Difficult Airway and Oxygenation – Issues and Controversies: a review of the evidence.

Dr Roger Swift, SCGH ED, June 2016

The first aim of airway management is to maintain oxygenation

Preface

There have been several issues recently regarding airway management that I feel are worthy of closer consideration;

1. Assessment of the airway - What is the utility of the current 'standards' of airway assessment?
2. Positioning of the patient for optimal airway management and RSI
3. Oxygenation – How do we deliver high FiO_2?
4. RSI planning – the 'ABCD' paradigm

This is a review of the relevant literature regarding these points. Notably, much of the evidence in borrowed from Anaesthetics research rather than from management of patients in the ED.

1. Assess Airway

The usefulness of current methods of assessment for difficult airway has been questioned for more than a decade.[1] There is mounting evidence and opinion to indicate that current, common methods of identifying the difficult airway have both low sensitive and specificity. For instance, in a 2015 study from the Danish Anaesthetic Database, 93% of difficult airways were not predicted by standard methods. Of those patients assessed as difficult before intubation, only 25% were difficult in practice. Difficult mask ventilation was unanticipated in 94% of cases.[2] This is supported by other research.[3, 4, 5] Applying the anaesthetic techniques of airway assessment are specifically difficult in the ED because of factors such as; unconscious or uncooperative patients, cervical immobilisation, and lack of time (clinical urgency).[6] Also, there is a limitation of alternative intubation procedures. Despite this, traditional methods of airway assessment are still advocated in emergency medicine literature.[7, 8]

Also, traditional assessment of airway difficulty only considers patient factors;

> "… in current scoring systems, non-patient related factors that may complicate airway management and threaten patient safety are missing: experience; time pressure; available equipment; location; and human factors." [9]

In regard to non-patient factors and for those who like mnemonics;

Table 1 Complexity factors that may be a threat to patient safety during airway management, arranged according to a 'HELP-ET' checklist.[8]

Factor	Example(s)
Human factors	Language barrier, fatigue, stress
Experience	Lack of skills (e.g. flexible awake intubation)
Location	Remote hospital, no expert help available
Patient factors	Prior radiation therapy to the neck, airway obstruction
Equipment	Technical problems
Time pressure	Rapid desaturation, unstable vital signs

None-the-less, it is still considered standard practice to assess the airway for potential difficult intubation as time allows. The lesson is EVERY AIRWAY IS DIFFICULT UNTIL THERE IS AN ETT IN THE TRACHEA (and sometimes not even then.)

As a point of reference;

Factors Characterizing the Normal Airway in Adolescents and Adults[10]

1. History of one or more easy intubations without sequelae
2. Normal appearing face with "regular" features
3. Normal clear voice
4. Absence of scars, burns, swelling, infection, tumour, or hematoma; no history of radiation therapy to head or neck
5. Ability to lie supine asymptomatically; no history of snoring or sleep apnoea
6. Patent nares
7. Ability to open the mouth widely (minimum of 4 cm or three fingers held vertically in the mouth) with good TMJ function
8. Mallampati/Samsoon class I (i.e., with patient sitting up straight, opening mouth as wide as possible, with protruding tongue; the uvula, posterior pharyngeal wall, entire tonsillar pillars, and fauces can be seen)
9. At least 6.5 cm (three finger-breadths) from tip of mandible to thyroid notch with neck extended
10. At least 9 cm from symphysis of mandible to mandibular angle
11. Slender supple neck without masses; full range of neck motion
12. Larynx movable with swallowing and manually movable laterally (about 1.5 cm on each side)
13. Slender to moderate body build
14. Ability to maximally extend the atlanto-occipital joint (normal extension is 35°)
15. Airway appears normal in profile

Difficult Airway Definition: A difficult airway may be defined as one where an experienced provider anticipates or encounters difficulty with any or all of face mask ventilation, direct or indirect (e.g., video) laryngoscopy, tracheal intubation, Supra-Glottic Device (SGD, e.g. Laryngeal Mask), or surgical airway. This is a somewhat broad definition and published estimations will vary depending on what specific criteria are used.[11]

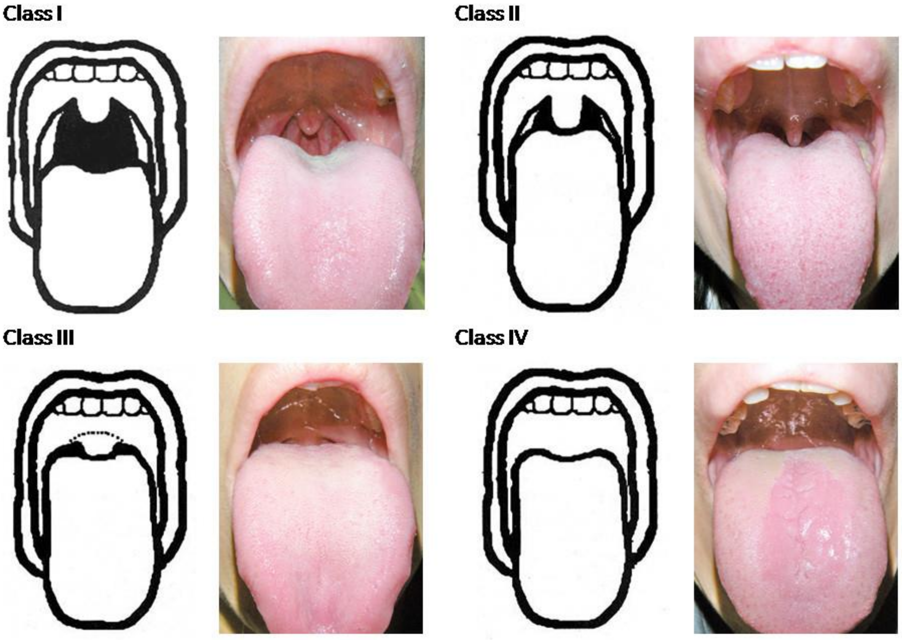
From the Danish Anaesthetic Database: Approximate incidence of difficulty with various airway interventions – by hospital location.[2]

	Operating Theatre %	ED %	ICU %
Cormack-Lehane Grade 3 view	0.8-7.0	6.1	11
Cormack-Lehane Grade 4 view	0.1-3.2	2.4	0.7
≥ 3 attempts at tracheal intubation	0.9-1.9	3.6-11.0	6.6-9.0
Surgical airway	0.002-0.02	0.05-1.7	no data

In Korea, the incidence of ≥ 3 attempts at intubation in the ED was 3.9%.[12] The incident of failed intubation in a USA ED was estimated at 1 in 50 to 100 intubations.[13]

Standard Methods of Assessing the Airway (in an ideal world) [10]
We borrow these from the anaesthetists and anaesthetist in our Hospital will uses some or all of these for their assessment.

1. Mallampati Score [14]



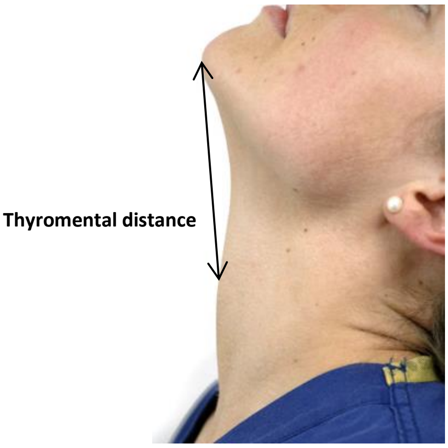
2. Inter-Incisor Distance (IID – i.e. Mouth Opening); A patient should be able to open their mouth more than three of their fingers (3 cm) breadth to allow passage of airway devices.

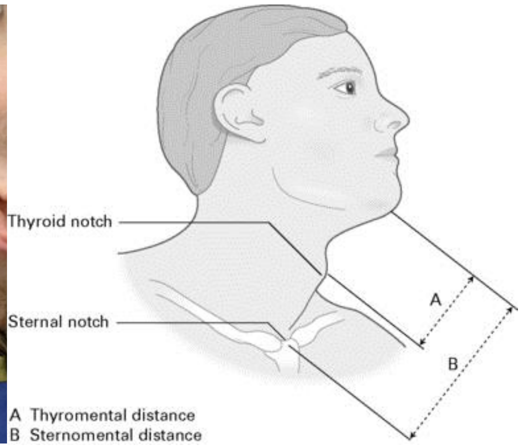
- If mouth opening is between 2 cm and 2.5 cm laryngoscope and LMA placement may be difficult.
- If mouth opening is less than 2 cm laryngoscope or LMA may be impossible.

Prominent dentition goes along with mouth opening – it's a significant adverse event to damage or displace teeth, not just because of cosmetic affect but also potential aspiration.

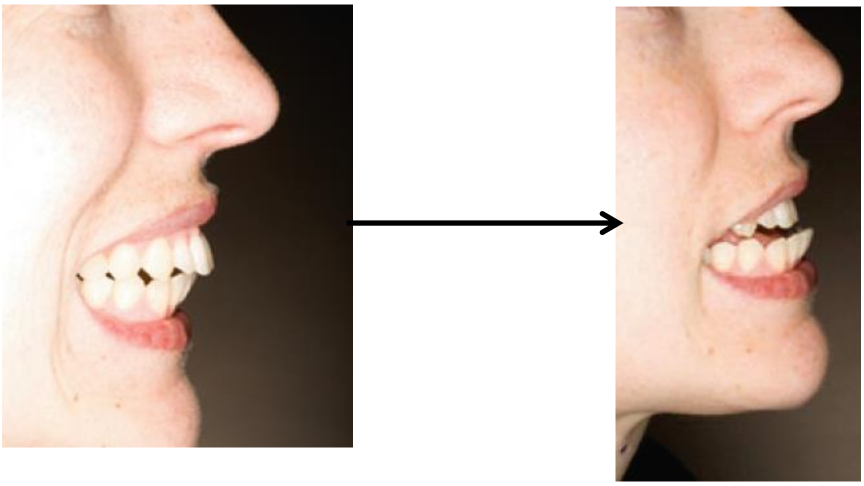
3. Thyromental Distance (TMD) – In fully extended head, from the tip of the thyroid cartilage to the chin (mentum); at least 4 fingers, < 6.0 cm = difficult intubation.

4. Sternomental Distance (SMD) – In fully extended head, from the sternal notch to the chin; < 12.5 cm = difficult intubation.

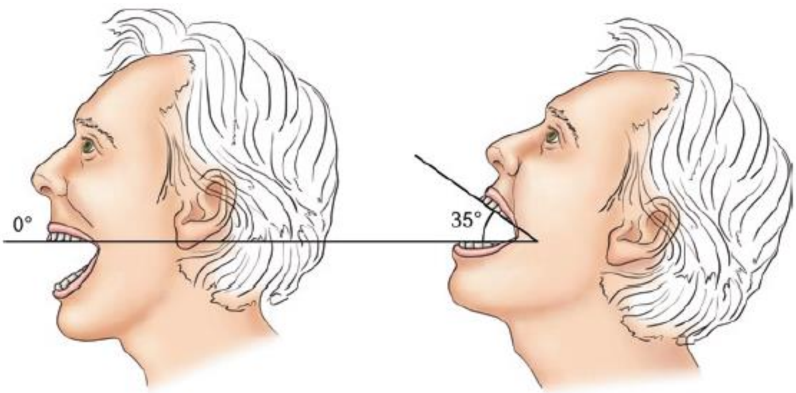




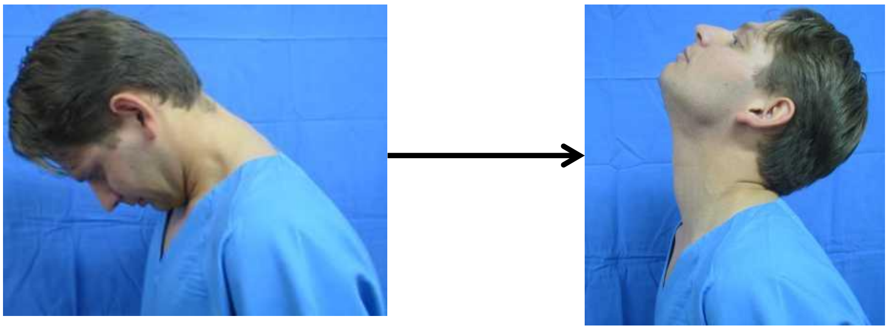
5. Temporomandibularmobility –How far can the mandible move forward in relation to the maxilla. Should be at least one finger (1 cm). How far can patient push lower teeth forward compared to upper teeth.



6. Atlanto-occipital Joint Extension (head extension) – The normal range of the atlanto-occipital joint Is 35^{o} as measured by movement of the plane of the maxilla in relation the neck, as per this diagram;



7. Neck Flexion (cervical spine) e.g. RA and ankylosing spondylitis)



8. Hyoid Mental Distance;distance from the tip of the chin to the neck should be at least three fingers – e.g. receding chin may make intubation difficult

9. Distance between the base of the tongue and the thyroid notch should be at least 2 fingers – e.g. "Bull" neck

10. Neck circumference in the obese - > 43 cm potentially difficult

11. Narrow, high dental arch

12. Facial trauma, large tongue, intraoral swelling and other anatomical anomalies

In Summary – Anaesthetic Assessment of Airway

For a non-time critical, cooperative, non-immobilised patient - assessment may include some or all of the following;

Ask/Listen
- Stridor/Dysphonia
- Previous difficult intubation
- Snoring/Sleep apnoea
- Cervical spine/TMJ problems

Look
- Facial and Oropharyngeal swelling, injury, scars or asymmetry
- Receding chin
- Short neck
- Mallampati Score
- Dentures

Move/Measure
- Inter Incisor Distance (≥ 3 fingers or 3 cm)
- Atlanto-occipital Joint Extension (35^o)
- In fully extend head
  - Thyromental Distance (TMD ≥ 6.5 cm)
  - Sternomental Distance (SMD ≥ 12 cm)

± Hyoid Mental Distance ≥ 3 fingers, base of the tongue to the thyroid notch
≥ 2 fingers if measuring impractical)

The techniques above are commonly used by anaesthetists. If you need to discuss a patient with the anaesthetists, they may respond intuitively to a description the physical findings as described above.

What is a reasonable approach to Air Assessment in a time critical situation (i.e. standard operating procedures for an ED)?

Many patients may need RSI without commonly used airway assessment methods because the patient is non-cooperative (e.g. unconscious or trismus), have C spine immobilisation or urgency mandates immediate intubation.[6]

In a time critical situation, assessment is done in conjunction with active airway management (i.e. airway manoeuvres and adjuncts) and pragmatically may be limited to the following;

Look
- Facial and neck swelling, scars or asymmetry
- Mouth opening, prominent anterior dentition, dentures and oropharyngeal swelling or abnormalities
- Receding chin
- Short neck
- Neck immobility

Listen
- Stridor
- Dysphonia

Feel
- Head and neck movement during positioning for management of airway and intubation
- Tracheal position (i.e. palpable, midline?)

In reality, in time-critical situations we push ahead and follow our intubation plan (i.e. 'ABCD'). However, when the indications for intubation aren't so time-critical we may consider alternatives such as consulting Anaesthetics and Intensivists for advanced intubation procedures. For instance, an unconscious overdose who is maintaining their airway, is not in respiratory failure, and is haemodynamically stable but requires airway protection.

Many Anaethetists are uncomfortable working outside the operating theatres. Working in an unfamiliar environment, with unfamiliar equipment are well recognised risks for adverse outcomes. Therefore, we do not consult the Anaesthetists lightly but may do so when there are obvious gross anatomical difficulties with the airway. If a patient requires advanced airway procedures by an Anaesthetist, it may be safer to transfer the patient to the Operating Theatres. This would be problematic if the patient is haemodynamically unstable. Risks and benefits in these situations may be complex. Planning needs to be tailored to the patient's needs and requires discussion with Anaesthetics and ICU.

LOOK FOR THE OBVIOUS PROBLEM

Predictors of difficult face mask ventilation (similarities to difficult intubation predictors)

- Obesity
- Age> 55
- Male sex
- Unable to protrude mandible (jaw thrust)
- Trismus
- Beard
- Lack of teeth (Edentulous)
- Sunken cheeks
- Oropharyngeal swelling
- Airway foreign body
- Lung disease, chest wall rigidity and gastric distention
- History of snoring or obstructive sleep apnea
- History of neck radiation

Grading scale for mask ventilation[15]

Classification	Description
Grade 0	Ventilation by mask not attempted
Grade 1	Ventilated by mask
Grade 2	Ventilated by mask with oral airway or other adjunct
Grade 3	Difficult MV (inadequate, unstable, or 2 person technique)
Grade 4	Unable to mask ventilate

Predictors of difficult supraglotticairway device use

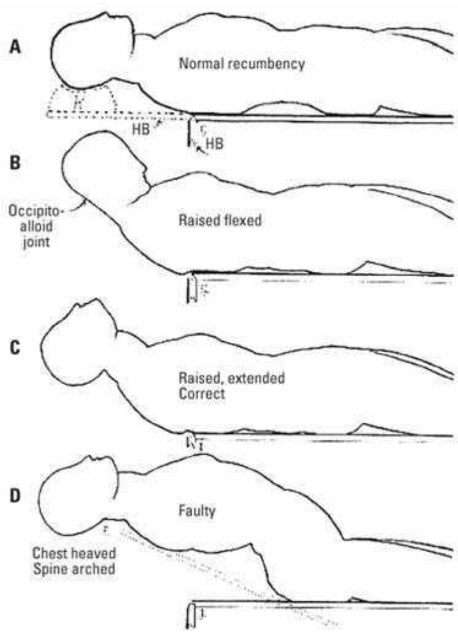
- Reduced mouth opening
- Supra- or extraglottic pathology (e.g., neck radiation, lingual tonsillar hypertrophy)
- Glottic and subglottic pathology
- Fixed cervical spine flexion deformity
- Applied cricoid pressure
- Male sex
- Increased body mass index
- Poor dentition

2. Positioning

Getting the position of the patient right before intubation is critical.

The minimum will include;

- Flat on their back – may delay lying flat till the point you are ready to insert the laryngoscope
- Top of the head level with head end of the bed
- Body in the centre of the bed
- Trolley at belt height or patient head at the level of the lower sternum of the Airway Doctor
- Neck flexion of 35° and face plane extension of 15° (also see **Horizontal alignment of the sternal notch with the external auditory meatus** below)

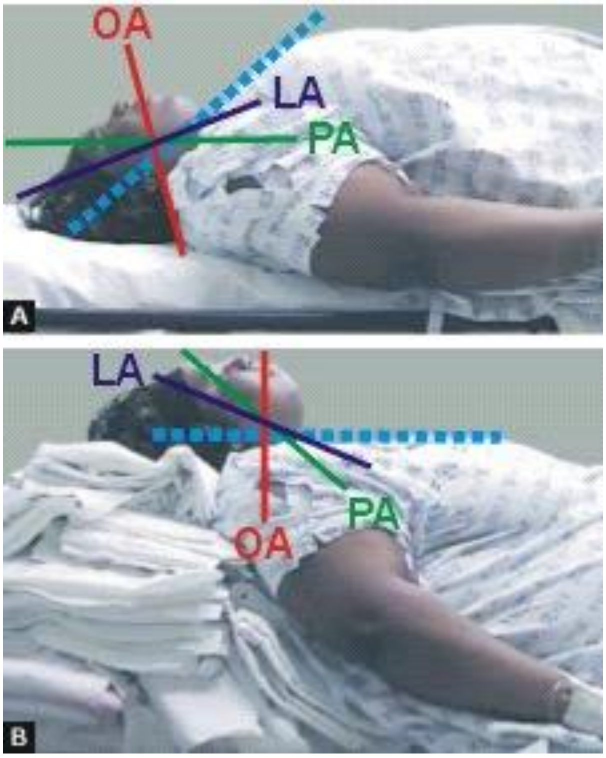


- Further flexion of the neck and extension of the head, beyond what is described above, may improve view for intubation.[16]
- If spinal precautions are required, have a plan for collar removal and inline manual immobilisation

In addition, for the **Bariatric Patient;**

- Head up (i.e. torso) 25^{o} while pre-oxygenating.[17] This may also be useful for patients with **Respiratory Failure.**
- Reverse Trendelenburg with stretcher head up at 30^{o} has also been described for obese patients. [18] However, it presents problems with the patient sliding down the stretcher.
- 'RAMP' - elevate head and shoulders with trolley or pillows and blankets, as in the picture below. Note, Ramping will achieve some of the head up elevation described previously.
- **Horizontal alignment of the sternal notch with the external auditory meatus**, as described by Levitan, et al and by Collins, et al as an indicator of effective 'ramp' positioning in obese patients.[19, 20] This anatomical rule of thumb is also commonly applied to non-obese patients with some supporting evidence.[21]

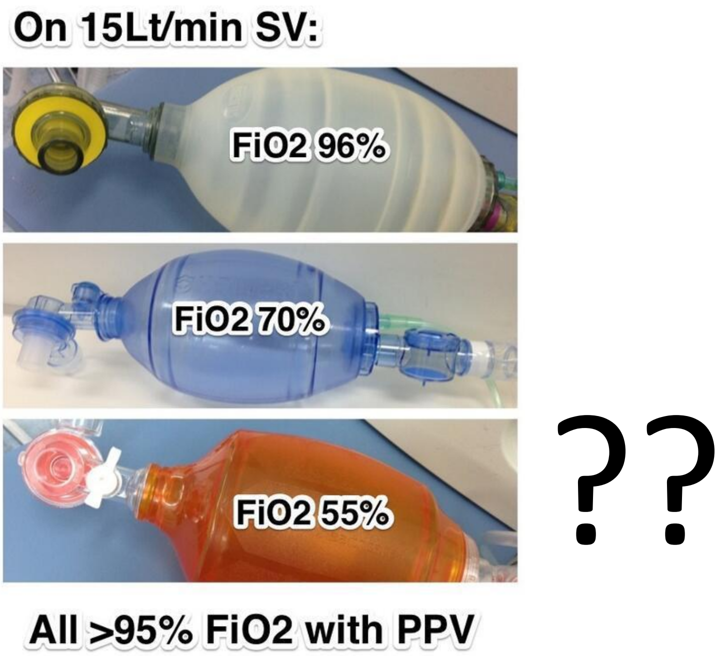
Ramping the Obese Patient



OA Oral Axis, LA Laryngeal Axis, Pharyngeal Axis
Note the Ear Canal is at the same level as the sternal notch

3. Oxygenation

Oxygen Delivery
In recent time, there has been some debate over the relative effectiveness in delivering high FiO_2 of Non-rebreather Mask (NRM) vs Bag-Valve-Mask (BVM). In my experience, the BVM has been the gold standard for high FiO_2 delivery in ED. The reusable Laerdal or Ambu bag were said to provide FiO_2 of 95%. In recent years we have switched to the single-use Mayo BVM. It seems that there has been assertion in the blogosphere that the Mayo bag in significantly inferior to the reusable BVMs and to NRM. This information was derived, from among other sources, lifeinthefastlane.com (since revised in March 2016) and prehospitalmed.com as below (accessed march 2016);

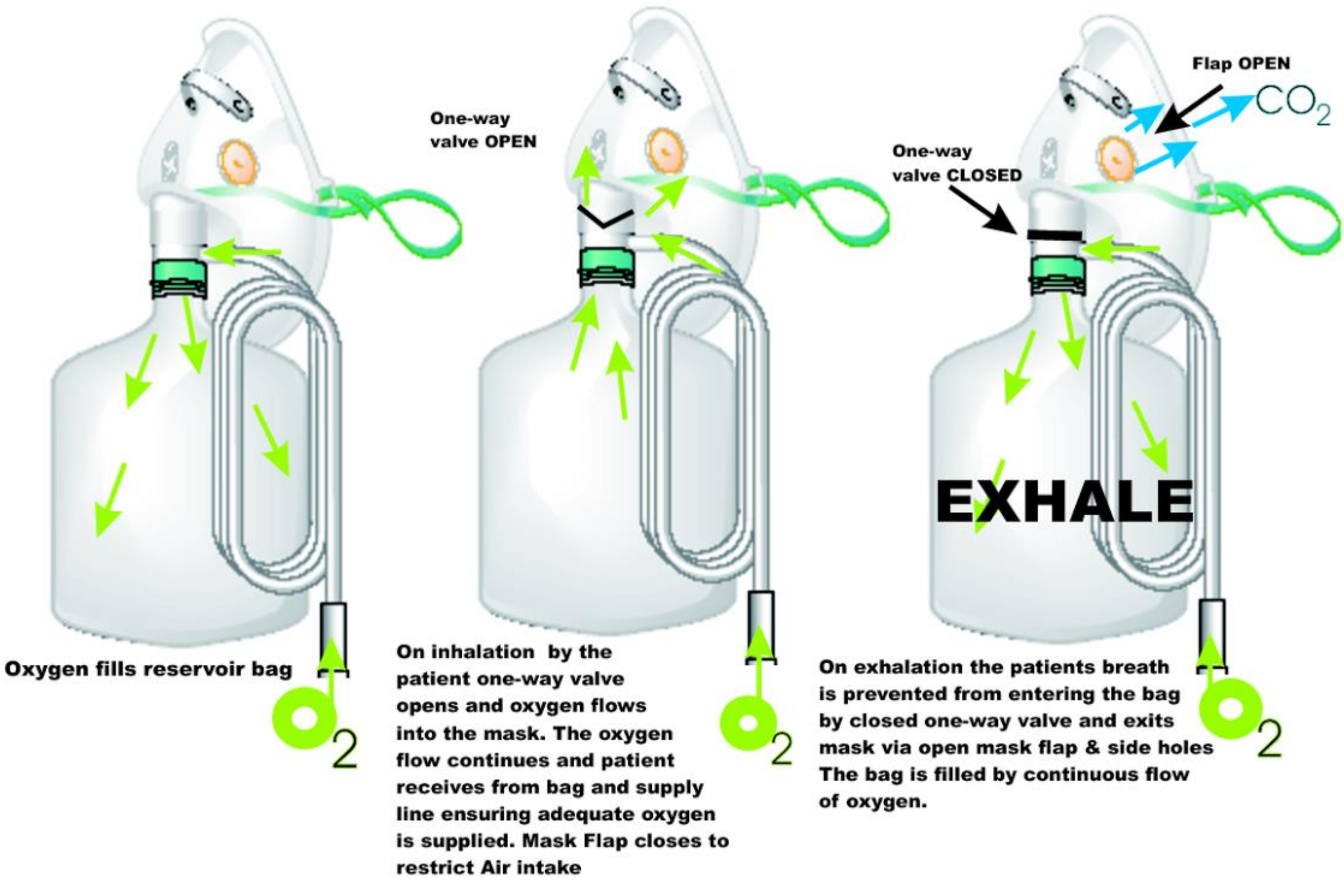


The source of the information in the picture above is quoted as monashanaesthesia.org but I could not find it on that web site. Discussions I have had often lead to critiques of the mechanics of each device but, in fact, there is little published evidence in terms of measures of FiO_2 in ill ED patients to differentiate the two devices. Notably, the Mayo BVM's accompanying literature says it can deliver up to 80% FiO_2 when an expiratory port valve is used.

Both the NRM and BVM are **Variable Performance Devices**. That is, the FiO_2 delivered will be affected by the variables of patient ventilation, such as the respiratory rate and tidal volume. The Peak Inspiratory Flow Rate (PIFR) of a normal resting person is approximately 30 Lpm. This can increase up to 120 Lpm or more when a patient is hyperventilating, for instance because of hypoxemia or shock. Although the tidal volume may be less than the reservoir volume of the oxygen delivery device, maintaining a very high PIFR requires the entrainment of room air during that peak of inspiration. That is, these devices cannot deliver O_2 at a flow rate of 120 Lpm. Hence, a device that, with an oxygen flow rate of 15 Lpm, can deliver 80% FiO_2 to a normally breathing patient may deliver < 60% in a hyperventilating patient. This may be alleviated by supplying higher oxygen flow rates. The BVM has inlets to allow entrainment of air during high inspiratory flow rates. The NRM allows entrainment of air between the mask and the face. If there was no entrainment of room air in these devices, patients with very high inspiratory flow rates will generate high negative airway pressure (i.e. feel like they are suffocating). It is recognised that if there is not an air-tight seal with the BVM then its efficiency is significantly reduced. I think that the same is true of a NRM and that it is unlikely that a relatively inflexible plastic mask held in position with a piece of elastic is more likely to have an air-tight seal than a soft, contour-conforming mask held on by a skilled operator. Having said that, I will review the evidence of effectiveness for each device in ED.

Firstly, a description of each device.

Non-Rebreather Mask (NRM)



Application of the Non-Rebreather Mask

Airtight fit between the mask and the patients face

Valve on either side of the mask prevents entry of room air

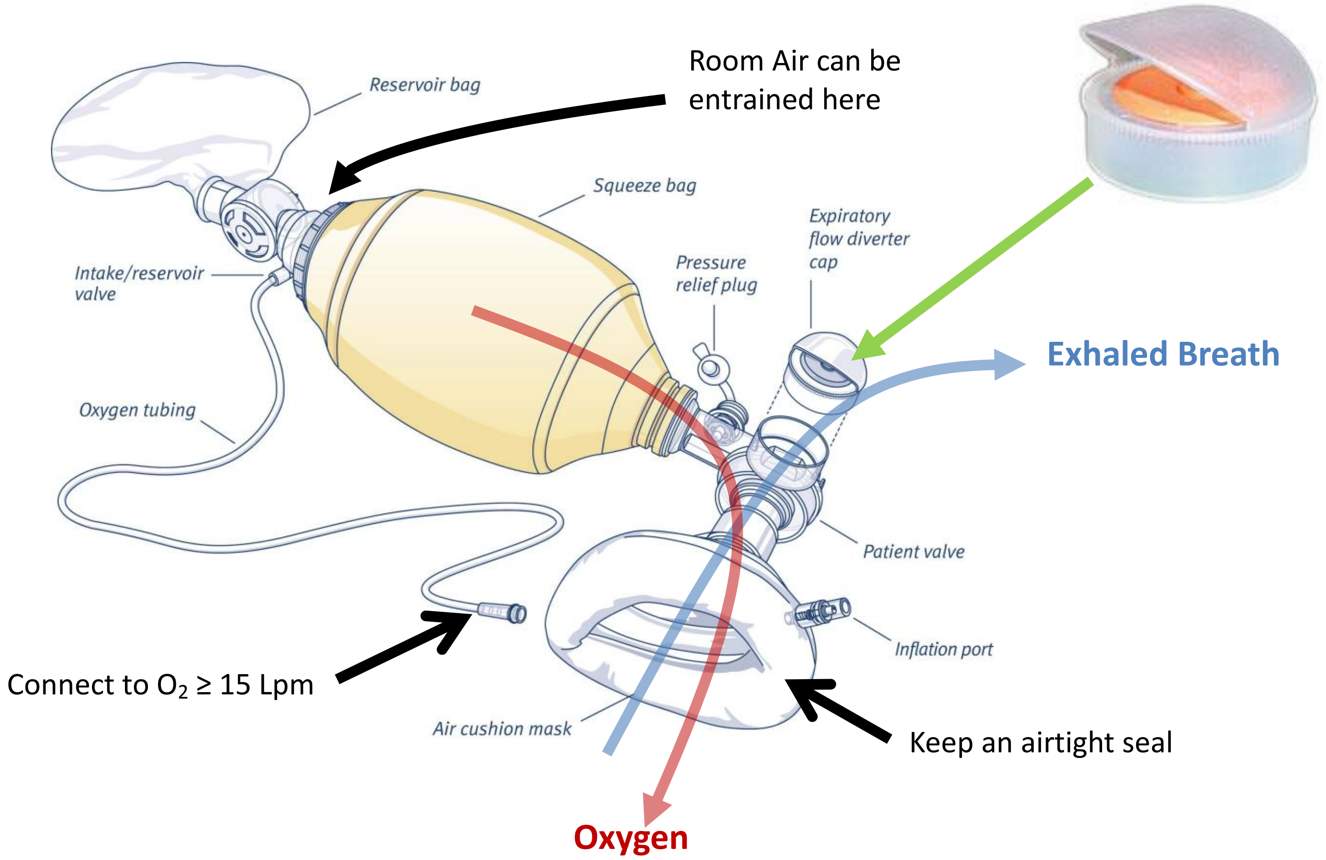
Valve allows oxygen to enter the mask and prevents exhaled air entering the reservoir.

Set oxygen flow at 12-15 l/m or fully open for severe hypoxia or preoxygenation

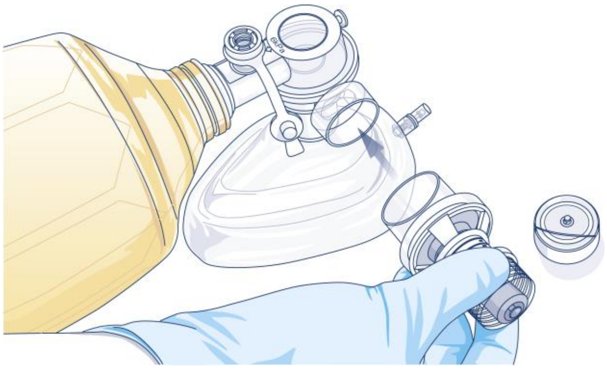
The reservoir should be full on expiration and partially collapse during inspiration

Bag-Valve-Mask (BVM)

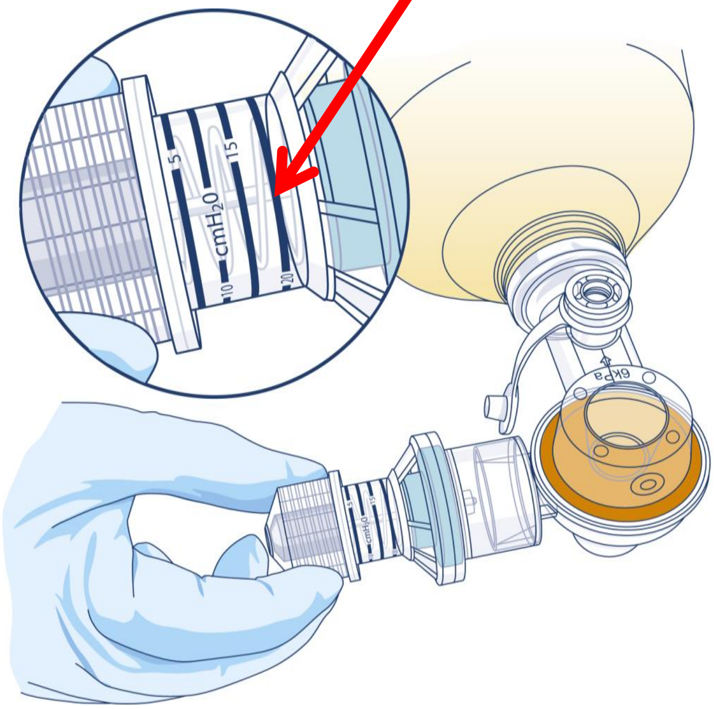
This one-way valve prevents entrainment of room air at the expiratory port



Expiratory port valve or PEEP valve



Rotate the cap until the desired PEEP number is in line with the base of the cap



Rotate out for lower PEEP and in for higher

The Oxylog ventilator default PEEP is set at 5 cm H_2O

Non-Rebreather Mask versus Bag-Valve-Mask

1. Which is best for delivering high FiO_2?
2. Which do you choose for preoxygenation?

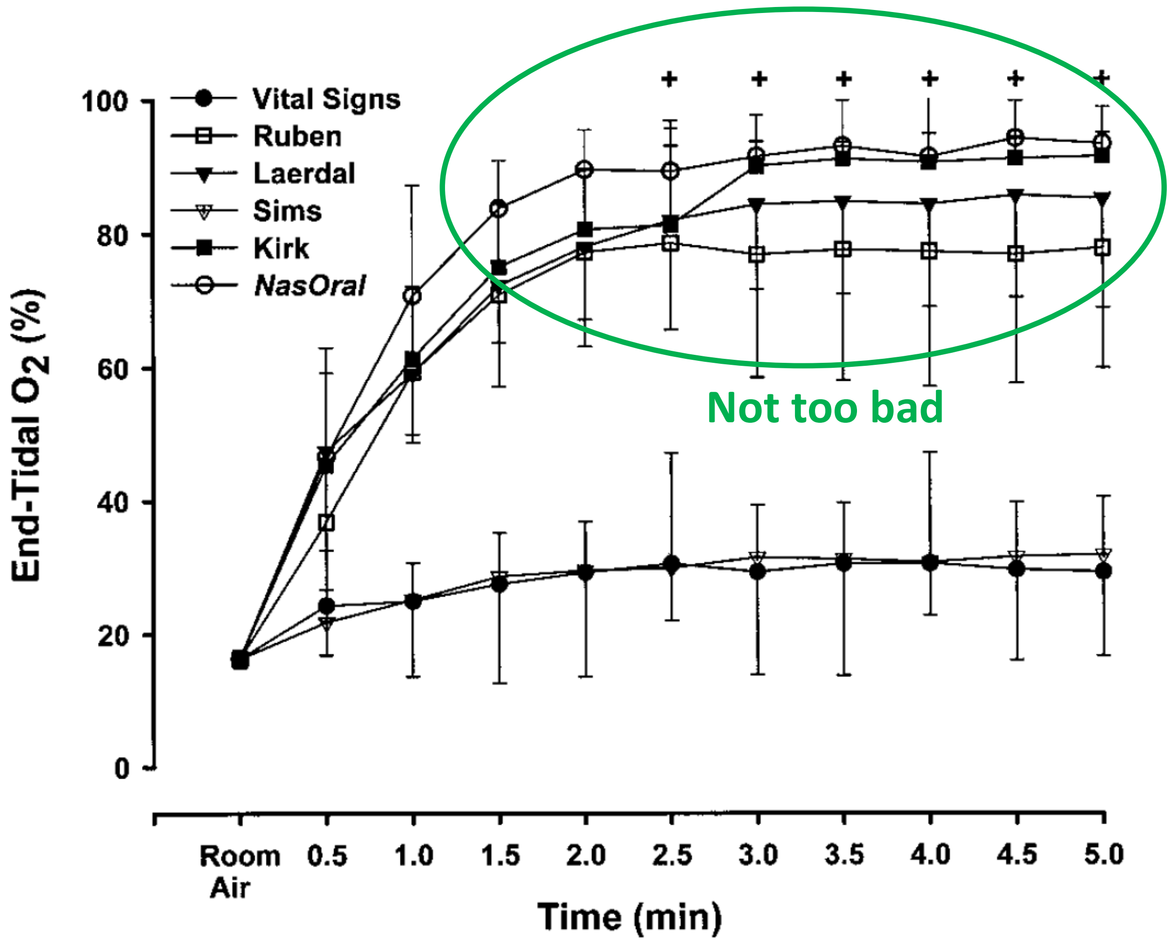
Much of the evidence published on preoxygenation is by Anaesthetists and it's important to remember *they don't use NRM or BVM for Preoxygenation.* Anaesthetists use anaesthetic circuits, which are **Fixed Performance** devices. That is, they deliver a fixed FiO_2 regardless of the patient's ventilation requirements. They are able to deliver very high flow rates of O_2. There is limited evidence for the use of BVM and MRM devices in the ED. Note, lack of evidence is not the same thing as lack of effect.

It is also important to know that the gold standard for measuring preoxygenation in the Operating Theatre is Fraction of Expired Oxygen (FeO_2). Adequate preoxygenation has been achieved if FeO_2 is ≥ 80% and preferably ≥ 90%.

Most of the evidence for NRM and BVM is derived from trials of small numbers of healthy volunteers breathing normally at rest. For instance, an English study on 12 healthy volunteers found BVM and NRM had equivalent FeO_2, with each device receiving O_2 at 10 Lpm.[22] They did note a slightly higher $FeCO_2$ with the BVM which they suggested was due to higher airflow resistance in the BVM.

Of interest, Mills et al, in 1991 reported that BVM devices with "disc" valves gave more efficient oxygen delivery, while "duck-bill" valves did not reliably prevent air entrainment.[23] Subsequent to this commercial BVM devices seem to all use disc valves.

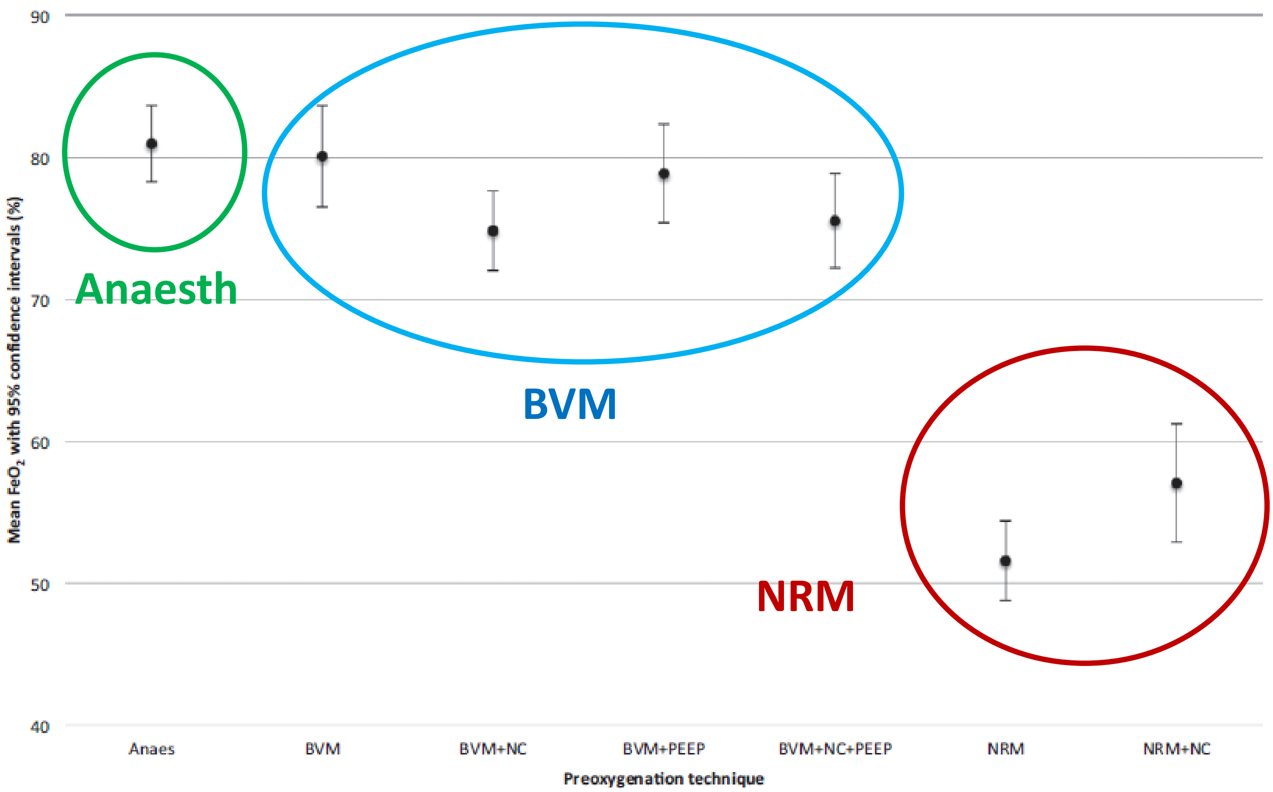
Nimmagadda et al, 2000 published data on five different resuscitation devices, although the focus of the article was on use of device for preoxygenation called "NasOral".[24] The Laerdal BVM performed reasonably well with $FeCO_2$ > 80% (see chart below). The reason the 'Vital Signs' and 'Sims' device performed poorly was attributed to the lack of expiratory port valve. They found that duck-bill valves seemed to perform as well as disc valves.



Groombridge, et al from NSW this year published a study of 30 healthy adult volunteers, measuring FeO_2 with 7 different setups; [25]

1. Anaesthetic Circuit
2. BVM
3. BVM + NC
4. BVM + PEEP
5. BVM + PEEP + NC
6. NRM
7. NRM + NC

Figure 1, page 345



Of note in this study was that O_2 flows of 15 Lpm was used for each devices other than Nasal Cannula, which was given at 5 Lpm. PEEP was 5 cm H_2O. There was no statistical difference between the variations of BVM setup or between NRM setups. However, BVM was significantly better than NRM. The issue I see with this comparison is to do with O_2 flow rate. It is likely very high flow rates are required to achieve best FiO_2; greater than 15 Lpm for BVM and NRM, and up to 15 Lpm for NC.

Weingart, et al state in review article from 2012;[26]

> "Standardly available nonrebreather masks can deliver FiO_2 greater than or equal to 90% by increasing the **flow rate to 30 to 60 L/minute**. Such flow rates may be achievable on most flow regulators in EDs by continuing to open the valve, though there will be no calibrated markings beyond 15 L/minute."
> ***NOTE***: *the SCGH Department of Medical Technology and Physics have tested the wall O_2 flow meters and they deliver approximately 20 Lpm when fully opened. High flow O_2 flow meters (up to 60 Lpm) are readily available in ED.*
>
> "Some ED providers use the self-inflating bag-valve-mask device to provide preoxygenation. Bag-valve-mask devices lacking 1-way inhalation and exhalation ports will deliver only close to room air FiO_2 when not actively assisting ventilations. Even with ideal 1-way valves, the devices will deliver oxygen only in 2 circumstances: the patient generates enough inspiratory force to open the valve or the practitioner squeezes the bag. In both circumstances, to obtain any FiO_2 above that of room air, a tight seal must be achieved with the mask, which usually requires a 2-handed technique….."

Also Weingart states in his 2011 review article; [27]

> "In this circumstance of low saturation before RSI, many airway experts recommend preoxygenation with a bag/valve/mask device (BVM). When the BVM is manufactured with an appropriate exhalation port and a tight mask seal is obtained, it can deliver 0.9 FiO_2 both when the patient spontaneously breathes and with assisted ventilations"

Summary of BVM versus NRM for Preoxygenation

I think, it may be reasonable to assume they are approximately equivalent *when used properly.* It may be reasonable then to use NRM for spontaneously breathing patients for the purpose of preoxygenation and BVM when the patient needs assisted ventilation or application of PEEP. High flow O_2 is required, probably for both devices but especially for NRM. If NRM is being used for preoxygenation then I recommend O_2 flow at least 30 Lpm. A flow rate of 20 Lpm (usual flow meter fully opened) with the addition of NC with flow rate of ≥ 10 Lpm may be adequate but I have no solid evidence for that.

Apnoeic Oxygenation

The effectiveness of apnoeic oxygenation has been well demonstrated in anaesthesia in a variety of situations, as early as 1959.[28, 29, 30, 31, 32, 33] There is far less evidence of its efficacy in the ED.

In a 2015 French ICU study, a historic control group receiving preoxygenation via a BVM device with O2 at 15 Lpm was compared to High Flow Nasal Prongs (HFNP) at 60 Lpm.[34] The HFNP group had oxygen delivery continued during intubation and had lower incidence of hypoxaemia. An Australian study of apnoeic oxygenation for prehospital intubations showed using nasal prongs at 15 Lpm during the procedure reduced rates of hypoxaemia compared to historical controls.[35] However, a USA ICU randomised controlled study didn't show a benefit with O_2 at 15 Lpm delivered by NC during intubation, preoxygenation performed as per the intubator's usual practice.[36] Notably, most patients in the USA trial were intubated for respiratory failure as opposed to protection of the airway in the other two studies (i.e. for trauma or neurological condition).

Apnoeic oxygenation using O_2 flow of 15 Lpm during intubation is recommended, although it may not be effective for patients with respiratory failure. Awake patients may not tolerate a flow rate of 15 Lpm but should be given as high a flow as tolerated and increased to 15 Lpm when the patient is sedated. The use of NC with BVM and NRM is questioned because it may affect the seal between the mask and face. There is no clear answer to this concern but the risk of reducing the effect of the BVM or NRM needs to be weighed with the benefit of delivery extra oxygen.

Non-Invasive Ventilation in Preoxygenation

Use of CPAP or PEEP improves preoxygenation obese patients undergoing anaesthesia.[37] Noninvasive Ventilation (NIV) is effective in reducing risk of desaturation for intubation of hypoxic patients in a critical care setting and obese patients.[38, 39] NIV should be considered, with elevation of the head of the stretcher, for obese patients and patients with respiratory failure. This is in line with the concept of delayed sequence intubation.[40] In our Department I recommend using the BiPAP machine for this purpose. Note that BiPAP is normally considered contraindicated in patients with reduced GCS but for the purpose of preoxygenation this is not an issue. The other advantage of the BiPAP machine is it is a **Fixed Performance** device. That is, it can reliably deliver up to FiO_2 of 100%; it can deliver O_2 at very high flow rates. BVM can deliver PEEP but cannot reliably deliver CPAP.

The use of a portable ventilator with the appropriate settings as a NIV device has been reported.[41] However, because we do not commonly use our Oxylog 3000 for this purpose I don't recommend that. Rather, use the BiPAP machine as above.

4. RSI Planning

"Never fail to be prepared for failure. It happens: even when not predicted. The skilled, prepared anaesthetist will have numerous options to manage failure and will have decided the appropriate strategy (next step) before starting. Full preparation involves training, institutional preparedness, and personal preparedness." [7]

IntubationPlanning

This is how I use the ABCD paradigm;

Plan A Initial intubate strategy (Limit time – 60 seconds)	Optimise patient position (ear vs sternal notch, ramp) Pre-oxygenate (aka de-nitrogenation) Apnoeic oxygenation Direct Laryngoscopy and blade size choice Stylet Intubation catheter (aka "Bougie" e.g. Cook Medical **Frova** Catheter found on difficult intubation trolley) External laryngeal pressure (BURP) Direct Laryngoscopy vs Video Laryngoscopy
IF HYPOXIC – Rescue oxygenation and ventilation prior to second attempt	
Plan B[^ *] Alternative intubation strategy	Video laryngoscopy (if not primary method) • C-mac • Glidescope • King Vision Bougie / Cook catheter Further neck flexion and head extension Abandon cervical immobilisation Change operator
Plan C Can't Intubate; Rescue oxygenation and ventilation	CALL FOR HELP BVM – one operator (one hand on mask)/two operator (two hands on mask) ±Oxylog 3000 to ventilate the patient while holding mask Exaggerated head extension Exaggerated jaw thrust NPA/OPA LMA /intubating LMA (aka Supra-Glottic Airway [SGA]or Supraglottic Airway Device [SAD]) Consider reversing paralysis (*Sugammadex* 16 mg/kg for Rocuronium or Vecuronium)
Plan D[#] Can't Intubate / Can't Oxygenate (CICO[42]) (aka Can't Intubate / Can't Ventilate)	Cricothyrotomy (aka Infra-Glottic Airway) Percutaneous wide-bore cannula (e.g. Melkor) or open surgical technique (if bradycardia should occur, administration of adrenaline or atropine may forestall cardiac standstill)

^ Current Difficult Airway Society guidelines suggest Supraglottic Device for Plan B.[43] However, I still consider a second attempt at intubation with a change in technique or personnel is appropriate.

* One study noted that > 2 laryngoscopies led to a 7-fold increase in hypoxia (incidence 70%), 6-fold increase in oesophageal intubation (52%), 7-fold increase in regurgitation (22%), 4-fold increase in aspiration (13%), and 7-fold increase in cardiac arrest (11%).[44]

NOTE: is has been reported that a significant proportion of patients with profound prolonged hypoxia (e.g. saturations ≈50% for 30 min) have made a full recovery.[7] Prolonged attempts at reoxygenation don't always have a bad outcome.

REFERENCES

1 Yentis SM. Predicting difficult intubation - worthwhile exercise or pointless ritual? Anaesthesia, 2002; 57(2): 105-9.

2 Nørskov AK, et al. Diagnostic accuracy of anaesthesiologists' prediction of difficult airway management in daily clinical practice: a cohort study of 188, 064 patients registered in the Danish Anaesthesia Database. Anaesthesia, 2015; 70(3): 272–81.

3 Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology, 2005; 103(2): 429–37.

4 Law JA, et al. The difficult airway with recommendations for management – Part 1 – Difficult tracheal intubation encountered in an unconscious/induced patient. Can J Anesth/J Can Anesth, 2013; 60:1089–1118.

5 Badhe VK, et al. Clinical comparison of five different predictor tests for difficult intubation. Anaesth Pain & Intensive Care, 2014; 18(1):31-37.

6 Levitan RM, Everett WW, Ochroch EA. Limitations of Difficult Airway Prediction in Patients Intubated in the Emergency Department. Ann Emerg Med, 2004; 44:307-13.

7 Overbeck MC. Airway Management of Respiratory Failure. Emerg Med Clin N Am, 2016; 34:97–127

8 Mace SE. Challenges and Advances in Intubation: Airway Evaluation and Controversies with Intubation. Emerg Med Clin N Am, 2008; 26:977–1000.

9 Editorial. The myth of the difficult airway: airway management revisited. Anaesthesia, 2015; 70:241–57

10 Finucaine BT, et al. Principles of Airway Management – Chapter 2: Evaluation of the Airway. ©Springer Science and Business, 2011.

11 Cook TM, MacDougall-Davis SR. Complications and failure of airway management. British Journal of Anaesthesia,2012; 109(S1):i68–i85.

12 Kim JH, Kim Y, Choi HJ, Je SM, Kim E. Factors associated with successful second and third intubation attempts in the ED. American Journal of Emergency Medicine, 2013; 31:1376–81.

13 Sakles JC, Laurin EG, Rantapaa AA, Panacek EA. Airway management in the emergency department: a one-year study of 610 tracheal intubations. Ann Emerg Med, 1998; 31:325–32.

14 Mallampati SR, Gatt SP, Gugino LD, et al. A clinical sign to predict difficult tracheal intubation: a prospective study. Can Anaesth Soc J, 1985; 32:429–34.

15 Han R, Tremper KK, Kheterpal S, O'Reilly M. Grading scale for mask ventilation. Anesthesiology, 2004; 101:267.

16 Schmitt HJ, Mang H. Head and Neck Elevation Beyond the Sniffing Position Improves Laryngeal View in Cases of Difficult Direct Laryngoscopy. J. Clin. Anesth., 2002; 14:335-8.

17 Dixon BJ, et al. Preoxygenation Is More Effective in the 25° Head-up Position Than in the Supine Position in Severely Obese Patients: A Randomized Controlled Study. Anesthesiology, 2005; 102:1110–5.

18 Perilli V, Sollazzi L, Modesti C, et al.Comparison of positive end- expiratory pressure with reverse Trendelenburg position in morbidly obese patients undergoing bariatric surgery: effects on hemodynamics and pulmonary gas exchange. Obes Surg, 2003; 13:605–9.

19 Levitan RM, Ochroch AE. Airway management and direct laryngoscopy: a review and update. Crit Care Clin North Am, 2000; 16:373-88.

20 Collins JS, Lemmens HJ, Brodsky JB, Brock-Utne JG, Levitan RM. Laryngoscopy and morbid obesity: a comparison of the "sniff" and "ramped" positions. Obes Surg, 2004; 14(9):1171-5.

21 Greenland KB, Edwards MJ, Hutton NJ, Challis VJ, Irwin MG, Sleigh JW. Changes in airway configuration with different head and neck positions using magnetic resonance imaging of normal airways: a new concept with possible clinical applications. Br. J. Anaesth., 2010; 105(5): 683-90.

22 Robinson A, Ercole A. Evaluation of the self-inflating bag-valve-mask and non-rebreather mask as preoxygenation devices in volunteers. BMJ Open 2012;2:e001785. doi:10.1136/bmjopen-2012-001785

23 Mills PJ, Baptiste J, Preston J, et al. Manual resuscitators and spontaneous ventilation—an evaluation. Crit Care Med, 1991; 19:1425-31.

24 Nimmagadda U, Salem MR, Joseph NJ, et al. Efficacy of preoxygenation with tidal volume breathing. Comparison of breathing systems. Anesthesiology, 2000; 93:693-8.

25 Groombridge, Chin, Hanrahan, Holdgate. Assessment of Common Preoxygenation Strategies Outside of the Operating Room Environment Academic Emergency Medicine, 2016; 23:342–6.

26 Weingart SD Levitan RM Preoxygenation and Prevention of Desaturation During Emergency Airway Management. Ann Emerg Med, 2012; 59:165-75.

27 Weingart SD. Preoxygenation, Reoxygenation, and Delayed Sequence Intubation in the Emergency Department. The Journal of Emergency Medicine,2011; 40(6):661–7.

28 Frumin MJ, Epstein RM, Cohen G. Apneic oxygenation in man. Anesthesiology, 1959; 20:789-98.

29 Teller LE, Alexander CM, Frumin MJ, Gross JB. Pharyngeal insufflation of oxygen prevents arterial desaturation during apnea. Anesthesiology, 1988; 69:980–2.

30 Taha SK, Siddik-Sayyid SM, El-Khatib MF, Dagher CM, Hakki MA, Baraka AS. Nasopharyngeal oxygen insufflation following preoxygenation using the four deep breath technique. Anaesthesia, 2006; 61:427–43.

31 Baraka AS, Taha SK, Siddik-Sayyid SM, Kanazi GE, El-Khatib MF, Dagher CM, Chehade J-MA, Abdallah FW, Hajj RE. Supplementation of pre-oxygenation in morbidly obese patients using nasopharyngeal oxygen insufflation. Anaesthesia, 2007; 62:769–73.

32 Ramachandran SK, Cosnowski A, Shanks A, Turner CR. Apneic oxygenation during prolonged laryngoscopy in obese patients: a randomized, controlled trial of nasal oxygen administration. J Clin Anesth, 2010; 22:164–8.

33 Ramachandran SK, Cosnowski A, Shanks A, Turner CR. Apneic oxygenation during prolonged laryngoscopy in obese patients: a randomized, controlled trial of nasal oxygen administration. Journal of Clinical Anesthesia, 2010; 22:164–8.

34 Miguel-Montanes R, Hajage D, Messika J, Bertrand F, Gaudry S, Rafat C, Labbe´ V, Dufour N, Jean-Baptiste S, Bedet A, et al. Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia. Crit Care Med, 2015; 43:574–83.

35 Wimalasena Y, Burns B, Reid C, Ware S, Habig K. Apneic oxygenation was associated with decreased desaturation rates during rapid sequence intubation by an Australian helicopter emergency medicine service. Ann Emerg Med, 2015; 65:371–6.

36 Semler MW, Janz DR, Lentz RJ, et al. Randomized Trial of Apneic Oxygenation during Endotracheal Intubation of the Critically Ill. Am J Respir Crit Care Med, 2016; 193(3):273–80.

37 Gander S, Frascarolo P, Suter M, Spahn DR, Magnusson L.Positive end-expiratory pressure during induction of general anesthesia increases duration of nonhypoxic apnea in morbidly obese patients. Anesth Analg, 2005; 100:580–4.

38 Baillard C, Fosse J, Sebbane M, Chanques G, et al. Noninvasive Ventilation Improves Preoxygenation before Intubation of Hypoxic Patients. American Journal of Respiratory and Critical Care Medicine, 2006: 171-7.

39 Delay J, et al. The Effectiveness of Noninvasive Positive Pressure Ventilation to Enhance Preoxygenation in Morbidly Obese Patients: A Randomized Controlled Study. Anesth Analg, 2008; 107:1707–13.

40 Weingart SD, Trueger NS, Wong N, Scofi J, Singh N, Rudolph SS. Delayed Sequence Intubation: A Prospective Observational Study. Ann Emerg Med, 2015; 65:349-55.

41 Grant S, Khan F, Keijzers G, Shirran M, Marneros L. Ventilator-assisted preoxygenation: Protocol for combining non-invasive ventilation and apnoeic oxygenation using a portable ventilator. Emergency Medicine Australasia, 2016; 28:67–72.

42 Transition from supraglottic to infraglottic rescue in the “can’t intubate can’t oxygenate”(CICO) scenario. Report from the ANZCA Airway Management Working Group November 2014

43 Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. British Journal of Anaesthesia, 2015; 115(6): 827–48.

44 Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. Anesth Analg, 2004; 99:607–13.