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Rapid sequence induction and intubation

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Learning objectives

By reading this article, you should be able to:

- Identify the patient at risk of pulmonary aspiration during airway management.
- Generate a plan to prepare a patient safely for rapid sequence induction and intubation (RSII).
- Describe the Project for Universal Management of Airways (PUMA) universal principles for RSII and recall the components which are recommended, suggested and optional.
- Discuss the current evidence base supporting various components of the RSII procedure.

Key points

- Pulmonary aspiration remains the commonest cause of anaesthesia-related death and brain damage.
- Rapid sequence induction and intubation has evolved since its classical description; however, recent modifications are poorly defined.
- Adequate preparation for RSII helps to mitigate risk, increase success and address patient-specific challenges.
- The PUMA collaboration has proposed universal principles for RSII.
- The PUMA universal principles aim to overcome practice variation and outline recommended, suggested and optional components of RSII.

Evolution of rapid sequence induction and intubation

Pulmonary aspiration is defined as the introduction of gastric or oropharyngeal matter into the lower respiratory tract.[1] Rapid sequence induction and intubation (RSII) is a procedure that aims to reduce the incidence of pulmonary aspiration during airway management. This is achieved by minimising the time between drug-induced loss of protective airway reflexes and the successful insertion and inflation of a cuffed tracheal tube. The fourth UK National Audit Project (NAP4) identified that pulmonary aspiration accounted for 50% of deaths reported in NAP4, and was the most common cause of anaesthesia related death.[2] Aspiration events are less common in the appropriately fasted patient. Despite this, 28% of aspiration events in NAP4 occurred in fasted patients. Significant risk factors for pulmonary aspiration were present in many of these cases. These results have been replicated more recently in the USA. An ASA closed claims analysis revealed that in 115 cases of pulmonary aspiration, death occurred in 57% and severe permanent injury in 14%.[3] It was found that 61% of those patients had presented with clear indications for RSII. The appropriate use of RSII when indicated is therefore as important as the technique. Pulmonary aspiration remains a significant risk in emergency surgery and in specific patient groups such as obstetrics where Mendelson first described the eponymous aspiration syndrome in 1946.[4] Commentary on pulmonary aspiration has long featured in the medical literature. Snow and Nunn reported in 1959 that aspiration of gastric contents was the most common cause of death associated with anaesthesia.[5] Strategies to avoid pulmonary aspiration were identified as early as 1951 when Morton and Wylie discussed the concepts of positioning and

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neuromuscular block.[6] Sellick and Lond first suggested the use of cricoid pressure at induction of anaesthesia in 1961.[7] Approximately 10 yr later, Stept and Safar[8] published the first complete description of 'rapid induction/intubation'. The paper outlined a 15-step procedure to avoid the aspiration of gastric contents.[8] Many of the key components of this 'classical' RSII still exist in current practice. Their procedure included preoxygenation of the lungs, giving predetermined doses of drug, the application of cricoid pressure, omission of facemask ventilation and tracheal intubation with a cuffed tube. More than 50 yr have passed since RSII was first described, and a number of recent surveys of anaesthetists suggest there is little consensus over the delivery of RSII and practice is highly variable.[9–11] The term 'modified rapid sequence induction' is in common use but its meaning is poorly defined. The Project for Universal Management of Airways (PUMA) group is a collaboration of airway experts who propose a universal description of RSII. This group aims to standardise the conduct of RSII internationally. Their proposed universal guidelines for rapid sequence intubation contain recommended, suggested and optional components which represent a benchmark for future practice.[12]

Indications

The indications for RSII can be divided into:

(i) Patients in whom fasting has occurred but is unreliable.
(ii) Patients in whom the fasting time is inadequate or unidentified.

Risk factors for pulmonary aspiration are outlined in Table 1.

An anaesthetist should perform RSII in the following situations:

(i) Patients for elective surgery who are adequately fasted but have risk factors for aspiration (e.g. hiatus hernia, gastro-oesophageal reflux, previous bariatric surgery, oesophageal pathology, delayed gastric emptying).
(ii) Patients for emergency surgery who are not fully fasted, or, regardless of fasting status, have risk factors for aspiration (e.g. bowel obstruction, gastric outlet obstruction, acute severe pain, upper gastrointestinal bleeding).
(iii) Obstetric patients requiring elective or emergency anaesthesia.
(iv) Critical care patients who require tracheal intubation (e.g. those with altered consciousness, respiratory failure, or multiple trauma).

Table 1 Risk factors for pulmonary aspiration.

Fasting unreliable	Pregnancy (>20 weeks) Obesity (BMI $\geq$40 kg m^{-2}) Hiatus hernia/gastro-oesophageal reflux History of oesophageal cancer/stricture or upper gastrointestinal surgery/bariatric surgery/gastric outlet obstruction Advanced chronic disease resulting in gastroparesis (diabetes mellitus/chronic kidney disease/neuromuscular disorders)
Not fasted/emergency procedure	Patient who is not fasted as per local guideline or fasting status unknown Acute intra-abdominal pathology (bowel obstruction) Acute pain or trauma resulting in gastric stasis

Risks of RSII

Adverse events may occur during RSII, the most significant of which include hypoxia, hypotension and pulmonary aspiration. Rapid sequence induction and intubation is associated with an increased risk of difficulty in airway management. The NAP4 identified that failed intubation occurs in 1 in 2,000 elective cases, but this number increases to 1 in 300 with RSII. The incidence of failed intubation is even higher (1 in 50–100) with RSII in the emergency department, critical care or obstetric patients.[2] Hypoxia can occur despite adequate preoxygenation of the lungs in a patient who is critically ill, obese or in the peripartum period. Oxygen desaturation may occur even when successful intubation is performed swiftly. Hypotension and cardiovascular instability is another concern, particularly in a frail patient or those in circulatory shock. Although the objective of RSII is to prevent pulmonary aspiration, it is recognised that this may still occur during airway management. The risk of pulmonary aspiration also exists during extubation of the trachea. The anaesthetist must ensure the patient can protect their airway before removing the cuffed tracheal tube. If a nasogastric tube is present it should be aspirated before extubation. The prospect of RSII can generate much anxiety in patients, particularly if cricoid pressure is planned. Anaesthetists should remain mindful of this and explain the procedure carefully.

Preparation and performance

Creating a plan for RSII can help to reduce some of the associated risks. A recent Difficult Airway Society (DAS) guideline recommends the use of an intubation checklist for RSII (Fig 1).[13] Although this checklist was developed for the critical care environment, the four headings – prepare the patient, prepare the equipment, prepare the team and prepare for difficulty – neatly summarise a safe approach to RSII in any group.

The patient

An airway assessment is essential to help anticipate difficulty with airway management and generate a plan. Predicting a difficult airway is addressed by a recent paper in this journal; however, a DAS guideline suggests use of the MACOCHA score (Table 2).[13–15] A MACOCHA score of >2 predicts difficulty.

Reliable intravenous access must be established to deliver medications for induction. The ideal patient position for RSII is one which facilitates preoxygenation, optimises laryngoscopic view and opposes passive regurgitation of gastric contents. The head up position appears to meet these criteria, but the optimal degree is not yet determined by evidence. The most common position described in practice is 20° head up. A 'ramped' position with horizontal alignment of the tragus and the sternal notch is recommenced for obese and obstetric patients.[16,17]

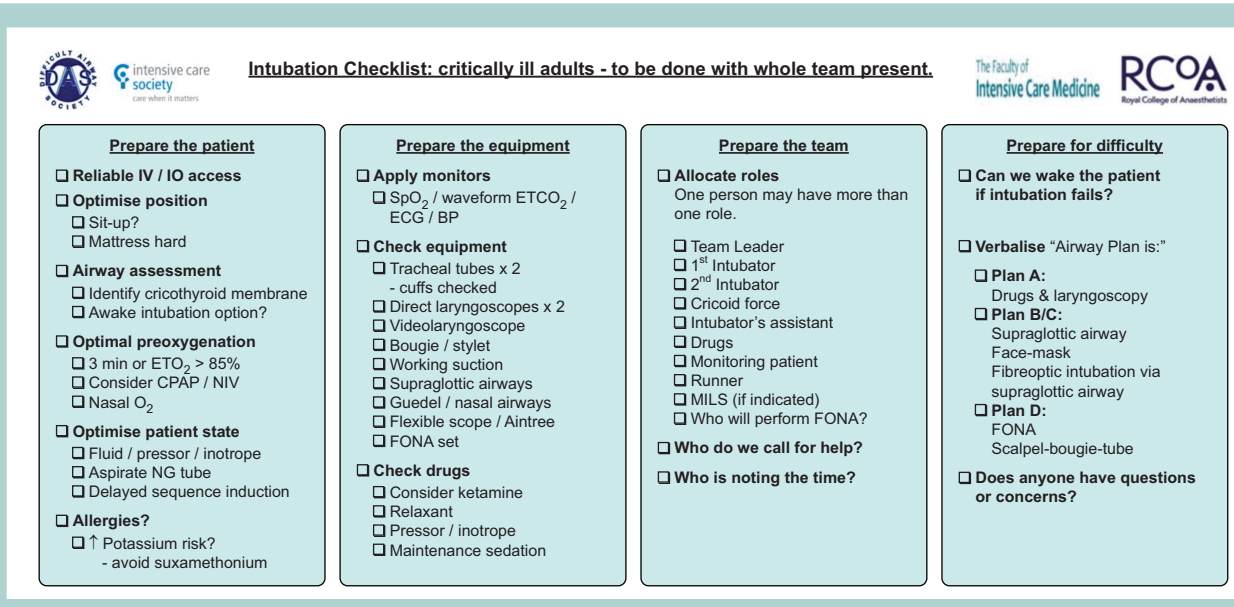

Figure 1 Intubation checklist for critically ill adults. CPAP, continuous positive airway pressure; FONA, front-of-neck airway; MILS, manual in-line stabilisation; NG, nasogastric; NIV, noninvasive ventilation.

Preoxygenation of the lungs is essential before RSII. The aim of preoxygenation is to accumulate a reservoir of oxygen, which will help to delay the onset of hypoxia during the period of apnoea which follows induction and before successful tracheal intubation and ventilation are achieved. The adequacy of preoxygenation can be evaluated by measurement of the fraction of expired oxygen ($F_E'O_2$). An $F_E'O_2$ of 0.85 or greater indicates adequate preoxygenation. Preoxygenation in a spontaneously ventilating patient is performed using a closed anaesthetic machine circuit with a fraction of inspired oxygen (F_IO_2) of 1.0. Otherwise a semi-closed circuit such as the Mapleson C circuit with a fresh gas flow of 15 L min^{-1} can be used. A high fresh gas flow is required to prevent rebreathing with a Mapleson C circuit. Preoxygenation is performed by tidal volume breathing of oxygen with a tight fitting facemask for 3 min, or alternatively with eight vital capacity breaths. Preoxygenation involves denitrogenation of the functional residual capacity of the lungs. Patients who are pregnant or obese have a reduced functional residual capacity, therefore optimal positioning and adequate preoxygenation is especially important in these groups. The use of a self-inflating bag-valve-mask resuscitator to preoxygenate the lungs of a patients breathing spontaneously is inappropriate as the integrated valve in these appliances requires the generation of considerable negative pressure to open it.[18] There is an emerging role for high-flow nasal oxygen (HFNO) techniques in preoxygenation and apnoeic oxygenation during RSII. High-flow nasal oxygen has been investigated as an alternative to preoxygenation using a facemask, and although the safe apnoea period may be extended, there is no evidence to suggest HFNO is a superior device for preoxygenation.[19] Alternatively, a standard nasal cannula may be used for apnoeic oxygenation after loss of consciousness using an oxygen flow rate of 15 L min^{-1}: this can also extend the safe apnoea period after spontaneous breathing ceases. In critically ill adults who are hypoxaemic, adding continuous positive airway pressure (CPAP) of 5–10 cmH_2O during facemask preoxygenation is advised.[13] Continuous positive airway pressure can help prevent the development of absorption atelectasis associated with breathing high concentration oxygen. Finally, if a nasogastric tube is present it should be aspirated and left open to air before RSII. The insertion and aspiration of a nasogastric tube before RSII can be considered in patients who are likely to a have a significant volume of gastric residue.

Table 2 MACOCHA score (score >2 predicts difficulty).[15]

Factors	Points
Mallampati class III or IV	5
Obstructive sleep **A**pnoea syndrome	2
Reduced mobility of **C**ervical spine	1
Limited mouth **O**pening <3 cm	1
Coma	1
Hypoxaemia	1
Non-**A**naesthetist	1

Equipment

Minimum monitoring, as described by the Association of Anaesthetists, should be applied to the patient before RSII. Waveform capnography is essential to confirm correct tracheal tube placement. The insertion of an arterial cannula for invasive blood pressure measurement is recommended in patients with haemodynamic instability. Central venous access may also be required for vasoactive infusions in the critically ill. A functioning airway suction device should be available and placed under the patient's pillow. The presence of two active suction catheters is recommended if significant airway contamination is likely. A recent Cochrane systematic review concluded that when compared with direct laryngoscopy, videolaryngoscopy results in higher rates of successful

Table 3 Medications for rapid sequence induction and intubation.

Indication	Medication	Dose	Specific considerations
Induction	Etomidate	200–300 μg kg^{-1}	Consider in patients with hypovolaemia or circulatory shock
	Propofol	1–3 mg kg^{-1}	Universal intravenous induction agent but can cause significant cardiovascular depression
	Thiopental	3–5 mg kg^{-1}	Consider in patients in refractory status epilepticus
	Ketamine	1–2 mg kg^{-1}	Consider in patient with hypovolaemia, circulatory shock or life-threatening asthma
Neuromuscular blocking agent	Suxamethonium	1–2 mg kg^{-1}	Avoid in patients with hyperkalaemia, crush injuries and more than 24 h after severe burns
	Rocuronium	1–1.2 mg kg^{-1}	Reversible with sugammadex 16 mg kg^{-1}
Optional adjuncts	Fentanyl	1–3 μg kg^{-1}	To attenuate the sympathetic response to laryngoscopy.
	Alfentanil	10–50 μg kg^{-1}	Consider in patients with raised intracranial pressure, malignant hypertension, aortic dissection, pre-eclampsia/eclampsia or significant cardiovascular disease
	Remifentanil	1 μg kg^{-1}	
	Lidocaine	1–1.5 mg kg^{-1}	

tracheal intubation on the first attempt.[20] A videolaryngoscope may be advantageous for RSII if difficulty is anticipated providing the operator is familiar with its use. A tracheal tube introducer, such as a bougie, should be immediately available to assist tracheal intubation.

The ideal medications to induce anaesthesia in the setting of RSII are specific to the patient and the situation. Whichever agents are used, it is established practice to use predetermined doses of an intravenous anaesthetic agent and a neuromuscular blocking drug in immediate succession. The combination of thiopental and suxamethonium is being replaced with agents such as propofol and rocuronium. Although not described in classical RSII, using opioids to blunt the sympathetic response to laryngoscopy has become common practice, though this remains optional. The use of a rapid acting neuromuscular blocking drug is mandatory. The choice between rocuronium and suxamethonium is a source of debate and has been discussed recently in this journal.[21] Table 3 summarises potential choices of medications for induction and neuromuscular block in RSII. The dose for each adjunct and induction medication is given as a range and must take account of the specific clinical context and cumulative effect if multiple agents are used. Conservative doses are required in patients who are older, frail or hypovolaemic.

The team

Rapid sequence induction and intubation for an elective case may involve only the anaesthetist and a trained assistant. The conduct of RSII in the critical care setting necessitates a larger team. In such cases, the following roles should be assigned before commencing the procedure:

(i) Airway management/intubator
(ii) Airway assistant/application of cricoid pressure
(iii) Team leader/medications/monitor/second intubator
(iv) Runner (any healthcare staff member who can reliably fetch equipment)

Perhaps the most debated element of RSII is the application of cricoid pressure. Cricoid pressure involves applying force to the cricoid cartilage in an attempt to compress the oesophagus between the posterior cricoid ring and the body of the fifth cervical vertebra. Sellick proposed that pulmonary aspiration could be prevented by compression of the oesophagus; however, a number of subsequent studies involving radiological imaging have concluded that this is unreliable.[22] The oesophagus appears to reside posterolaterally to the cricoid cartilage in many humans and cricoid pressure simply results in further lateral displacement of the oesophagus. Direct compression may not be the actual mechanism by which cricoid pressure works. It is possible that cricoid pressure actually prevents regurgitation through occlusion of the postcricoid hypopharynx. A Cochrane review conducted in 2015 concluded that no randomised controlled trial exists to support or refute the use of cricoid pressure.[23] In the absence of such evidence, when considering the potential benefits, many experts continue to recommend the use of cricoid pressure.[24]

Several techniques to apply cricoid pressure are described in the literature. Correct identification of the cricoid cartilage is essential. The cricoid cartilage is found in the midline of the neck, inferior to the thyroid cartilage. Cricoid pressure involves the application of vertical, downward pressure using the thumb and first or middle finger. A force of 10 N is applied when the patient is awake, and increased to 30 N once the patient becomes unresponsive.[25] The pressure is maintained until inflation of the tracheal tube cuff and confirmation of successful placement with waveform capnography.

The application of cricoid pressure is associated with difficulty in facemask ventilation and placement of supraglottic airways. Recently a randomised controlled trial involving 3,472 patients undergoing RSII found pulmonary aspiration occurred in 10 patients (0.6%) in the group receiving cricoid pressure and in 9 patients (0.5%) in the control group.[26] Laryngoscopy was more difficult and intubation times were longer in the group receiving cricoid pressure. Studies concerning the performance of cricoid pressure by clinicians suggest that's its use is inconsistent. A survey of anaesthetists in the UK identified significant variability around the timing of its application.[27] There is also concern that applying cricoid pressure can cause relaxation of the lower oesophageal sphincter, thereby increasing the risk of passive regurgitation. Although its use remains controversial, it is recommended that if difficulty is encountered with airway management cricoid pressure should be released. Educating staff to apply cricoid pressure correctly is a further challenge. Training can be facilitated with the use of a biofeedback device, which indicates the amount of pressure applied in a simulated setting.

Such equipment can be purchased or constructed locally with clinical equipment found in any anaesthetic department.[28]

The ergonomics of the patient, equipment and team should also be considered. If possible all team members should be able to view the patient monitor. If a second intubator is present they should be positioned appropriately, facilitating rapid handover if necessary. The monitor's pulse oximeter tone should be audible, and this may require adjustment in the critical care or emergency department setting.

Prepare for difficulty

An airway plan should be shared with the team members before RSII. The presence of all of the equipment necessary to execute the airway plan must be confirmed before commencing the procedure. In the event of failed intubation, the team should focus on rescue oxygenation. This will include facemask ventilation or the placement of a supraglottic airway. Gastric insufflation during facemask ventilation can be reduced by:

(i) Maintaining a patent airway, with airway adjuncts and two-handed technique if necessary.
(ii) Restricting peak inspiratory pressures to 15 cmH_2O or less during positive pressure ventilation.

The specific clinical context will determine if it would be appropriate to wake the patient in the event of failed intubation. If the procedure is elective this may be possible, but it is unlikely to be an option for time-critical surgery.

RSII in special groups

Current evidence suggests the use of classical RSII in paediatric anaesthesia is limited. A survey of British anaesthetists identified only half would use the classical RSII to intubate a child with a 'full stomach'.[29] The various anatomical and physiological differences in infants and children make the classical approach less favourable have been described previously in this journal.[30] Conversely, the use of RSII in obstetric anaesthesia has persisted. To avoid desaturation adequate preoxygenation, gentle bag-mask ventilation and apnoeic oxygenation are all recommended during RSII in obstetric anaesthesia. Furthermore, because of the higher incidence of difficult airway in obstetric practice, it is suggested a videolaryngoscope be used as first line.[31]

Defining RSII

The PUMA group is an international collaboration of experts who have proposed a set of universal principles for the conduct of RSII.[12] The principles (listed in Table 4) include recommended, suggested and optional components of the procedure based on consensus and the current evidence base. Project for Universal Management of Airways recommend 10 core elements that must be completed to meet the definition of RSII. Steps applicable to a standard induction of anaesthesia such as monitoring do not feature as they are not specific to RSII. The suggested components should be included but may be omitted in specific situations. The optional components are elements of the procedure for which supporting evidence is weak. This allows a practitioner to use their judgement for certain components depending on the context.

Future directions

Several developments concerning RSII are ongoing. The use of paratracheal force has recently been suggested as an alternative to cricoid pressure. Paratracheal pressure has been associated with a reduction in gastric insufflation of air during positive pressure ventilation and the effects on view at laryngoscopy may be non-inferior compared with cricoid pressure.[32] The investigators also reported easier bag-mask ventilation and lower peak inspiratory pressures in the paratracheal force group. The use of ultrasound to evaluate residual gastric volume is also being explored. Gastric ultrasound could contribute to the assessment of aspiration risk for individual patients. A retrospective cohort study of fasted elective surgical patients using point-of-care ultrasound involving 538 patients found that 6.2% presented with a 'full stomach'.[33] Furthermore, a randomised controlled trial involving healthy volunteers and blinded sonographers found

Table 4 Project for Universal Management of Airways (PUMA) universal principles for rapid sequence induction. NMBA, neuromuscular blocking agent.

Recommended	Suggested	Optional
Preoxygenation	Apnoeic oxygenation during attempts at laryngoscopy	Prokinetic drugs
Suction turned on and placed under the pillow	Able to adopt Trendelenburg position if regurgitation occurs	Non-particulate or intravenous antacids
Confirmed and reliable intravenous access	Suction and leave open to air an in situ nasogastric tube	Nasogastric tube placement and suction
Tracheal introducer prepared		Avoid agents with potential sedative or hypnotic effects before induction
Predetermined dose of induction agent		Avoid facemask ventilation before laryngoscopy
No latency between giving induction agent and NMBA		Position change
Use of rapid-onset NMBA		Cricoid pressure
Apnoeic oxygenation between attempts at laryngoscopy if facemask ventilation not used		
Confidence in complete paralysis before instrumenting airway		
Tracheal tube cuff inflation before positive pressure ventilation		

that gastric ultrasound is highly sensitive and specific when identifying residual gastric content.[34] Fifty years after RSII was first described it continues to evolve. The addition of the PUMA universal guidelines will address the variability observed in current practice and offer a clear definition for this procedure. Future studies will need to assess if these developments reduce the incidence of pulmonary aspiration and the associated mortality and morbidity.

Declaration of interests

EPO is a former president of the Difficult Airway Society, past president and current airway advisor to the College of Anaesthesiologists of Ireland, and is on the working group of PUMA. JC declares that they have no conflicts of interest.

MCQs

The associated MCQs (to support CME/CPD activity) will be accessible at www.bjaed.org/cme/home by subscribers to *BJA Education*.

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