Pediatric rapid sequence intubation: emergency department approach

Seqüência rápida de intubação em pediatria: abordagem no pronto-socorro

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ABSTRACT

The present paper describes the current knowledge on rapid sequence intubation applied to critical cases in the Emergency Department. A bibliographic search was performed through Medline and Lilacs databases. Keywords used for search were: rapid sequence intubation and emergency tracheal intubation. Rapid sequence intubation consists of appropriate use of medications to facilitate emergency tracheal intubation and decrease its adverse effects. This technique requires an organized approach involving sedatives and paralyzing agents. It should, therefore, be performed only by skilled professionals, who will take into account the risks and benefits of the procedure after careful assessment of the patient’s conditions. Although several potential complications may occur, efficacy and safety of rapid sequence intubation were documented and proved to reduce the risks of tracheal intubation. This is achieved by rapid anesthesia induction, which mitigates the autonomic reflexive response caused by the direct laryngoscopic procedure, and by prompt occurrence of ideal conditions which makes laryngoscopy easier, reducing the risks of pulmonary aspiration. In conclusion, rapid sequence intubation is the method of choice in most pediatric emergency intubations since it is associated with a high success rate and a low incidence of adverse reactions when it is carried out by skilled professionals.

Keywords: Intubation, intratraqueal/methods; Emergency medical services; Emergency identification; Child

RESUMO

Com o objetivo de descrever o conhecimento atual sobre seqüência rápida de intubação aplicada às situações de emergência no pronto-socorro foi realizada busca bibliográfica por meio do banco de dados Medline e Lilacs, utilizando as palavras-chave: seqüência rápida de intubação e intubação traqueal de emergência. A seqüência rápida de intubação consiste no uso apropriado de medicamentos para facilitar a intubação traqueal de emergência e reduzir os efeitos adversos desse procedimento. Esta técnica emprega uma abordagem organizada que envolve o uso de agentes sedativos e paralisantes. Dessa forma, deve ser realizada por profissional adequadamente treinado, após avaliação criteriosa de cada paciente, pesando os riscos e benefícios. Apesar das possíveis complicações, a seqüência rápida de intubação tem segurança e eficácia documentadas e diminui o número de complicações causadas pela intubação traqueal. Isso é obtido por propiciar rápida indução de anestesia, atenuando a resposta reflexa autonômica que ocorre devido ao procedimento de laringoscopia direta e pelo rápido aparecimento de condições ótimas que facilitam a laringoscopia, reduzindo o risco de aspiração pulmonar. Pode-se concluir que a seqüência rápida de intubação é o método de escolha na maioria das intubações pediátricas de emergência, pois está associada a uma alta taxa de sucesso e baixa incidência de reações adversas, quando realizada por profissional habilitado para tal.

Descritores: Intubação intratraqueal/métodos; Serviços médicos de emergência; Identificação da emergência; Criança

INTRODUCTION

Rapid sequence intubation (RSI) is a medical term used in emergency medicine and consists of airway control through safe and rapid tracheal intubation of severe patients by means of an organized approach involving sedation and paralyzing agents(1). RSI is indicated by well-trained professionals after careful risk-benefit assessment of patients(2).

Tracheal intubation of adults and children out of the operating room presents a 15%-38% complication rate, and particular features of the child airway and some conditions, such as respiratory tract infection,
congenital heart disease and neuromuscular disease, increase the risk of patients at this age range\(^3\). When conducted by non-specialists, complications rate may be as high as 48%, which reinforces the importance of medical training\(^4\). Despite potential complications, RSI has proved to be safe and effective, while it reduces the number of complications caused by tracheal intubation\(^1,5\).

**Physiological consequences of laryngoscopy and intubation.** Efferent responses by laryngoscopy and intubation are due to stimulation of the glossopharyngeal nerve above the epiglottis and of the vagus nerve below it. In general, efferent response to direct laryngoscopy, resulting from the airway protective reflex, is short and of reduced clinical relevancy. However, in some circumstances, the pathophysiological effects may be more severe and last longer. The airway protective reflex response may be expressed as apnea, nausea, cough, laryngospasm and bronchospasm and, as consequence, a gastroesophageal reflux may occur, as well as difficult visualization of larynx, airway obstruction, hypoxia, hypercapnia, pulmonary edema and reduced cardiac output. RSI with anesthetic induction and muscular relaxation aims to reduce time course of direct laryngoscopy, facilitating passage of the tracheal tube and, thus, minimizing all adverse effects described above.

In addition to respiratory reactions, direct laryngoscopy also alters the cardiovascular function, and severity of these reactions is directly correlated with duration of direct laryngoscopy. Due to stimulation of the sympathetic and parasympathetic nervous system, arterial hypertension and tachycardia occur with consequent increased oxygen consumption. However, in pediatric patients, particularly those aged under five years, cardiovascular disorder may initially occur with bradyarrhythmia. Moreover, significant increase of intraocular and intracranial pressure, when associated to hypoxia, hypercarbia and to other effects resulting from airway protective reflex response, contribute to injuring the central nervous system.

**OBJECTIVE**

To describe the current knowledge on rapid sequence intubation applied to critical events at the emergency department.

**METHODS**

For this study, a literature review was conducted through electronic search in the MEDLINE and LILACS databases in the period from 1980 to mid-2005, considering the age range of 1 month to 18 years. The bibliographic search was carried out using the following key-words: rapid sequence intubation and emergence tracheal intubation.

The criteria used to include the articles in this study were original research articles and reviews in Portuguese, English and Spanish, of which outcome (or one of the outcomes) were efficacy and safety of tracheal intubation in children.

As a result, 381 studies were obtained. Brief reading of the articles’ abstracts led to exclusion of not-so relevant editorials, case reports and articles, and 143 studies were selected for initial analysis. After evaluating the methodology and results, 90 articles were chosen for review and 46 were cited.

**RESULTS**

RSI is indicated for patients needing emergency tracheal intubation. These patients are rarely at fast, have delayed gastric emptying due to hypoxemia and, thus, present high risk of aspiration\(^5,6\).

The great advantage of RSI is that it eliminates direct laryngoscopy resistance\(^7\) due to:

- rapid anesthetic induction that mitigates autonomic reflexive response resulting from direct laryngoscopic procedure;
- rapid onset of optimal conditions that favor laryngoscopy;
- reduced risk of pulmonary aspiration by means of cricoid pressure (sellick maneuver) after sedation, reduced time of unprotected airway and reduced vomiting reflex due to muscular relaxation.

In general, the indications of RSI coincide with those for emergency tracheal intubation involving patients with intact upper airway reflex\(^7\). However, some contraindications should be taken into consideration: inexperience with the technique sequential steps and events in which tracheal intubation and bag-valve-mask ventilation are inaccessible, such as obstruction of the upper airways (abscesses, tumors, foreign bodies etc.), facial and/or laryngeal trauma and distorted facial anatomy.

Intense sedation with no paralysis should not be taken as substitute for RSI. Managing intubation with high-dose sedation may lead to some inconveniences, such as procedure delay, loss of airway protective reflexes without paralysis benefits, and apnea. Some authors demonstrated increased number of complications due to tracheal intubation with deep sedation as compared to RSI\(^8\).
tracheal intubations conducted in large academic centers in the United States. Reports of RSI at hospitals with medical residence in pediatric emergency demonstrated high intubation success rate with this technique\(^{(5,8)}\). RSI is a method of choice for most emergency pediatric intubations, because it is associated to a high success rate and low incidence of adverse effects when managed by skilled professionals or by pediatrics resident under medical supervision\(^{(9)}\).

RSI is not indicated for patients with cardiorespiratory arrest (CRA) or in deep coma lacking muscular tonus. In these circumstances, tracheal intubation should be immediately performed, without previous sedation, analgesia and use of neuromuscular blockers (NMB)\(^{(7)}\).

It is understood that tracheal intubation under RSI is faster and safer, even in children and infants, while the RSI benefits have already been reported in several circumstances\(^{(5-10)}\). However, the risks related to this procedure should not be ignored since drug adverse effects and difficulties with the airway\(^{(11)}\) are major issues that deserve strong consideration. Prediction of potential complications resulting from a difficult airway and adverse effects of drugs\(^{(12)}\) are relevant in RSI.

RSI steps are listed below\(^{(7,13)}\):

1. history and clinical examination;
2. preparation: equipment, staff, medication;
3. monitoring;
4. preoxygenation: it should last 3 to 5 minutes;
5. premedication: at 5 to 5.50 minutes;
6. sedation: at 5.50 to 6 minutes;
7. cricoid pressure and ventilation, if necessary;
8. neuromuscular blockage: at 7 to 7.5 minutes;
9. tracheal intubation: at 8.5 minutes;
10. post-intubation observation and monitoring;
11. continuous sedation and paralysis;

Regardless of some steps being performed simultaneously, the sequence should be conducted by a skilled professional\(^{(10)}\).

1. **History and clinical examination**

Present and past histories are essential for aiding in medication selection and warning about potential complications\(^{(14)}\). For instance, a past history of malignant hyperthermia and myopathies, such as muscular dystrophies, contraindicate the use of succinylcholine; time course from the last meal indicates higher or lower risk of regurgitation and aspiration; associated events may suggest potential complications, for instance, head trauma related to intracranial hypertension. History should be brief and objective and cover the following issues represented by the acronym AMPLE, which is a mnemonic rule to facilitate in practice: A = Allergies, M = Medications, P = Past history, L = Liquids and last meal, E = Event that requires intubation.

The clinical examination focusing on anatomic assessment of the airways aims to detect disorders that might contribute for a difficult airway. Although the concept of difficult airway is not precise, most authors accept it when tracheal intubation or bag-valve-mask ventilation is rough.

**Difficult airway.** The incidence of difficult airway is variable and not well-defined in children. Many variables interfere in the statistics\(^{(11)}\). When a procedure is performed by anesthetists in the operating room, intubation failure occurs in 0.1 to 0.3% of cases; four or more attempts are needed in 0.5% and less than two attempts in 2 to 4%. It is reported that 15% of difficult intubations are followed by problems with bag-valve-mask ventilation. Data on intubation performed not in ideal operating room conditions, indicate that multiple attempts are done in 8 to 12% of cases, suggesting a higher difficulty grade in airway management when under inadequate conditions\(^{(1,5)}\).

The risk of multiple intubation attempts is not insignificant – besides hypoxemia, edema resulting from inadequate airway management is associated to significant increased morbidity\(^{(15)}\). Therefore, stressful events in the emergency department require the first attempt be done under conditions that optimize well-succeeded ventilation through tracheal intubation. Hence, the need of previous assessment is evident and prediction of a difficult airway demands appropriate preparation to reduce time of hypoxia and its consequences, which are frequently catastrophic.

Examination of the airway, which is recommended before intubation, is mandatory when performed in the emergency department, where patients are usually in severe cardiorespiratory conditions and are immediately worsen in the presence of hypoxemia. Head, face, teeth, neck and cervical spine should be assessed\(^{(16-18)}\). The main physical features associated with difficult airway are small mouth with limited opening, prominent incisives, space between upper and lower incisives, macroglossia; short neck with reduced mobility; backward or hypoplastic jaw; high, arched or narrow palate; presence of cervical collar; obesity and infants with congenital malformations.

Rigorous assessment of the airway before RSI is an essential step to choose the best access to it and to estimate risks. A high-risk estimation may contraindicate RSI and favor the use of alternative techniques, such as intubation under sedation, assuring spontaneous ventilation of the child. Sudden use of
NMB, in these cases, can cause a tragic outcome in an inaccessible airway, since gas changes will not happen due to absence of ventilatory movement. In addition, assisted ventilation through a bag-valve-mask may also be inaccessible, since lack of muscular tonus of the tongue, pharynx, larynx and suspensory ligaments may lead to airway obstruction and difficult management\(^{(18)}\).

Child airway, especially of those aged under 2 years, even in the absence of anatomic abnormalities, presents peculiarities\(^{(19)}\) that increase the chance of difficult intubation. Not only the child’s airway anatomy contributes to difficult airway, but also the professional’s skills to perform the procedure, as well as patient’s clinical conditions may significantly interfere. Both bag-valve-mask ventilation and tracheal intubation require skills that are hard to acquire and easily forgotten. The characteristics of a small child airway are listed below:

- prominent occiput, enabling airway flexion and obstruction;
- large tongue, leading to poor visualization of larynx and yielding a smaller space for tube passage;
- reduced neck muscular tonus, leading to airway obstruction;
- small, narrow, fragile and horizontal epiglottis; these characteristics favor trauma and edema, and lead to poor visualization of vocal folds;
- anterior larynx, leading to poor visualization of vocal folds;
- short trachea facilitating selective intubation of the bronchia;
- cricoid ring is the narrowest portion of the airway, increasing the chance of local trauma during tube insertion.

2. Preparation: team, equipment, medication

Preparing the procedure is fundamental, since as soon as RSI begins, interruption is not recommended. When all items are available, the procedure may be started. At least three professionals are necessary to perform RSI. One is responsible for airway and intubation; the other for cricoid pressure (Sellick maneuver) and monitoring; and the third, for drug preparation and administration.

3. Monitoring

Monitoring is essential in any child requiring airway manipulation. Under ideal conditions, an oximeter, a cardiac monitor and a blood pressure monitor must be available during the preparatory stage and intubation. At post-intubation, the use of an end-tidal CO\(_2\) monitor or detector is strongly recommended\(^{(20)}\).

The oximeter during intubation early detects hypoxia development as compared to a cardiac monitor. The latter detects arrhythmia and bradycardia, which are extreme hypoxia events, requiring immediate procedure. Therefore, cardiac oximeter and monitor are crucial and represent RSI minimal acceptable monitoring.

4. Preoxygenation

In spontaneous breathing patient, preoxygenation should be performed for 2 to 5 minutes (its end is considered the 5\(^{th}\) minute of RSI), using 100% oxygen, through a well-adjusted mask while positive pressure ventilation should be avoided\(^{(21)}\). Preoxygenation maximizes hemoglobin saturation and develops oxygen storage in the lungs. This way, patient’s tolerance to apnea is improved during laryngoscopy and need of bag-valve-mask ventilation is reduced. In cases where positive pressure ventilation by means of a bag-valve-mask is mandatory, most reduced time is desired and minimal inspiratory volume must be employed, since this type of pre-intubation ventilation provides gastric inflation and higher risk of regurgitation and aspiration.

In patients with inappropriate ventilation or apnea who require bag-valve-mask, need of sedation should be assessed and ventilation be performed with cricoid pressure (Sellick maneuver).

5. Premedication

The purpose of premedication is to minimize the physiological response to laryngoscopy: vagal stimulus with bradycardia (more commonly in infants), tachycardia, hypertension, hypoxia, increased intracranial and intraocular pressure. It should be performed at 5.0-5.5 minutes of RSI, after preoxygenation.

Medication selection at this phase will depend on patient’s clinical condition and sedatives/NMBs\(^{(16)}\) chosen. This selection varies in each service and it is essential that the professionals are familiar with local protocols.

At this stage, medications include atropine, an analgesic (in general, opioid or lidocaine) and a defasciculating agent (only necessary when succinylcholine is the drug of choice for neuromuscular block).

Atropine. Atropine minimizes harmful responses resulting from vagal stimulation caused by laryngoscopy, mainly bradycardia and asystolia\(^{(22)}\), and it also reduces oral secretions facilitating larynx visualization. Tachycardia may be observed as an adverse effect of atropine. Atropine may conceal the presence of hypoxemia, once reflexive bradycardia will not occur as an alert. Thus, oxygenation assessment through pulse oximetry is highly recommended.
Indications for atropine include age under one year, presence of bradycardia, use of ketamine as sedative, indication of succinylcholine as paralyzing agent in children between 1 and 5 years old, and indication of a second dose of succinylcholine in patients at any age\textsuperscript{(13)}.

The recommended intravenous dose is 0.02 mg/kg; minimal dose of 0.1 mg and maximum of 0.5 mg for children. Doses below 0.2 mg, despite body weight, may cause paradoxal bradycardia due to direct stimulus of the medullary vagal nucleus. When indicated, it should be administered 1 to 2 minutes before tracheal intubation.

**Opioids.** They are indicated as strong analgesics, besides their sedative features and reversible action, producing hemodynamic stability both in presence and absence of harmful stimuli. Among opioids, fentanyl and alfentanil are the most indicated for RSI due to their fast onset and short action. Both drugs act on opioid receptors of the cardiovascular system, the central nervous system, vagal nucleus and adrenal medulla and, therefore, can minimize the response to harmful stimulus, thus providing hemodynamic stability.

They are normally well-tolerated, may adversely cause thoracic stiffness and consequent raise in intracranial pressure\textsuperscript{(23)}. Thoracic stiffness, more frequently observed in neonates and infants, is associated to high dosages and rapid infusion, which may be avoided by using low doses of fentanyl, 1 to 3 mcg/kg, slow infusion, with maximum speed of 1 mcg/kg/min, which may be reverted by the use of muscular relaxants and naloxone.

Action of opioids over intracranial pressure is controversial, since they are generally indicated for neuroanesthesia for their neuronal protective feature, with consequent non-alteration of intracranial pressure\textsuperscript{(24)}.

Even though high doses of 5 to 7 mcg/kg may be used, the initial recommended dose is 2 to 3 mcg/kg. Fentanyl should be used one to three minutes before tracheal intubation.

**Defasciculating agents.** The indication of defasciculating agents aims to inhibit muscular fasciculation caused by succinylcholine, thus minimizing drug adverse effects, such as rhabdomyolysis, myoglobinuria, muscular pain, hyperkalemia, elevated intracranial pressure, elevated intraocular pressure and gastroesophageal reflux.

Defasciculation consists of small-dose administration of BNM, 10% of usual dosage of vecuronium, pancuronium or succinylcholine, previously to infusion of succinylcholine in children aged over 5 years\textsuperscript{(13)}. These patients have higher risk of complications from fasciculation due to increased muscular mass.

**Lidocaine.** Lidocaine has an anesthetic action and lessens the adrenergic effect caused by laryngoscopy\textsuperscript{(25)}. The mechanism of action is not well-understood, but it is likely to be associated with the anesthetic effect in the central nervous system with lower intracranial and intraocular pressure\textsuperscript{(25-26)}. This is a safe medication for it does not cause respiratory depression. A dose of 1.5 to 3.0 mg/kg, 2 to 5 minutes before intubation is recommended\textsuperscript{(25)}.

6. Sedation

Appropriate sedation is a mandatory and crucial step for patients submitted to tracheal intubation, except for those in coma. It should be performed at the 5.50-6.0 minutes of RSI and its purpose is to induce amnesia, lower consciousness and eliminate paralysis perception caused by NMBs, as well as the discomfort resulting from the procedure itself, particularly of laryngoscopy and insertion of the tracheal tube\textsuperscript{(27)}.

Sedatives should be of fast onset and short action\textsuperscript{(29)}. Hypotension and cardiovascular depression are common effects caused by all sedatives, which are more intense in patients presenting previous hypovolemia and hypotension.

**Thiopental.** Barbiturates without analgesic effect and of fast onset (around 10 to 20 seconds) have the advantage of reducing intracranial pressure and metabolic demand\textsuperscript{(29)}. The undesirable effects are vasodilation and myocardial depression, with consequent hypotension, respiratory depression and histamine discharge. The latter requires careful use of thiopental in asthmatic patient, although slow infusion minimizes these effects.

Tremors, hypertonia, muscular contraction, cough, laryngospasm and hiccups are effects caused by the use of thiopental alone, without the use of paralyzing agents. In general, barbiturates may trigger several episodes of intermittent acute porphyria. Thiopental should be avoided in hypotensive patients, otherwise, only half of the recommended dosage should be used\textsuperscript{(30)}.

**Midazolam.** Midazolam is a benzodiazepine of fast onset and short action\textsuperscript{(29,31)}. Besides being a strong sedative, it offers two other advantages – amnesia and mild reduction of intracranial pressure. Due to its pharmacodynamic features and possibility of reversion using an antagonist, midazolam is part of the RSI protocol in several services.

In RSI, the dose of midazolam is higher than that recommended for sedation and should be administered 2 minutes before paralysis.
Propofol. As a highly lipophilic agent, propofol is rapidly spread in the brain and presents very rapid onset (10 to 20 seconds) and short duration (10 to 15 minutes), while its recovery is faster than other barbiturates\(^{(29)}\).

Propofol produces fast and deep depression of consciousness and cardiorespiratory function, while hypnosis is its ultimate state\(^{(16)}\). Its use in children should be better evaluated, since it not only causes myocardial depression and reduced systemic vascular resistance, but it also alters the baroreflex, not yielding a significant tachycardiac response in face of resultant hypotension, and should be avoided in patients with hypotension or shock. Approximately 15% of normotensive patients present significant fall, and therefore, administration of propofol require frequent hemodynamic re-evaluation\(^{(16,30,32)}\). There are also reports of cardiorespiratory arrest in children submitted to continuous infusion for long periods\(^{(30,32)}\).

Propofol has the advantage of reducing intracranial pressure and metabolic demand\(^{(33)}\).

Since propofol is available as a lipidic emulsion, it should be managed with asepsis, to avoid contamination and potential sepsis. Other adverse effects are apnea and pain at the injection site, which can be mitigated by infusion in larger vessels.

Etomidate. It is a very short-action sedative available in the market for 30 years, which lacks analgesic properties. It presents minimal respiratory effects and lower cardiovascular depression as compared to other sedatives, such as barbiturates and propofol\(^{(29,32,34)}\).

Etomidate is an effective drug to be used for RSI in emergency departments\(^{(34)}\), because it is one of the best options at emergency situations. Moreover, it is the sedative of choice in children presenting head trauma\(^{(32)}\), since it dramatically reduces intracranial pressure and cerebral blood flow. Vomiting is frequently observed in patients receiving etomidate without NMB\(^{(34)}\). Care should be taken with the use of etomidate in patients with focal seizures. Another adverse effect of this drug is suppressed cortisol synthesis; even though it is a rare occurrence, it may last 5 to 8 hours\(^{(30,34)}\) and is contraindicated in cases of septic shock.

Ketamine. Ketamine produces a dissociation of thalamocortical axon leading to sedation, analgesia and amnesia, although patients remain with open eyes; a cataleptic state with no hypnosis is observed when airway protective reflexes are preserved. Due to its dissociating features, some common signs of deep sedation are not relevant\(^{(16)}\).

This medication produces depression of consciousness, culminating with general anestheisa and lower cardiorespiratory depression as compared with other sedatives\(^{(16)}\). Ketamine safety and effectiveness for sedation and analgesia in a well-equipped an emergency department with skilled professionals is supported by the literature\(^{(27)}\).

Ketamine presents a mild sympathomimetic effect, producing increased blood pressure and cerebral blood flow, although in presence of catecholamine depletion, as in prolonged shock, it may cause cardiovascular depression. Since it improves bronchospasm due to adrenergic discharge, it is a drug of choice for intubation in children under asthmatic crisis\(^{(31)}\), although it leads to increased airway secretion that could be mitigated by previous use of atropine\(^{(30)}\).

Certain clinical conditions, such as hypertension, head trauma with potential increase in intracranial pressure, ocular trauma, glaucoma, psychiatric disorders, thyroid disorders and seizures are contraindications for the use of ketamine\(^{(30,32)}\). Some authors recommend using benzodiazepines prior to ketamine administration to lessen the risk of psychotic reaction (agitated awakening), although this benefit was not observed in children\(^{(55)}\).

There is not an optimal sedative for all cases\(^{(36)}\). Selection should be based on the pharmacological properties and on the child’s clinical condition, as follows:

- normal blood pressure: thiopental, midazolam, propofol;
- mild hypotension with head trauma: thiopental, midazolam, etomidate;
- mild hypotension with no head trauma: ketamine, etomidate, midazolam;
- severe hypotension: ketamine, etomidate, midazolam (low dosage);
- head trauma alone: thiopental, propofol, etomidate;
- asthmatic crisis: ketamine, midazolam, propofol;
- status epilepticus: thiopental, midazolam, propofol;

7. Cricoid pressure and assisted ventilation, if required

Immediately after sedation, pressure should be applied on the cricoid cartilage and maintained until passage and placement of the tracheal tube is assured. This procedure is also known as Sellick maneuver and aims to facilitate vocal fold visualization and reduce air flow into stomach, thus avoiding regurgitation\(^{(37)}\). Pressure should be stable, without producing tracheal collapse.

When positive pressure ventilation is required before intubation, this procedure should be concomitant with Sellick maneuver. However, this approach is contraindicated when patients are awake and but should be done under sedation.
8. Neuromuscular block

Normal nervous conduction occurs by action potential propagation along the nerve, through opening of calcium channels. Calcium flow discharges acetylcholine that acts over the muscular cell through nicotine receptor binding. The excitatory process ends when acetylcholine is hydrolyzed by acetylcholinesterase.

The NMBs act through interrupted nervous transmission between the somatic nerve and the muscular fiber, leading to paralysis by avoiding acetylcholine action at the neuromuscular joint. Blockers may be classified as depolarizing (succinylcholine) and non-depolarizing (rocuronium, vecuronium, etc.)\(^{(38)}\).

Several factors interfere in NMB selection, including drug potency, onset of action, duration of effect and patient’s conditions, such as age, past history and history of present illness\(^{(39)}\). The NMBs used in RSI should present fast onset and short action.

The adverse effects of NMBs may be divided into three main categories: effects caused by depolarization, by histamine release and cholinergic effects\(^{(39)}\). The depolarization effects are observed with the use of succinylcholine, a depolarizing agent, and they include tension or spasm of masseter muscles, fever, increased catecholamines, myoglobinuria, subclinical muscular lesion, hyperkalemia and elevated intragastric pressure. Several NMBs cause histamine discharge and signs of anaphylaxis may be observed. Succinylcholine, vecuronium and atracurium cause these effects more often, although NMB cross-reactions may be observed. The cholinergic effects that occur due to NMBs bound to muscarinic receptors give rise to tachycardia and bronchospasm, while these can be mitigated by previous use of atropine.

The NMBs are indicated one to two minutes after sedation, that is, at 7.0-7.5 minutes of RSI. For RSI employment, the paralyzing agent should be of fast onset and short action and always be preceded by appropriate analgesia and sedation.

**Succinylcholine.** Succinylcholine, a depolarizing agent, binds to postsynaptic receptor and opens sodium channels, so that the membrane remains depolarized and the muscle rapidly gets into fatigue, that is, refractory to subsequent stimulation. Differently from acetylcholine, succinylcholine produces continuous receptor stimulation. Metabolization occurs through the action of acetylcholinesterase.

Immediately after succinylcholine infusion, fasciculation may be clinically observed, more frequently in children aged over 5 years, coming to end when paralysis is reached. However, this condition may be avoided with the use of defasciculating agents during premedication. Hyperkalemia produced by succinylcholine is generally insignificant. Nevertheless, care should be taken in patients with kidney failure and major burn.

Developing intracranial hypertension with succinylcholine, which was observed in animals, is an issue of concern. However, there is little scientific evidence supporting significant clinical elevation of intracranial pressure during administration of succinylcholine\(^{(40)}\).

Bradycardia and asystolia have been reported in children and can be avoided by prior administration of atropine\(^{(10)}\). Such effects are more common in children under 1 year of age or after a second dose of succinylcholine.

The rise of new and safer NMBs that presenting similar potency, made succinylcholine a drug less often indicated by several authors. If succinylcholine is employed, its use should be carefully assessed from the contraindication perspective\(^{(40)}\).

Due to several adverse effects, several medical associations have not recommended using succinylcholine for elective procedures\(^{(41)}\). The Food and Drug Administration contraindicates succinylcholine in children and adolescents, except when immediate tracheal intubation is required\(^{(41)}\).

The clinical events in which succinylcholine is officially contraindicated include glaucoma, myotonia, paraplegia, neuromuscular diseases, hyperkalemia, crush injuries, ocular lesion, previous trauma or recent burn (48 to 72 h), history of malignant hyperthermia or cholinesterase deficiency.

**Non-depolarizing NMBs.** Non-depolarizing NMBs act through competitive binding in acetylcholine receptors. Since these agents are nicotine receptor antagonists and do not present intrinsic stimulating action, they do not produce fasciculation, and their main adverse effects are associated with histamine discharge, which is more frequent in adults than in children.

**Vecuronium.** This is a NMB with dose-dependent onset of action onset and intermediate duration. A 0.1 to 0.2 mg/kg dose produces a 30-second effect, 45-second muscular relaxation, optimal intubation conditions within one to four minutes and duration of 30 to 60 minutes. Higher doses produce faster onset of action and longer action.

Vecuronium is considered safe in emergency cardiovascular, pulmonary and neurological events and there are no contraindications for most pediatric patients\(^{(42)}\).

**Rocuronium.** Rocuronium is a neuromuscular blocker similar to vecuronium, but presenting one-eighth to one-
tenth of its potency (42). It presents faster onset of action than most non-depolarizing agents in similar doses. Doses of 0.6 a 0.8 mg/kg produce paralysis in infants within 60 seconds and, in children, within 28 seconds (43).

In RSI, rocuronium must be the drug of choice, due to its fast onset, short action and easy preparation of the requested dose (differently from other NMBs, rocuronium is presented as a solution and does not require previous dilution).

Statistically, appropriate intubation conditions are equally reached with succinylcholine and rocuronium; however, it should be emphasized that block recovery is slower with rocuronium, which takes 30 to 45 minutes, depending on age and dose administered (44).

Mivacurium. Mivacurium presents similar onset of action to that provided by vecuronium, that is, 30 to 60 seconds, but its effect lasts shorter – 15 to 20 seconds. It is metabolized by plasma cholinesterase and, thus, it is dependent on renal function. It more frequently produces histamine discharge in children as compared with other non-depolarizing NMBs; reactions observed are skin rash and blood pressure fall, most commonly of self-limited types (39).

Atracurium. Another intermediate-action NMB produces neuromuscular block within 1 to 1.5 minute and offers a 30-minute action in infants and a 40-minute action in older children. Despite the short action, association with histamine discharge and slow onset limit its use in emergency events (39).

9. Intubation
Tracheal intubation should be performed after 60 to 90 seconds of NMB administration, at 8.5 minutes of RSI. It is a procedure that requires a well-trained professional, once it involves skilled manipulation of the airways, with potential risk of worsening or triggering hypoxia.

10. Post-intubation observation and monitoring
RSI is not concluded with a well-succeeded tracheal intubation, as post-intubation clinical vigilance and monitoring are mandatory. Ideally, monitoring a patient at perfusion rhythm, that is, not under cardiac arrest, should include oximetry, cardiac monitor, blood pressure monitor (BP) and end-tidal CO2 detector or capnography (45).

11. Sedation and continuous paralysis
Continuous sedative administration is imperative at post-intubation stage. Care should be taken as to avoid maintenance of patients under NMB effect without appropriate sedation and analgesia. Signs of adrenergic activity, such as tachycardia and hypertension, are caused by inadequate sedation and analgesia in a conscious patient who is unable to move, cry or express pain. Without sedation, patients can have their auditory function preserved and, thus, certain comments should be avoided.

DISCUSSION
The management of a child requiring intubation may be technically difficult and challenging; however, knowledge of appropriate techniques can facilitate the procedure. Taking due precautions, RSI provides faster and safer tracheal intubation in children and infants, and should be considered in every emergency intubation involving patients with intact upper airway reflex (46).

RSI is a fundamental skill for physicians that deal with severely ill children or victims of severe lesions. Careful use of this method should be encouraged for emergency department physicians.

Two complication groups may be observed: those resulting from intubation procedure and the adverse effects of drugs used in RSI (8, 46).

Intubations may cause complete tooth fracture, avulsion of dental root, mucosal lesions (lips, tongue, pharynx and larynx), dissociation of the temporomandibular joint, arytenoid displacement, vocal fold paralysis, laryngeal granuloma, laryngotracheal stenosis, selective intubation, esophageal intubation, among other complications.

Intubation may not be possible due to a difficult airway; however, the professionals must be well-trained for this circumstance. Should the patient be under NMB action, intubation must be attempted while there are adequate signs of oxygenation, and this time period varies from 30 seconds to 4 minutes, depending on the technique used at preoxygenation stage. In case of any sign of hypoxygenation, a bag-valve mask ventilation should be used and a new intubation be tried as soon as the patient is prepared. The use of alternative ventilation types, such as laryngeal mask, retrograde intubation, combitube, cricothyroidectomy, and tracheotomy should be assessed on a case-to-case basis.

CONCLUSION
Rapid sequence intubation is an approach of choice for most pediatric emergency intubations since it is associated with a high success rate and low incidence of adverse effects, when performed by skilled professionals.
REFERENCES


