Airway Management of the Critically Ill Patient: Modifications of Traditional Rapid Sequence Induction and Intubation

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Discussion about airway management is common amongst clinicians involved in critical care, regardless of background. The technique of rapid sequence induction and intubation (RSI) was described in 1970 and there are many accepted variations in modern day practice. Sadly this can lead to difficulty, particularly in the event of an airway misadventure, as clinicians may be subject to post hoc critique from expert opinion in other disciplines, and often held to a 'standard' of RSI that no longer exists. Experts may differ in opinions, and expertise in one arena may not translate to another. This paper outlines the variations in RSI practice and the rationale for deviation. Such discussion is necessary, as expert opinion referring to a 'standard' RSI may be inappropriate for the critically ill patient, exposing practitioners to medico-legal risk. Acknowledgement of variations in RSI practice allows the development of institutional procedures, with potential for future consensus recommendations guided by both published studies and expert opinion.

Keywords: Airway management; Rapid sequence induction; Endotracheal intubation; Emergency intubation; Difficult airway

Introduction

Rapid sequence induction and intubation (RSI) has been considered the gold standard in emergency airway management. Core elements of the classical RSI include rapid induction of anaesthesia followed by administration of a paralysing agent, techniques to minimise aspiration risk and a goal of first pass placement of a cuffed endotracheal tube in the trachea.

There is evidence for variation in how individuals, institutions and nations practice RSI [1]. The technique of RSI is centred around reduction of risk; that of regurgitation/aspiration, and that associated with the procedure itself, including failure to rapidly secure the airway, hypoxia, airway trauma, and hypotension from induction agents. Analysis of airway complications reveals a higher incidence of difficulty in intensive care unit (ICU) and emergency department (ED) intubations than in the operating theatre (OT) (incidence of death or brain damage 38-fold higher in the ED and 58-fold higher in the ICU compared with OT) [2–4].

RSI is a technique utilised by clinicians in anaesthesia, emergency medicine, and intensive care, both in hospital and in the prehospital environment [5]. Variations in RSI are inevitable given the heterogeneous mix of patient pre-morbid physiology, RSI operators, teams, environment and available options. Indeed it is appropriate that RSI is modified to the circumstances, particularly in the critically ill patient [6]. Unfortunately, the existence of such appropriate heterogeneity in practice can lead to criticism, whether between clinical experts, between health institutions, between medical specialties or in the medico-legal arena [7–9].

It is not the purpose of this paper to outline a uniform standard for RSI; rather to explore issues pertaining to expertise, to discuss recognised variations in components of the RSI technique and to advocate for pragmatic modifications for RSI in the critically ill patient.

Individual organisations may wish to use this as a guide to formulate institutional standard operating procedures for RSI of the critically ill, as well as for training programs for those involved in emergency RSI, thus helping to mitigate recognised complications of airway management.

The dilemma of defining an expert

Anaesthetists are traditionally regarded as the experts in airway management, reflecting the duration of their training and pivotal role in airway management. Nevertheless, airway management is a core skill of staff in other disciplines, particularly those who are actively involved in resuscitation and emergency management, or in circumstances where a specialist anaesthetist is not immediately available. The appropriate degree of diligence and expertise is expected from all providers caring for the critically ill, whether anaesthetist, intensivist, emergency physician, rural proceduralist, retrieval nurse practitioner or prehospital paramedic.

Inevitably there will be differences of opinion between experts, with previously 'indisputable truths' in difficult airway management having been challenged in recent times [10]. This lack of scientific consensus is problematic. In the case of an airway catastrophe, expert witnesses are usually drawn from those who may refer to classical RSI, reflecting their own traditional teaching, not the current practice of modified RSI in the critical care arena. There are documented medico-legal critiques leading to censure, including expert opinion that it was negligent to fail to pass a nasogastric tube pre-RSI, inappropriate use of a bolus dose of induction agent, and negligent to omit cricoid force during RSI [11, 12]. Post hoc expert criticism can be catastrophic for individuals. It is more appropriate to refer to the expertise of highly-trained peers regularly practicing in a similar environment. This requires acknowledgement of variations in practice in emergency airway management, whether in operating theatre, emergency department, intensive care, prehospital or in situations limited by available resources. Moreover there is heterogeneity in expert opinion and Cook *et al* have previously described the difficulties of contrary expert opinion in airway management, with implications for incident review, medico-legal claims and closed claim analysis [13].

Rapid Sequence Induction and Intubation: a standardised process or not?

Basic airway management (maintenance of oxygenation and ventilation) by use of adjuncts such as suction, oro- and nasopharyngeal airways, bag-mask ventilation and even placement of a laryngeal mask in the truly obtunded is well within the expected competency of all clinicians working in acute care. However, RSI is expected of advanced airway practitioners, with indications including:

- failure to maintain airway patency by other means

- failure of airway protection

- failure of ventilation or oxygenation

- for anticipated clinical course

- to facilitate transportation

- for humanitarian reasons

The original 15-step technique of RSI was described in 1970 [14], yet this form of RSI is not uniformly applied in modern practice [15] and nor should we expect it to be. Advances in equipment, induction drugs and paralysing agents have allowed refinement of the technique over time, with RSI modifications made as appropriate to the clinical circumstances of individual patients, to the skill mix of airway teams and to the environment in which airways are managed.

Therein lies the difficulty. Despite the universal acceptance of RSI as the 'gold standard' in securing the airway in a critically ill patient, the actual components of RSI are known to differ markedly between individuals, institutions and countries, as well as between practitioners in different arenas (prehospital, ED, ICU or OT) [1, 16, 17]. Documented modifications to RSI technique include patient position, pre-oxygenation strategies, pre-RSI decompression of gastric contents with a nasogastric tube, choice and method of administration of induction agent, application of cricoid pressure, choice of paralysing agent, use of manual ventilation and options for failed RSI (not least whether awakening is an option) [18]. However the key elements of RSI remain, namely:

- pre-oxygenation or denitrogenation to prolong time to critical desaturation

- prevention of hypoxia and hypotension during the induction and intubation sequence

- passage of a cuffed endotracheal tube with confirmation of placement

In short, a refinement of the classical RSI technique as defined by Stept and Safar [14] is called for, with a need for a consensus position allowing for variation in the practice of RSI between experts, as governed by the requirements of the patient, team and clinical circumstances. Accepted practice variation should be understood in the context of both the need to minimise aspiration risk and to avoid complications of the RSI technique itself.

RSI of the Critically Unwell Patient

Airway Team and Dynamics

Regardless of the individual expertise of the intubator, team factors will impact on performance of the RSI process. Team members should be adequately trained prior to involvement in airway management, preferably involving simulation training under increasing degrees of cognitive load to allow a degree of 'stress inoculation' and to reinforce the importance of human factors in performance [19].

Use of a standardised approach to RSI may be appropriate within an institution or service [6, 20]. A challenge-response RSI checklist is recommended [21], but any such checklist should be short, clear and contain a check only of essential items. Checklists should be designed to be read aloud to verify 'essential items completed' rather than being presented as a 'how to cookbook'. Completion should take no more than 60 seconds and the process can be completed during pre-oxygenation [22]. For austere environments, or RSI where assistants may be unfamiliar, this checklist can be combined with a shadow board kit dump (Figure 1) to ensure all of the required equipment is readily available [23].

Roles should be clearly assigned prior to performing RSI and will usually include: intubator, airway assistant, provision of manual in-line immobilisation (if required) and someone responsible for giving medications. A 'reader' may be assigned for reading of both a pre-RSI challenge-response checklist and for crisis management checklists in case of difficulty [24].

Airway teams should regularly engage in simulation training, using their own equipment and personnel, simulating both common and uncommon scenarios. This may include common critical care presentations, but will also incorporate changes in team members, equipment failure and other measures to encourage understanding of human factors in team performance.

RSI CHALLENGE-RESPONSE

Monitoring - BP, ECG, SpO2, ETCO2	CHECK
Nasal Cannulae at 15l/min PLUS Mask O2	CHECK
Pre-oxygenation for FOUR minutes	CHECK
Suction checked working & available	CHECK
Patient Positioned? RAMP OBESE	CHECK

IV & DRUGS

IV Cannula connected to fluid & running	CHECK
NIBP on contralateral arm and BP seen	CHECK
Spare cannula in situ	CHECK
INDUCTION AGENT drawn up, dose checked	CHECK
SUX or ROC drawn up, dose checked	CHECK
VASOPRESSORS drawn up, labelled	CHECK
POST INTUBATION drugs drawn up & labelled	CHECK

INTUBATION EQUIPMENT

BVM connected to oxygen	CHECK
Guedel & two NPO airways available	CHECK
Laryngoscope blade chosen, light working	CHECK
ET tube size chosen, cuff tested	CHECK
ETT preloaded on bougie, Kiwi Grip	CHECK
Alternate tube size chosen & cuff tested	CHECK
Syringe for cuff inflation	CHECK
Stylet & Rapi-Fit Bougie connectors available	CHECK
Gooseneck, filter, inline ETCO2	CHECK
Tube Tie & Tape available	CHECK
Ventilator settings determined	CHECK
Difficult airway plan's A, B, C, D discussed	CHECK
LMA, iLMA and Surgical Airway available	CHECK

TEAM BRIEF

In-line immobilisation person briefed	CHECK
Cricoid pressure person briefed	CHECK
Drug giver briefed	CHECK
Anticipated problems & post RSI care brief	CHECK
Ventilator settings determined & switched on	CHECK
TIME OF INTUBATION NOTED & 30 sec DRILLS	CHECK

NASO-PHARYNGEAL & ORO-PHARYNGEAL AIRWAYS

ET ADAPTOR, IN-LINE FILTER and ETCO2 LINE or EASYCAP

SELF-INFLATING BAG-VALVE-MASK CONNECTED TO HIGH FLOW OXYGEN consider using PEEP Valve

plus

NASAL SPECS DURING INTUBATION for Apnoeic Diffusion Oxygenation

TWO ET TUBES OF APPROPRIATE SIZE

CONSIDER LOADING A STRAIGHT-TO-CUFF ATRAUMATIC STYLET

LUBE

10 or 20 ml syringe

TAPE | TIES

SUCTION (confirm working then place under pillow)

DRUGS
INDUCTION AGENT
SUX or ROC
VASOPRESSOR
FLUIDS RUNNING

LARYNGEAL MASK AIRWAY - Classic / Supreme / iLMA (FastTrach or AirQ-II)

PLAN FOR FAILED RSI ?

KING VISION VL

DIFFICULT AIRWAY TROLLEY AVAILABLE ?

15 l/min O2

RapiFit Connectors for Frova Bougie

LARYNGOSCOPE with WORKING BULB & APPROPRIATE BLADE

BOUGIE with COUDE TIP (or can use FROVA OXYGENATING BOUGIE)

30 degree Coude tip

SURGICAL AIRWAY : CTM marked? Prepared to use SCALPEL-Finger-Size 6.0 ETT

Figure 1. Shadow Board Kit Dump with Challenge-Response Checklist

Airway Planning

Pre-RSI briefing should include planning for anticipated difficulties. Difficult airway plans usually include direct laryngoscopy for endotracheal intubation as the primary plan, with backup which may include alternative devices such as videolaryngoscopes or an intubating laryngeal mask to maintain oxygenation and facilitate subsequent intubation. Rescue ventilation via bag-mask or supra-glottic devices may be required as a bridge, but if they fail the team should be prepared to perform an emergency surgical airway.

Guidelines exist for management of the difficult airway and airway plans should be tailored to the availability of such equipment within an institution or location, as well to the anticipated clinical course [25]. Standard difficult airway plans which incorporate options to 'awaken the patient and abandon the procedure' may be wholly inappropriate due to the immediate need to secure an airway in the critically ill. An example of an institutional airway plan is shown in Figure 2.

In certain circumstances, such as anticipated failed intubation and rapid desaturation, it may be necessary to consider a 'double set up' approach, with one initial attempt at laryngoscopy and intubation before progressing to an emergency surgical airway. In cases of anticipated difficulty the cricothyroid membrane may be identified prior to RSI (clinically or with ultrasound) and marked using an indelible marker [26]. Identification of the cricothyroid membrane has obvious advantages, both to overcome the recognised cognitive hurdle to establishing an emergency surgical airway and to aid identification of the cricoid cartilage if cricoid pressure is to be applied by an inexperienced assistant.

Patient Positioning, Optimisation and Monitoring

Stept and Safar described RSI with the patient in a recumbent position, with legs raised (an attempt to counteract hypotension) and the trunk raised 30 degrees (to counteract regurgitation) [14]. However Sellick described the procedure of cricoid pressure in a steep head-down position with head and neck extended, ostensibly to tether the oesophagus to vertebral bodies in order to minimise aspiration [27].

Most clinicians perform RSI in the supine position. In the bariatric patient, 'ramping' of the upper body to around 45 degrees may be required to improve functional residual capacity, via displacing the weight of the anterior chest wall off the thoracic cavity and the weight of the intra-abdominal contents off the diaphragm. This ramped position is often referred to as the ear-to-sternum position as it results in the external auditory meatus being at the same horizontal level as the sternum. Head up positioning may be preferable for the non-hypotensive head-injured patient, to improve venous outflow from the brain, thus helping to reduce intracranial pressure [28]. It may also improve respiratory dynamics for pre-oxygenation [29].

The head up position has been suggested as an alternative, or in addition to, the application of cricoid pressure in reducing passive regurgitation. However, if the patient vomits it theoretically increases the chances of aspiration from the effects
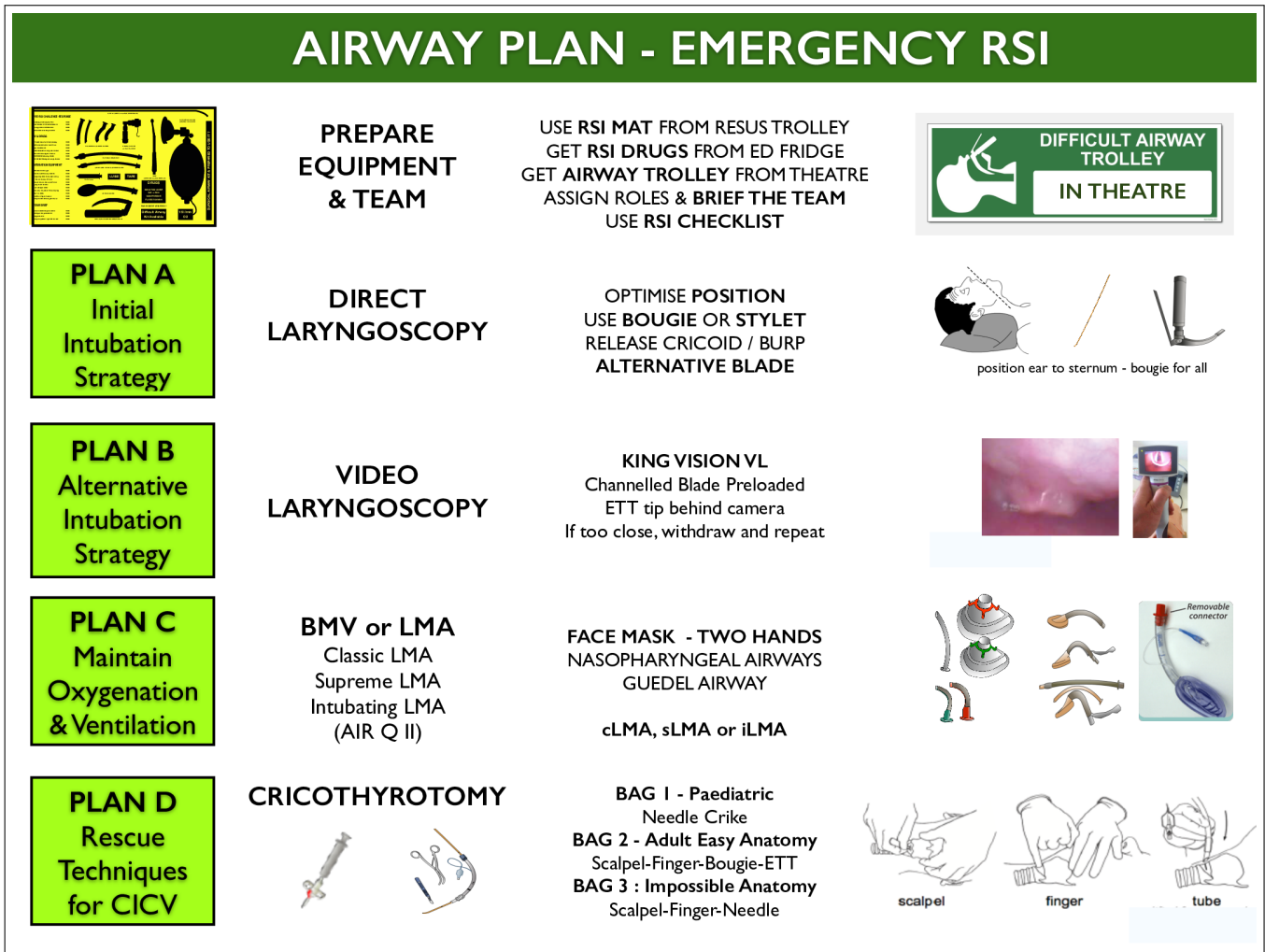
AIRWAY PLAN - EMERGENCY RSI

	PREPARE EQUIPMENT & TEAM	USE **RSI MAT** FROM RESUS TROLLEY GET **RSI DRUGS** FROM ED FRIDGE GET **AIRWAY TROLLEY** FROM THEATRE ASSIGN ROLES & **BRIEF THE TEAM** USE **RSI CHECKLIST**	**DIFFICULT AIRWAY TROLLEY IN THEATRE**
PLAN A Initial Intubation Strategy	**DIRECT LARYNGOSCOPY**	OPTIMISE **POSITION** USE **BOUGIE** OR **STYLET** RELEASE CRICOID / BURP **ALTERNATIVE BLADE**	position ear to sternum - bougie for all
PLAN B Alternative Intubation Strategy	**VIDEO LARYNGOSCOPY**	**KING VISION VL** Channelled Blade Preloaded ETT tip behind camera If too close, withdraw and repeat	
PLAN C Maintain Oxygenation & Ventilation	**BMV or LMA** Classic LMA Supreme LMA Intubating LMA (AIR Q II)	**FACE MASK - TWO HANDS** NASOPHARYNGEAL AIRWAYS GUEDEL AIRWAY **cLMA, sLMA or iLMA**	Removable connector
PLAN D Rescue Techniques for CICV	**CRICOTHYROTOMY**	**BAG 1 - Paediatric** Needle Crike **BAG 2 - Adult Easy Anatomy** Scalpel-Finger-Bougie-ETT **BAG 3 : Impossible Anatomy** Scalpel-Finger-Needle	scalpel finger tube

Figure 2. Example Airway Plan

of gravity, rather than particulate matter draining from the mouth.

Pregnant patients should be positioned in left lateral tilt and/or the uterus manually displaced to avoid aortocaval compression. Regardless of whether positioned supine, head up to limit regurgitation, head down to limit aspiration or in a left lateral position if pregnant, working suction should always be available.

For those in whom ear-to-sternum positioning is contraindicated (suspected spinal injury or musculoskeletal abnormality limiting spinal mobility), head position should minimise unnecessary flexion-extension or lateral rotation. Spinal precautions should be observed for the trauma patient, which may include manual inline stabilisation or use of an occipital pad to optimise laryngoscopy and minimise movement of the cervical spine [30].

Airway team members, monitors and equipment should be appropriately positioned to maximise visual cues and not hinder 360 degree access to the patient. Alarm limits should be pre-determined as appropriate for patient age and anticipated difficulties. Standard monitoring (oximetry, waveform end-tidal carbon dioxide, blood pressure and ECG) should be applied and abnormal physiology optimised pre-RSI wherever possible (where time permits this may include commencement of vasopressor infusions). A timer should be used both for pre-oxygenation and to facilitate rapid progression through agreed airway plans. Figure 3 illustrates an example set up.
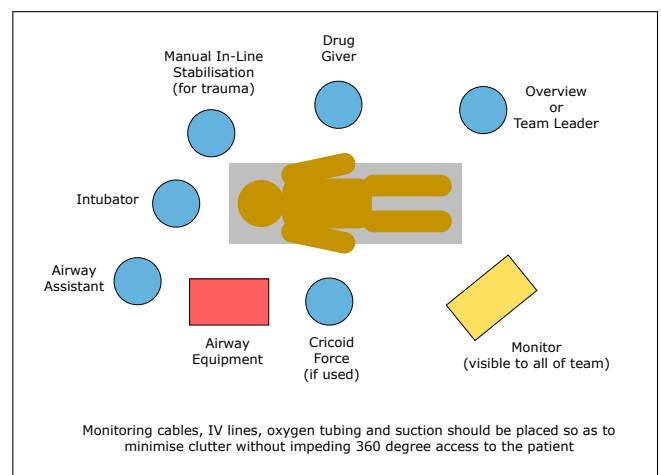

Figure 3. Example Equipment and Team Setup for Intubation

Avoidance of hypoxia and hypotension is essential in the critically ill patient. Pre-oxygenation strategies are discussed below. With regards to hypotension, many clinicians will consider the impact of induction and paralysis on both cardiac contractility and venous tone, along with effects of positive pressure ventilation, as mandating an intravenous fluid bolus to improve preload prior to induction, unless contraindicated.

Measurements of blood pressure should be made regularly, with either non-invasive blood pressure set to cycle at 1 minute intervals or placement of an arterial line if sufficient time allows.

Pre-oxygenation

The purpose of pre-oxygenation is to denitrogenate the lungs and create a reservoir of oxygen to allow a margin of safety before critical desaturation during attempts to secure the airway. An excellent summary of methods to maximise pre-oxygenation and prevent desaturation during emergency airway management is described by Weingart and Levitan [29]. Key steps include mandatory use of pre-oxygenation to extend safe apnoea time during RSI, along with appropriate positioning, and may involve the use of positive end-expiratory pressure (PEEP). The delivery of oxygen via nasal cannulae during intubation (apnoeic diffusion oxygenation) is increasingly being adopted for airway management of the critically ill patient [31].

The period of pre-oxygenation should adequately denitrogenate the lungs. An empiric approach applying high-flow oxygen for three minutes or eight vital capacity breaths is common anaesthetic practice. However, critically ill patients may require a longer period to denitrogenate and are often unable to perform eight vital capacity breaths. If available, measurement of expired end-tidal oxygen should be used as a guide to adequate pre-oxygenation, aiming for a value of at least 90% (FeO_2 of 0.9)

Pre-oxygenation technique may be governed by available equipment, personnel and patient requirements. Valid techniques include:

- use of a Mapleson B or C anaesthetic circuit. These lack the separate inspiratory or expiratory ports of traditional bag-valve-mask (BVM) devices, with exhaled gas flushed out of the circuit by high fresh gas flow via the pressure-release valve, ensuring maximal oxygen delivery [32].

- use of standard reservoir face masks on maximal oxygen flow and supplemented with nasal cannulae on maximal flow. This may be a preferred in the prehospital environment, where limitations of personnel preclude alternatives.

- use of standard bag-valve-mask devices commonly used in ED, ICU or by emergency medical services. Caution is needed as such devices may entrain room air during spontaneous ventilation [33]. Addition of a PEEP valve to the expiratory port of BVM assembly obviates this.

- use of existing non-invasive ventilation modes. For many critically ill patients, RSI may represent the end result of a failure of non-invasive ventilation (NIV). NIV masks may be left in situ and used to pre-oxygenate. CPAP/NIV may be very useful in pre-oxygenation of the morbidly obese patient.

On occasions, the combative patient (e.g. intoxicated, head injured, hypoxic) will thwart best attempts at both positioning and pre-oxygenation. Pre-treatment with small titrated aliquots of a sedative agent can be effective (so-called 'delayed sequence intubation'), with ketamine the preferred agent to facilitate assessment, monitoring, positioning and pre-oxygenation [34].

Choice and Timing of Induction Agent

Commonly used induction agents include thiopentone (as originally described by Stept and Safar), etomidate (not available in all countries), propofol, benzodiazepines such as midazolam (relatively slow onset compared to other agents) and ketamine. Ketamine is gaining favour within emergency and critical care circles due to relative cardiovascular stability [35]. It should be noted that all induction agents (including midazolam and ketamine) have potential for cardiovascular depression and hypotension if too high a dose is used. In addition, combinations of agents may be synergistic with amplification of effect. Previous concerns of deleterious effects of ketamine on intracranial pressure in head injury have been challenged and as such, use of ketamine has much to commend it for RSI in the critically ill patient [36].

Whilst the original description of RSI involved a bolus of thiopentone based on patient weight, such weight-based calculations may not be appropriate in critical illness due to adverse haemodynamic effects. Doses should be adjusted according to pre-RSI physiology, requiring dose-reductions to as little as 10% of standard induction doses for the critically ill patient with haemodynamic compromise [37]. Both bolus dosing and titration of induction agent to loss of consciousness have been described. Bolus dosing from a pre-drawn syringe has the advantage of rapidity; however, there is potential for either under- or overdosing, the former perhaps contributing to increased reports of awareness during RSI in trauma and obstetric patients, the latter risking haemodynamic compromise. Currently, there are no data to compare the potential aspiration risks of a longer induction time via dose-titration versus the risks of either awareness or haemodynamic instability with a predetermined bolus technique.

Clinicians will determine the optimal choice of induction agent for the situation, often guided by personal expertise, institutional guidelines, available agents and appropriate patient selection. Regardless of induction agent used, delay between administration, loss of consciousness and administration of paralysing agent may prolong the period of aspiration risk and increased the risk of desaturation.

Adjunct Opioid Agents

Adjunct agents are not described in the traditional teaching of RSI, yet many practitioners incorporate rapid acting opioids to attenuate the reflex sympathetic responses to laryngoscopy and intubation. This may be especially useful in critically ill patients with head injuries. Arguments against use of opioids include historical concerns due to slow onset and longer duration with older opioids, as well as concerns of decreased respiratory drive if intubation fails. This is less of a concern in the critically ill patient, as options to awaken the patient are generally not appropriate.

Lyon *et al* describe a modification of RSI technique using adjunctive fentanyl, along with ketamine induction and rocuronium paralysis within their prehospital service [38]. They note both superior intubating conditions and a more favourable haemodynamic response to intubation. Development of protocols for modified RSI within an institution, and their subsequent publication, is to be encouraged.

It should be noted that the use of opioids such as alfentanil and fentanyl may produce synergistic effects in combination with induction agents, and cautious dosing should be used in haemodynamically unstable patients to minimise hypotension.

Cricoid Force

Cricoid force has become an area of contention in airway management. Sellick's original description was of a 'firm' amount of pressure applied to the cricoid cartilage of a cadaver whilst in a steep head-down position to occlude the oesophagus and prevent regurgitation of fluid into the oropharynx [27]. The procedure was repeated during induction of 26 patients deemed at high-risk of aspiration. None experienced regurgitation with application of cricoid force; 3 experienced immediate reflux upon release of cricoid force after tracheal intubation. Cricoid force was incorporated into Stept and Safar's description of RSI and has since been considered an essential component. Refinements describe a force of 10N applied at the commencement of induction, increased to 30N with loss of consciousness [39]. Application of cricoid force remains a recommendation during RSI from the authors of the NAP4 audit in the United Kingdom [2].

However, application of cricoid force is not considered routine practice in some countries or organisations. There are concerns that cricoid force does not effectively occlude the oesophagus and thus prevent aspiration, is variably applied by assistants (often incorrect timing, incorrect position or force) and that cricoid force can impede view at laryngoscopy thus delaying first pass success [40–43].

Some have proposed that cricoid force is a low-risk procedure that works in a proportion of patients but is confounded by poor technique and relative infrequency of regurgitation. Thus, they propose application of cricoid force and early removal if this impedes laryngoscopy, if there is active vomiting, or if there is impediment of rescue ventilation via laryngeal mask airway or BVM [44, 45]. It can be argued that in certain arenas, particularly prehospital or with limited/untrained personnel (rural, small ED or ICU) application of cricoid pressure is more likely to hinder laryngoscopy and that the policy of 'apply, then release' adds additional cognitive load to an already high-stakes tightly-coupled procedure. On this basis, some airway experts may opt to omit cricoid force in such circumstances, based on limited evidence of efficacy and risk-benefit balance in regard to optimising first-pass intubation success [6, 46]. Meanwhile trials are under-way to test the hypothesis that use of cricoid force during RSI in ED does not prevent aspiration and investigate the effect of such force on difficult or failed intubation [47].

A decision not to apply cricoid force may be reasonable in airway management of the critically ill patient. It is recommended that any decision to use or omit cricoid force be supported by an institutional policy. Practitioners with clinical expertise in resuscitation are responsible for shaping such policy, mindful that this may differ from published national or international guidelines. Hence, despite a lack of absolute evidence of benefit, cricoid force may continue to be applied; reflecting medico-legal concerns as individual clinicians have been criticised for failing to apply cricoid force in post-event medico-legal dissection of airway catastrophes [12]. It is essential that any expert opinion on cricoid force, as indeed any other matter in RSI, acknowledges the existing variation in practice. At this point in time, the literature does not support evidence either for or against the application of cricoid force.

Paralysis

Use of succinylcholine (a depolarising neuromuscular blocker) as the preferred agent to facilitate vocal cord relaxation and endotracheal tube passage has been the accepted norm for RSI, with traditional teaching being that the short duration of action will allow return of spontaneous ventilation in the case of a failed RSI. Whilst awakening may be an option for some patients in the operating theatre, it is rarely the case for the unfasted, haemodynamically-compromised patient for whom RSI represents a commitment to securing the airway.

Rocuronium at a dose of 1.6 mg/kg gives the same onset of muscle relaxation as succinylcholine and is suggested as the preferred choice of non-depolarising neuromuscular blockers for RSI in the critically ill [48]. A commitment to full paralysis and rapid progression to a surgical airway in the case of failed intubation and ventilation in the critically ill patient is congruent with pre-agreed airway plans between team members, appropriate for the patient (whose pathology requires a cuffed tube in the trachea by whatever means) and avoids the possibility of attempting a surgical airway in a combative, coughing patient.

Manual Ventilation between Induction and Intubation

Manual ventilation has traditionally been avoided in classical RSI, due to concerns of gastric insufflation and aspiration. However, gentle ventilation has been advocated in both obstetric and paediatric RSI due to concerns of rapid desaturation in these populations [49]. Anecdotal evidence from experienced resuscitationists includes use of gentle manual ventilation whilst awaiting onset of paralysis as a 'do least harm' approach. A decision on whether to gently ventilate will be guided by aspiration risk - the patient with ileus, with gastroparesis or with upper gastrointestinal bleeding is clearly at higher risk than the fasted patient. For the critically ill patient, risks of hypoxia and hypercapnia may require gentle manual ventilation. Critically ill patients commonly have an existing metabolic acidosis with respiratory compensation, and periods of apnoea can result in significant reductions in pH which amplify haemodynamic risk. Manual ventilation attempts should be initiated with pressures less than 15 cmH$_2$O to minimise gastric insufflation [50]. There is potential for the use of adjuncts such as automatic, low pressure, constant flow ventilation devices to minimise ventilation pressures during RSI [51].

Maximising First-Pass Success

It is important to appreciate that repeated attempts at laryngoscopy may increase rates of aspiration [52]. Thus, maximising the potential for first pass success is essential in RSI of the critically ill patient.

Direct laryngoscopy using an appropriate blade and light source (modern day LED optics offer excellent illumination and contrast) remains the cornerstone of intubation. Careful and sequential visualisation of landmarks and avoidance of repeated attempts causing airway trauma are key skills [53].

Adjuncts such as a bougie or malleable stylet are commonly used in cases of difficult intubation. For intubation of the critically ill patient, such adjuncts should be used routinely. Understanding appropriate use is vital as infrequent users may not appreciate the nuances of these devices, which are designed to facilitate navigation to the laryngeal inlet in difficult cases.

Stylets, if used, should be shaped 'straight-to-cuff' i.e. the stylet should remain straight as far as the proximal part of the endotracheal tube cuff where it should be angled to no more than 35 degrees (angles beyond 35 degrees increase difficulty) [54]. Traditional teaching has been to avoid pre-loading endotracheal tubes onto bougies, as the weight of the tube may impair control of the bougie tip; however, hang-up of the bougie on the endotracheal tube connector may impede
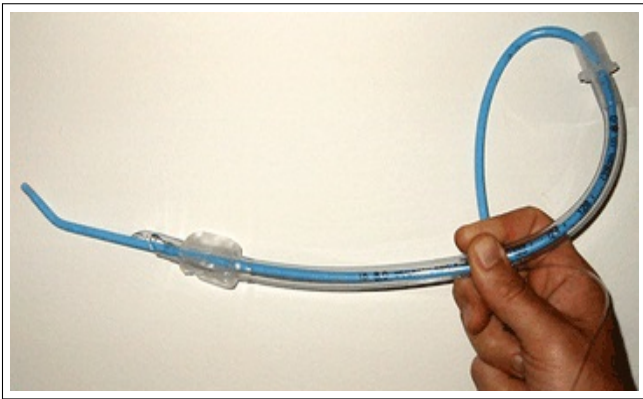
Figure 4. Endotracheal Tube Pre-loaded on Bougie

Figure 5. The Vortex Cognitive Aid

Figure 6. Vortex Optimisation Strategies. OPA oropharyngeal airway; NPA nasopharyngeal airway; FM facemask; VL video-laryngoscope; BZD benzodiazepine; NMBD neuromuscular blocking drugs; GZ green zone

smooth rail-roading of the endotracheal tube, causing delay in tube passage and risking a loss of situational awareness in the operator. A refinement is to pre-load an endotracheal tube onto a bougie and hold them in such a grip that control of the bougie is maintained during navigation to the laryngeal inlet (Figure 4).

It is not uncommon for the leading edge of bevel-shaped endotracheal tubes to hang up on the right arytenoid cartilage; gentle slight withdrawal and a counter-clockwise rotation of the endotracheal tube/bougie complex allows the free-edge to enter the glottic opening and advance.

Some advocate the use of video-laryngoscopy over direct laryngoscopy, particularly for a known or anticipated difficult airway [55]. Currently there is a plethora of available devices available. Cited advantages include improved view of the glottic opening for difficult airways, allowing other members of the team to visualise tube passage, and potential for recording of intubation procedures for audit and training [56]. Videolaryngoscopy may afford better visualisation of the glottic opening in a difficult airway; caution is recommended as a better view with some devices does not translate to easier tube passage unless the operator is experienced in use of the particular device. Additional caveats include cost, poor performance in the presence of blood/secretions and many require a different technique to traditional direct laryngoscopy.

The optimal video-laryngoscope would be low cost, have the same technique as standard direct laryngoscopy, have similar blade geometry and tube passage, perform well in the presence of both a soiled airway and in the presence of bright sunlight. At present no such device exists. If a video-laryngoscope is used, operators must be fully aware of nuances of the device and be trained to use in elective settings prior to an emergency [57].

Failed RSI

A difficult airway plan should be discussed and a checklist should be completed prior to RSI such that a shared mental model of actions to be undertaken exists between team members, both for routine and in case of difficulty [13, 58]. Many such difficult airway plans exist [59, 60].

Another cognitive aid showing promise is The Vortex Approach (Figures 5 and 6).

The Vortex approach is designed to optimise rescue techniques whether through endotracheal intubation, placement of a supra-glottic airway or rescue bag-mask ventilation [61, 62]. Time-limited drills should be agreed prior to RSI and then completed sequentially. In a 'cannot intubate, cannot oxygenate' situation the operator is prompted towards establishment of a surgical airway.
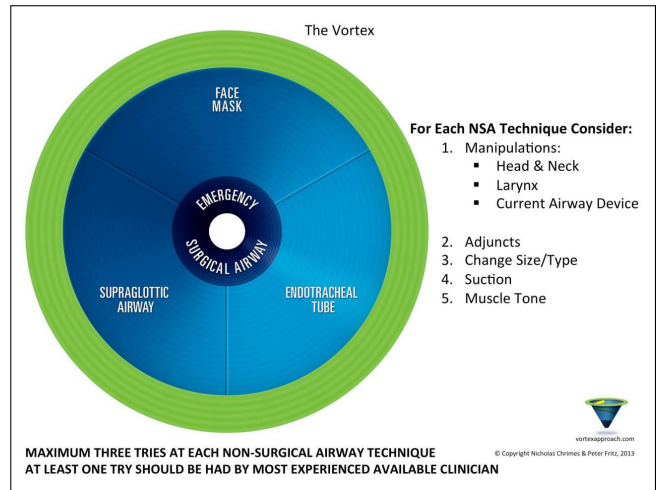
Standards exist for equipment to manage the difficult airway and such equipment should be available wherever airways are managed [63]. Regular practice of RSI competency and airway planning using simulation is a hallmark of a well-functioning airway team. Such rehearsal may facilitate swift transition through airway plans and crisis algorithms, with early use of appropriate equipment and decisions [24]. In particular, rescue surgical airway techniques must be regularly practiced as they are infrequently used in anger and as such remain a common area of unease.

Post-Intubation Care

Once the trachea has been intubated and endotracheal tube cuff inflated, placement should be confirmed with waveform end-tidal CO_2 (colorimetric devices, although inferior, will suffice if waveform end-tidal CO_2 is unavailable). Potential exists for haemodynamic instability post-RSI; whilst efforts may have been made to mitigate against this (e.g. preloading fluid and dose reduction in the haemodynamically compromised, use of adjunct opioid to blunt response to intubation in the head injured), post-RSI monitoring of heart rate and blood pressure

is vital. The combination of worsening acidosis from peri-intubation apnoea, the presence of hypovolaemia, the impact of induction agents on cardiac contractility and vasomotor tone, and the effects of over-zealous post-intubation ventilator settings on right ventricular preload (reduction) and afterload (increase) is a potent trigger for haemodynamic collapse. Post-intubation ventilation and sedation plans should be previously agreed during airway planning, and should be enacted. RSI of the critically ill patient may pose a challenge for the most experienced operators and care must be taken to avoid clinical inertia and to continue resuscitation and vigilant monitoring for complications [34].

Summary

Rapid sequence induction and intubation has evolved since the original description by Stept and Safar in 1970, with many practitioners using a modified RSI. Variations in technique exist between individuals, specialties, institutions and countries. Whilst some components of RSI are unchanged, refinements may be made as appropriate to the needs of individual patients, composition of airway team and the clinical environment. No doubt some of the current controversies in RSI will be resolved in time; meanwhile, the evidence-base for practice remains predominantly based on tradition and expert opinion (Level V evidence).

Although standardisation in procedures is to be applauded for the purposes of training, quality control and audit, the existence of variation between expert practitioners should not be a cause for inappropriate concern nor litigation. Sadly, post hoc analysis of adverse outcomes in emergency airway management may fail to acknowledge the accepted variations in RSI practice, with expert opinion on the same case differing widely due to individual preference, discordance in expertise between arenas and low quality evidence in the literature.

This paper discusses the variation in RSI practice and highlights specific measures for consideration in the critically ill. Acknowledgement and thorough understanding of available options in airway management of the critically ill patient should form a central component when training clinicians. In the absence of an agreed international standard for RSI and with documented variation in practice, this paper may form the basis for development of agreed procedures at the level of institutions or organisations, as well as guide future medico-legal opinion. Opportunity exist for development of consensus recommendations for airway management in the critically ill, based on both published literature and Delphi methodology [64].

Acknowledgements

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