglycosides, polymyxin A&B, colistin, clindamycin, lincomycin).

After a full pre-operative evaluation and investigation, patients meeting the inclusion criteria were taken for the study. Patients were taken to the operation theatre, all standard ASA monitors – pulse oximetry, electrocardiogram, heart rate, non-invasive blood pressure were attached and baseline values were noted. An 18G cannula was secured on the dorsum of the left hand and IV fluids infusion was started. Patients who participated in the study were randomly allocated into two groups using computer generated random numbers. *Group 1*: Patients received pretreatment with 50mg/kg of magnesium sulphate (maximum up to 4g), diluted in 100 ml of normal saline (0.9% NaCl) over 15 minutes and *Group 2*: Patients received 100ml of normal saline (0.9% NaCl) over 15 minutes. Preoxygenation was done in all patients with 100% oxygen for 3 minutes. Anaesthesia was induced with Inj. midazolam 0.02 mg/kg, inj. fentanyl 2 mcg/kg and inj. propofol 2 mg/kg.

Neuromuscular blocking agent was given according to the group allocated to the patient. *Group 1*: patients were given rocuronium 0.6 mg/kg diluted in 5ml Normal saline. and *Group 2*: patients were given succinylcholine 1.5 mg/kg diluted in 5ml of Normal saline. No mask ventilation was done till intubation. No cricoid pressure was applied. Direct laryngoscopy was performed at 60 seconds after giving the muscle relaxant and trachea was intubated with appropriate size endotracheal tube by an anaesthetist with at least 5 years' experience and intubating conditions noted. For assessing intubating conditions, we based them on Cooper's criteria [18] which included jaw relaxation, vocal cord movement and response to intubation with scores of 0-3 in each. Intubating conditions were graded based on the total score of all three parameters. They were graded as excellent (score 8-9), good (score 6-7), fair (3-5), poor (0-2) presented in Table 1.

Table 1. Cooper's criteria for intubating conditions.

Score	Jaw relaxation	Vocal cords	Response to intubation
0	Poor(impossible) to lift the jaw	Closed	Severe coughing or bucking
1	Minimal (difficult) to lift jaw	Closing	Mild coughing
2	Moderate(fair). Jaw can be lifted but with effort	Moving/Intermediate	Slight diaphragmatic movement
3	Good(easy) to lift jaw	Open(abducted)	None

The primary objective of this study was to compare intubating conditions during rapid sequence induction between rocuronium with magnesium sulphate pretreatment, and succinylcholine in patients undergoing elective surgery under general anaesthesia. Secondary objective of this study was to study side effects such as muscle pain, burning sensation, nausea, vomiting.

In statistical analysis was performed by the SPSS program for Windows, version 21.0. Normal distribution of different parameters was tested by the Shapiro-Wilk normality test. Quantitative data was expressed in mean $\pm$ standard deviation and depends on normality difference between mean of two groups and they were compared by Unpaired t test while for pre-post comparison, paired t test was used. Qualitative data were expressed in frequency and percentage and statistical differences between the proportions were tested by chi square test or Fisher's exact test. P' value less than 0.05 was considered statistically significant.

RESULTS

Total of 150 patients were included in the study. Mean age was 32.39 ± 7.77 years and 34.35 ± 10.25 years in group 1 and 2 respectively and the difference was not significant between the two groups in terms of age (p value 0.180). BMI was comparable among both the groups (p value 0.660). Both the groups were comparable regarding distribution of either gender (p value 0.510) presented in Table 2.

Table 2. Comparison of baseline characteristics between Group 1 and Group 2.

Demographic data	Group 1 (n=75) Mean $\pm$ SD	Group 2 (n=75) Mean $\pm$ SD	p value
Age (years)	32.39 $\pm$ 7.77	34.35 $\pm$ 10.25	0.180
Body mass index (kg/m ²)	21.83 $\pm$ 2.97	22.01 $\pm$ 1.77	0.660
Male	43 (57.3%)	39 (52.0%)	0.510
Female	32 (42.7%)	36 (48.0%)	

In 74 patients in each group, jaw relaxation was easy and in 1 patient in each group, it was fair. No patient in either group had difficult or impossible jaw relaxation. There was no difference in terms of jaw relaxation in both the groups (p=1.0). Vocal cords were found to be abducted in 70 patients (93.3%) in group 1 and 74 patients (98.7%) in group 2. Vocal cords were moving in 5 patients (6.6%) and 1 patient (1.3%) in group 1 and 2 respectively. No patients were found to have closing or closed vocal cords. This difference in vocal cord movement was not statistically significant (p=0.209). No patients had severe coughing or bucking and mild coughing in both the groups. There was no response to intubation in 67 patients (89.3%) and 73 patients (97.3%) in group 1 and 2 respectively. 8 patients (10.6%) in group 1 and 2 patients (2.7%) in group 2 had slight diaphragmatic movement. The difference in response to intubation between both the groups was not statistically significant (p=0.097). 71 patients (94.6%) in group 1 and 74 patients (98.7%) in group 2 had excellent intubating conditions. 4 patients in group 1 and 1 patient in group 2 had good intubating conditions and no patients in both the groups had poor or fair intubating conditions. Intubating conditions were comparable between both the groups (p=0.366) presented in Table 3.

Table 3. Variables of intubating conditions score in both groups according to Cooper's criteria.

Variables	Group 1 (n=75)	Group 2 (n=75)	p value
Jaw relaxation			
0	0	0	1.00
1	0	0	
2	1 (1.3%)	1 (1.3%)	
3	74 (98.7%)	74 (98.7%)	
Vocal cord			
0	0	0	0.209
1	0	0	
2	5 (6.6%)	1 (1.3%)	
3	70 (93.3%)	74 (98.7%)	
Response to intubation			
0	0	0	0.097
1	0	0	
2	8 (10.6%)	2 (2.7%)	
3	67 (89.33%)	73 (97.3%)	
Total score			
Poor	0	0	0.366
Fair	0	0	
Good	4 (5.3%)	1 (1.3%)	
Excellent	71 (94.6%)	74 (98.7%)	

Burning sensation was present in 33 patients (44%) during magnesium sulphate pretreatment and in 0 patients during saline pretreatment which was highly significant ($p<0.001$). Nausea and vomiting were seen in 2 patients in group 1 and 4 patients in group 2 and they were not statistically significant ($p=0.68$). Postoperative muscle pain was seen in 6 patients (8%) in magnesium-rocuronium group and 30 patients (40%) in saline-succinylcholine group and the difference was highly significant ($p<0.001$) presented in Table 4.

Table 4. Comparison of side effects between Group 1 and Group 2.

Side effects	Group 1 (n=75)	Group 2 (n=75)	p value
Burning sensation	33 (44%)	0	<0.001
Nausea & vomiting	2(2.66%)	4 (5.3%)	0.68
Muscle pain	6 (8%)	30 (40%)	<0.001

DISCUSSION

In this study showed no significant demographic differences among the two groups with respect to age, gender distribution and BMI ($p>0.05$). In this study, jaw relaxation and hence ease of laryngoscopy was good in 74 out of 75 patients in both the groups ($p=1$), Vocal cords movement was observed in 5 patients (6.6%) in group 1 and one (1.3%) patient in group 2, while in all the other patients, the vocal cords were fully relaxed. This difference was not statistically significant ($p=0.209$). Slight diaphragmatic movement was seen in 8 patients (10.6%) in group 1 and 2 patients (2.7%) in group 2. This response to intubation was statistically significant between the groups ($p=0.097$). However, the intubating conditions were clinically acceptable. Based on the total score, 71 patients in group 1 (94.6%) and 74 (98.7%) patients in group 2 had excellent intubating conditions. The difference was not statistically significant ($p=0.366$) and hence both groups were comparable. Thus excellent intubating conditions for rapid sequence intubation with magnesium pretreatment before 0.6mg rocuronium were found to be comparable with succinylcholine. Marsch SC. et al. demonstrated that time taken to achieve acceptable intubating conditions was longer with 0.6 mg/kg rocuronium as compared to succinylcholine, when no pre-treatment was used [19]. Kim MH et al. found that combination of magnesium sulphate priming with rocuronium accelerated the onset of neuromuscular blockade by 37% as compared to 0.6 mg/kg rocuronium alone and suggested that it could be used to achieve times comparable with succinylcholine [20]. Results similar to this study were found in a study conducted by Czarnetzki C. et. al. which showed comparable intubating conditions with magnesium-rocuronium and saline-succinylcholine group ($p=0.659$) [21]. Similar to this study, Park SJ. et al. also concluded that 0.6 mg/kg rocuronium was sufficient to achieve excellent intubating conditions after 60 seconds when used with magnesium sulphate pretreatment ($p<0.001$) [17].

The decrease in onset of action of rocuronium with pretreatment with magnesium occurs because of the effect of magnesium at the neuromuscular junction. Magnesium inhibits the voltage dependent calcium channels and therefore decreases the pre-junctional release of acetylcholine. It also decreases the sensitivity of acetylcholine at the end plate. Magnesium alters the electrical threshold of muscle membrane, thereby attenuating the direct excitability of muscle fibres [8]. Hence it potentiates the action of the muscle relaxants at the neuromuscular junction. In this study, the time to give magnesium pretreatment was over 15 minutes before induction, because earlier studies have shown that the end plate potential is affected by magnesium sulphate in 4-6 min and this is a suitable time for pretreatment with magnesium sulphate [17].

In our study, 33 patients (44%) in group 1 ($p < 0.001$) experienced burning sensation in the veins during magnesium sulphate infusion which were mild, resolved spontaneously and did not require further treatment or stoppage of infusion. Nausea and vomiting were present in 2 patients (2.66%) and 4 patients (5.3%) in group 1 and 2 respectively ($p > 0.05$) which was not statistically significant. Muscle pain was noted in 6 patients (8%) and 30 patients (40%) in group 1 and 2 respectively ($p < 0.001$) which is statistically highly significant. Studies conducted by Czarnetzki C. et al. [21], Kim MH. et al. [20], Park SJ. et al. [17], observed similar side effects during magnesium sulphate infusion like flushing and burning sensation which were resolved spontaneously. Czarnetzki C. et al. [21], also observed muscle pain in patients who received succinylcholine, as was seen in this study.

The study's limitations include a small sample size and short duration, as well as recruitment exclusively from a single tertiary care hospital. To enhance precision and applicability, broader participation from multiple tertiary care hospitals would strengthen the findings. Larger sample sizes and extended study durations are necessary to yield more robust the findings.

CONCLUSIONS

The study concluded that magnesium pretreatment before 0.6 mg/kg rocuronium provides clinically acceptable intubating conditions similar to succinylcholine making it suitable for rapid sequence induction with mild adverse effects which resolve spontaneously without any treatment.

SUPPLEMENTARY INFORMATION

Funding: No fund was received related to this study.

Institutional Review Statement: The study was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

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REFERENCES

- [1] Luxen J, Trentzsch H, Urban B. Rocuronium and sugammadex in emergency medicine: requirements of a muscle relaxant for rapid sequence induction. *Anaesthesist*. 2014; 63(4): 331-337.
doi: <https://doi.org/10.1007/s00101-014-2303-1>
- [2] Tran DT, Newton EK, Mount VA, Lee JS, Wells GA, Perry JJ. Rocuronium versus succinylcholine for rapid sequence induction intubation. *Cochrane Database Syst Rev*. 2015; 2015(10): CD002788.
doi: <https://doi.org/10.1002/14651858.CD002788.pub3>
- [3] El-Orbany M, Connolly LA. Rapid sequence induction and intubation: current controversy. *Anesth Analg*. 2010; 110(5): 1318-1325.
doi: <https://doi.org/10.1213/ANE.0b013e3181d5ae47>

- [4] Li G, Cheng L, Wang J. Comparison of Rocuronium with Succinylcholine for Rapid Sequence Induction Intubation in the Emergency Department: A Retrospective Study at a Single Center in China. *Med Sci Monit.* 2021; 27: e928462.
doi: <https://doi.org/10.12659/MSM.928462>
- [5] Fawcett WJ. Suxamethonium or rocuronium for rapid sequence induction of anaesthesia? *BJA Educ.* 2019; 19(12): 380-382.
doi: <https://doi.org/10.1016/j.bjae.2019.09.001>
- [6] McCourt KC, Salmela L, Mirakhur RK, Carroll M, Mäkinen MT, Kansanaho M, et al. Comparison of rocuronium and suxamethonium for use during rapid sequence induction of anaesthesia. *Anaesthesia.* 1998; 53(9): 867-871.
doi: <https://doi.org/10.1046/j.1365-2044.1998.00342.x>
- [7] Vinik HR. Intraocular pressure changes during rapid sequence induction and intubation: a comparison of rocuronium, atracurium, and succinylcholine. *J Clin Anesth.* 1999; 11(2): 95-100.
doi: [https://doi.org/10.1016/s0952-8180\(99\)00013-6](https://doi.org/10.1016/s0952-8180(99)00013-6)
- [8] Nirmal S, Khalid Z, Lokesh R, Salman M K, Surjya K M, et.al. The Effect of Magnesium Sulphate Pre-Treatment on Rocuronium Priming in Achieving Rapid Onset of Intubating Conditions. *J Anesth Inten Care Med.* 2018; 6(4): 555693.
doi: <https://doi.org/10.19080/JAICM.2018.06.555693>
- [9] Sharma M, Prakash R, Chaurasia MK, Prabha R, Raman R, Singh GP, et al. Comparison of Magnesium Pre-treatment With Two Different Doses of Rocuronium in Rapid Sequence Intubation: A Randomized Controlled Trial. *Cureus.* 2024; 16(3): e56794.
doi: <https://doi.org/10.7759/cureus.56794>
- [10] Van der Linden P, Fils JF, Schmartz D. Rocuronium-Magnesium Association for Rapid Sequence Induction: More Than a Question of Doses. *Anesth Analg.* 2022; 134(6): e36-e37.
doi: <https://doi.org/10.1213/ANE.0000000000005994>
- [11] Fuchs-Buder T, Tassonyi E. Intubating conditions and time course of rocuronium-induced neuromuscular block in children. *Br J Anaesth.* 1996; 77(3): 335-358.
doi: <https://doi.org/10.1093/bja/77.3.335>
- [12] Magorian T, Flannery KB, Miller RD. Comparison of rocuronium, succinylcholine, and vecuronium for rapid-sequence induction of anesthesia in adult patients. *Anesthesiology.* 1993; 79(5): 913-918.
doi: <https://doi.org/10.1097/0000542-199311000-00007>
- [13] Almeida CED, Carvalho LR, Andrade CVC, Nascimento PD Jr, Barros GAM, Modolo NSP. Effects of magnesium sulphate on the onset time of rocuronium at different doses: a randomized clinical trial. *Braz J Anesthesiol.* 2021; 71(5): 482-488.
doi: <https://doi.org/10.1016/j.bjane.2021.07.023>
- [14] Sun H, Jin T, Wu X, Yang L, Zuo Y, Liao R. Efficacy of magnesium sulfate as an adjuvant to rocuronium in general anaesthesia: a meta-analysis. *J Int Med Res.* 2021; 49(7): 3000605211027736.
doi: <https://doi.org/10.1177/03000605211027736>
- [15] Del Castillo J, Engbaek L. The nature of the neuromuscular block produced by magnesium. *J Physiol.* 1954; 124(2): 370-384.
doi: <https://doi.org/10.1113/jphysiol.1954.sp005114>
- [16] Fuchs-Buder T, Wilder-Smith OH, Borgeat A, Tassonyi E. Interaction of magnesium sulphate with vecuronium-induced neuromuscular block. *Br J Anaesth.* 1995; 74(4): 405-409.
doi: <https://doi.org/10.1093/bja/74.4.405>
- [17] Park SJ, Cho YJ, Oh JH, Hwang JW, Do SH, Na HS. Pretreatment of magnesium sulphate improves intubating conditions of rapid sequence tracheal intubation using alfentanil, propofol, and rocuronium - a randomized trial. *Korean J Anesthesiol.* 2013; 65(3): 221-217.
doi: <https://doi.org/10.4097/kjae.2013.65.3.221>

- [18] Cooper R, Mirakhur RK, Clarke RS, Boules Z. Comparison of intubating conditions after administration of Org 9246 (rocuronium) and suxamethonium. *Br J Anaesth.* 1992; 69(3): 269-273.
doi: <https://doi.org/10.1093/bja/69.3.269>
- [19] Marsch SC, Steiner L, Bucher E, Pargger H, Schumann M, Aebi T, et al. Succinylcholine versus rocuronium for rapid sequence intubation in intensive care: a prospective, randomized controlled trial. *Crit Care.* 2011; 15(4): R199.
doi: <https://doi.org/10.1186/cc10367>
- [20] Kim MH, Oh AY, Jeon YT, Hwang JW, Do SH. A randomised controlled trial comparing rocuronium priming, magnesium pre-treatment and a combination of the two methods. *Anaesthesia.* 2012; 67(7): 748-754.
doi: <https://doi.org/10.1111/j.1365-2044.2012.07102.x>
- [21] Czarnetzki C, Albrecht E, Masouyé P, Baeriswyl M, Poncet A, Robin M, et al. Rapid Sequence Induction with a Standard Intubation Dose of Rocuronium After Magnesium Pretreatment Compared With Succinylcholine: A Randomized Clinical Trial. *Anesth Analg.* 2021; 133(6): 1540-1549.
doi: <https://doi.org/10.1213/ANE.0000000000005324>