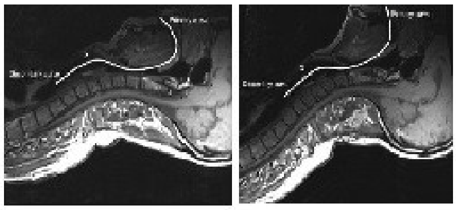
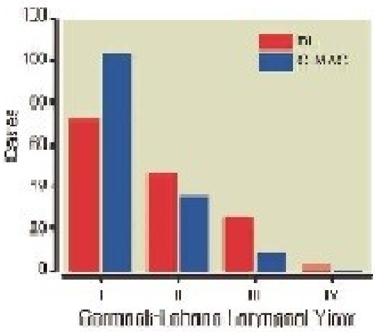
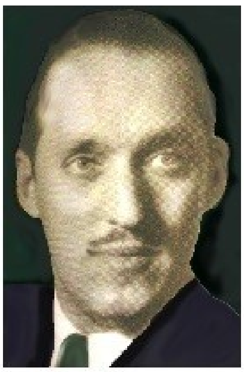
A Clinician's Guide to Video Laryngoscopes







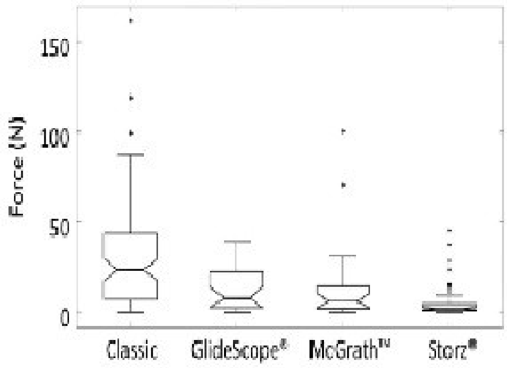


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Table of Contents

Overview:

This project aims to provide a **concise** overview of video laryngoscopes for the trainee or anaesthetist who has limited experience with these tools.

Our review is evidence based, and aims to tease out the most relevant aspects of the literature to inform the reader of the primary issues involved in understanding and developing competence in the use of these devices. However, it is not intended to be a definitive and comprehensive overview of the literature in the area, which is outside the scope of a work of this size, and further would needlessly replicate existing work (Pott et al. 2008, Niforopoulou et al. 2010, Behringer et al. 2011), but is rather intended as an accessible document of some utility to the time-poor practitioner who wishes to keep abreast of the most recent developments in video laryngoscopy.

To this end, we provide a brief history of video laryngoscopy, a classification for video laryngoscopes, an overview of their various applications, known complications, and, finally, the practicalities of their use with a particular emphasis on the C-Mac video laryngoscope. It will be apparent that our knowledge of the efficacy and applications for these devices is incomplete, and thus we discuss contemporary guidelines for assessing and selecting new airway devices ("ADEPT") for both personal and departmental use. It is hoped that at the completion of this review the practitioner will approach the patient with increased knowledge and confidence with these devices.

While we discuss several video laryngoscopes, we focus particularly on the practicalities of **using** the C-Mac video laryngoscope for the simple reason that this is the main device found within our own and adjacent Area Health Service(s), and thus of greatest interest to our intended audience.

History:

Attempts to visualise the vocal chords have a long and fruitful history in medicine. A Spanish vocal pedagogist, Manual Garcia, is recognised as the first to (indirectly) observe the function of a living glottis (his own) in 1854 by using a device consisting of two mirrors with the sunlight serving as an external light (Figure 1) . However, the first credited direct view of a larynx was made without instrumentation by the Berlin laryngologist Tobold whose patient, a female singer, was able to "press her exceedingly thin tongue against her lower incisors and hyperextend her neck, so the larynx could be glimpsed without any instrumentation" (Tobold 1869; requoted Jahn et al. 1996).

While important, of more interest to our study is those developments whose intention was to visualise the larynx with the goal of intubating the trachea. Chevalier Jackson (1913) reported a high rate of success with an instrument that used a light source at the distal tip, improving on earlier attempts by other workers (*eg* Alfred Kirstein). Finally, in the 1940s, the Miller and Macinstosh blades were developed specifically for the use of anaesthetists to intubate the trachea, and these remain the workhorse of today's anaesthetists (Figure 2).

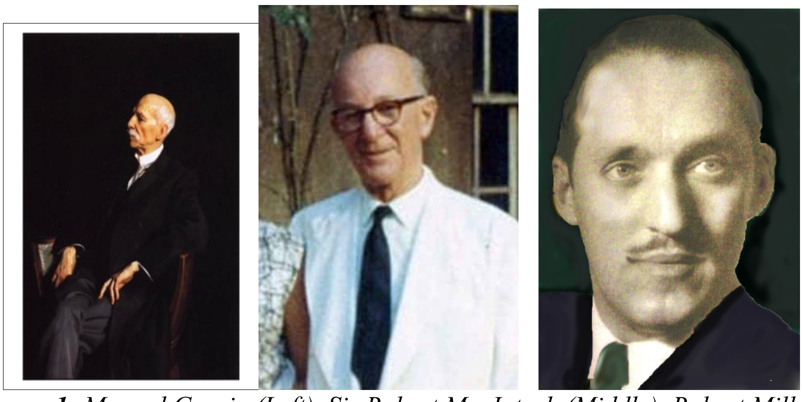


Figure 1: *Manual Garcia (Left), Sir Robert MacIntosh (Middle), Robert Miller (Right) (from Wikipedia 2013 & The History of Surgery & Anaesthesia 2013)*

The development of optic fibres in the 1960s/70s led to the appearance of fibreoptic bronchoscopes, which allowed the anaesthetist to “see around the corner”; while these devices provided a superior view, they also required specialist training and equipment to use. The advent of the video laryngoscopes is in large part due to the development of video cameras that are now small enough to be placed near the tip of both flexible and rigid laryngoscopes. Cost efficiencies have been achieved with increasing miniaturisation and industrialisation, to the point where even single use video laryngoscopes have become available (see Pott & Bosseau Murray 2008). These trends are likely to continue, with costs falling and miniaturisation increasing, making ever more sophisticated video laryngoscopes within the budget of individual anaesthetists.

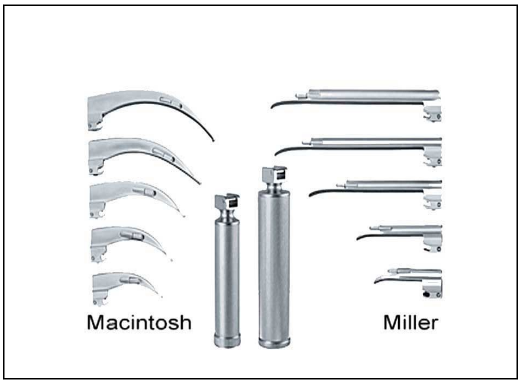


***Figure 2**: Macintosh & Miller Laryngoscopes*
(courtesy of AllBiz 2013).

Classification:

There is no universally accepted classification for video laryngoscopes. We prefer a practical classification that relies on separating the devices into those with Macintosh *vs* Non-Macintosh blades, and then further classifies them into those with and without dedicated channel for the endotracheal tube. This straightforward classification is a simplified version of that proposed by Behringer & Kristensen (2011).

Macinstosh blade-shaped video laryngoscopes:

These VLs are simply Macintosh-shaped blades combined with video technology. The obvious advantage is that the anaesthetist is already familiar with the use of the device to obtain a *direct view* of the larynx, and this use is simply extended to allow an *indirect view* via video technology. Other advantages include the ability to more easily coordinate external laryngeal manipulation with an assistant, as the view is now apparent to all members of the team. Further, the use of a conventional blade on a video laryngoscope can act as a teaching tool for the novice in learning the correct use of a classic laryngoscope. These type of video laryngoscopes are amongst the most common, for obvious reasons, and examples include the C-Mac video laryngoscope (Karl Storz, Culver City CA, USA, Figure 3- Left) and the McGrath MAC (Aircraft Medical, Edinborough, Scotland, Figure 3- Right).

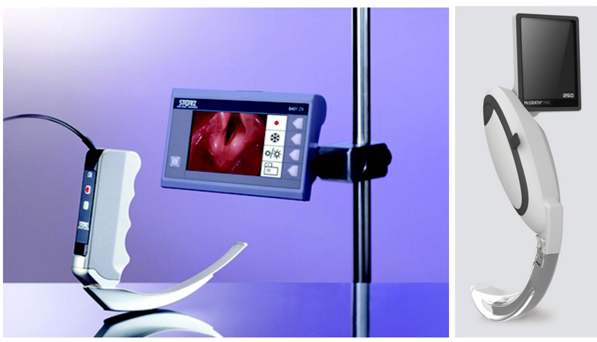


***Figure 3:** C-Mac (Left), McGrath MAC (Right)*
(from Karl-Storz 2013, Aircraft Medical 2013 Respectively)

Non-Macinstosh blade-shaped video laryngoscopes:

From an engineering viewpoint, an obvious limitation of a video laryngoscope based on the Macinstosh blade is that the blade's curvature was developed specifically for direct visualisation of the larynx, and while placing a camera on this blade increases the field of view, it still relies on some level of alignment of the relative oral-pharyngeal-laryngeal axes to assist even an indirect view. In principle, it is arguable that an optimum indirect view is obtained by increasing the curvature of the blade and thus minimising the requirement to lift the surrounding structures. A large number of devices are based on this concept, which includes the GlideScope (Veranthon Medical, Bothwell WA, USA, Figure 4- Left), McGrath Series 5 (Aircraft Medical, Figure 4- Middle), the Bullard laryngoscope; and the use of the "D Blade" on the C-Mac device (Figure 4- Right). As would be expected, a direct view of the glottis is **not** usually possible with these devices, although *a priori* we would anticipate an improved indirect view.

Figure 4: *Glidescope (Left), McGrath Series 5 (Middle), C-Mac with D Blade (Right)*
(From Verathon 2013, Aircraft Medical 2013, Karl Storz 2013 respectively).

Channeled vs Non-Channeled video laryngoscopes:

With conventional laryngoscopy a device sweeps aside and lifts airway structures in order to obtain a good direct view of the larynx which, once achieved, allows a tracheal tube to be separately and independently sited. An alternative is to have a guiding channel built into a device which directs the tracheal tube towards the glottic opening. Video laryngoscopes based on this idea include the Pentax-Airway Scope (Pentax-AWS, Ambu Glen Burnie MD, USA, Figure 5- Left), Airtraq (Prodol, Vizcaya, Spain, Figure 5- Middle) and the Bullard Laryngoscope (Bullard 1996). Note that the Bullard laryngoscope was not originally conceived as a video laryngoscope, but an optical laryngoscope; however it can be equipped with a video camera and thus function as a video laryngoscope (Niforopoulouet al. 2010). This concept allows a further subclassification of video laryngscopes into "channeled" or "non-channeled".

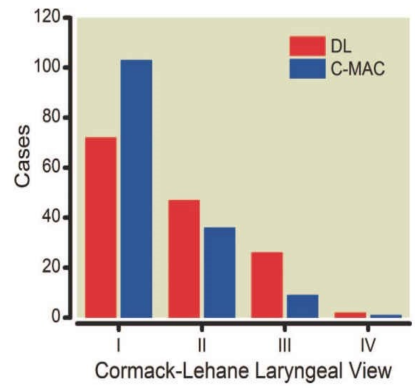
Figure 5: *Pentax ASW (Left), Airtraq (Middle), Bullard (Right)*
(from Ambu 2013, Pott et al. 2008, Legrand et al. 2012 respectively)

Specific Applications of Interest:

The Difficult Airway:

The primary goal for using a video laryngoscope is the perceived benefit in managing difficult airways; this section explores whether this perception is supported by the available evidence. One challenge in assessing this question is that difficult intubation is a relatively rare event, and thus trials need to have large numbers or selected subgroups to achieve sufficient power to be meaningful. Further, the prevailing method of conventional direct laryngoscopy with or without a gum-elastic bougie has a well proven track record and is highly successful which may limit the group for which video laryngscopy is in fact a *necessity.* For example, the study by Amathieu (2011) found only a 0.2% failure rate (29 failures out of 12,221 intubations) with conventional laryngscopy aided by a gum-elastic bougie, although these failures did require an Airtraq (VL), LMA-CTrach, or Fibreoptic Bronchoscope for subsequent intubation.

One interesting trial by Aziz et al (2012) had a single-blinded design with 300 patients randomised to either the C-Mac or a conventional laryngoscope for intubation. To increase the power of the study, these patients were specifically selected for having one or more predictors of anticipated difficult intubation, and thus represent a subgroup of the general population. The C-Mac performed better with more successful intubations at the first attempt (93% vs 84%), a better view (Cormack-Lehane view graded I or II in 93% vs 81%), and a reduced likelihood of requiring a gum-elastic bougie or external laryngeal manipulation (24% vs 37%). However, this was at the expense of an increased time to intubate the patient (46s vs 33s) and a slightly increased rate of minor complications in the C-Mac group (20% vs 13%), although this did not reach significance (Figure 6).



Cormack-Lehane laryngeal views achieved among successful intubations. Laryngeal view was better with C-MAC® (P = 0.001). DL = direct laryngoscopy.

Figure 6: *Cormack-Lehane views achieved with C-Mac vs DL (Aziz et al 2012).*

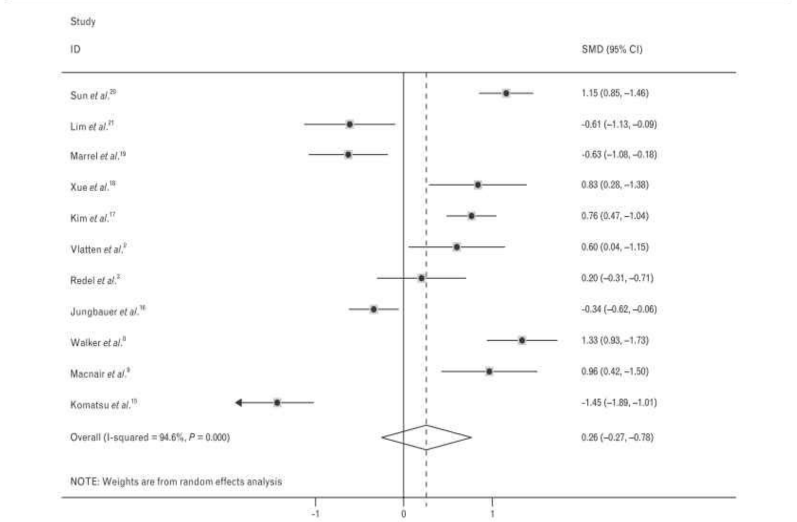
Another study retrospectively examined over 70,000 intubations, of which over 2000 used the Glidescope and reported a primary success rate of 98% for all intubations and 96% for "difficult" intubations (Aziz et al. 2010) . Of particular interest, they found that of the 239 patients that failed conventional laryngoscopy, 224 (94%) of them were subsequently intubated with the Glidescope, whereas historically this role would have been performed with a fibreoptic intubation. This study illustrates the emerging role of the video laryngoscopes as a rescue device, a role that is only now being incorporated into various difficult airway algorithms (*eg* [ASA] Practice Guidelines for Management of the Difficult Airway 2013). It can also be inferred that fibreoptic intubations are now becoming even rarer than was previously the case, which may well negatively impact on the challenges of maintaining proficiency is this technique.

While individual RCTs of Video Laryngoscopes are of interest, many are underpowered, and so there is potentially more utility in a meta-analysis. Su et al (2011) combined a variety of RCTs that used several video laryngoscopes (*eg* Storz, predecessor to the C-Mac, and GlideScope) to glean some interesting results. Table 1 shows the available trials at the time of publication. While the combination of these trials generally mirrors the conclusions of Aziz et al (2012) discussed above, one important contribution is where the trials are separated into "Difficult Intubation Scenarios" and "Non-Difficult Intubation Scenarios" as shown in Figures 8 & 9; it appears that for straightforward intubation a conventional laryngoscope is faster (and equally effective) than a video laryngoscope, whereas in difficult intubations the VL is faster (and more effective). Pragmatically, given that the vast majority of intubations are straightforward, it could be argued there is little advantage to be gained with the use of video laryngoscope, in fact, there may be a disadvantage given the increased time to intubate; in contrast, for the much smaller proportion of difficult intubations, the VL becomes a powerful and effective tool. Unfortunately, a significant proportion of difficult intubations are not predictable (*eg* Wilson et al. 1987), and so it is not *a priori* apparent whether the conventional laryngoscope or video laryngoscope is the most appropriate tool prior to commencing intubation.

Author	Year	No. of participants	Mean age (years)	% Male	Type of video laryngoscope	Difficult intubation	Measures of glottic view
Sun *et al.*[20]	2005	200	53	35	GlideScope	No	C&L grade
Lim and Yeo[21]	2005	60	39.5	0	GlideScope	Yes: in-line manual stabilisation of the head and neck	C&L grade
Marrel *et al.*[19]	2007	80	45	40	X-Lite	Yes: morbidly obese patients	C&L grade
Xue *et al.*[18]	2007	57	29.7	35	GlideScope	No	
Kim *et al.*[17]	2008	203	6.3	60	GlideScope	No	C&L grade
Vlatten *et al.*[2]	2009	56	2.4	68	Storz	No	C&L grade and POGO score
Redel *et al.*[3]	2009	60	4.3	52	GlideScope	No	
Jungbauer *et al.*[16]	2009	200	55.5		Storz	Yes: modified Mallampati score of III or IV, or a history of a difficult intubation and mouth opening of at least 2 cm	C&L grade
Walker *et al.*[8]	2009	120	54.3	30	McGrath	No	C&L grade
Macnair *et al.*[9]	2009	60	8.9		Storz	No	C&L grade
Komatsu *et al.*[15]	2010	100	56.5	48	Pentax-AWS	Yes: simulated ground-level position	C&L grade and POGO score

C&L, Cormack and Lehane; POGO, percentage of glottis opening.

Table 1: *RCT used in Meta-Analysis by Su et al. (2011)*



Pooled time to intubation using standardised mean difference (0.26; 95% confidence interval −0.27−0.78). Results towards the left favour the video laryngoscope.

Figure 7: *Time to Intubate Using Standardised Mean Differences between Video Laryngoscopy and Direct Laryngoscopy for all Pooled Trials; results towards LEFT favour the VL (Su et al 2011).*

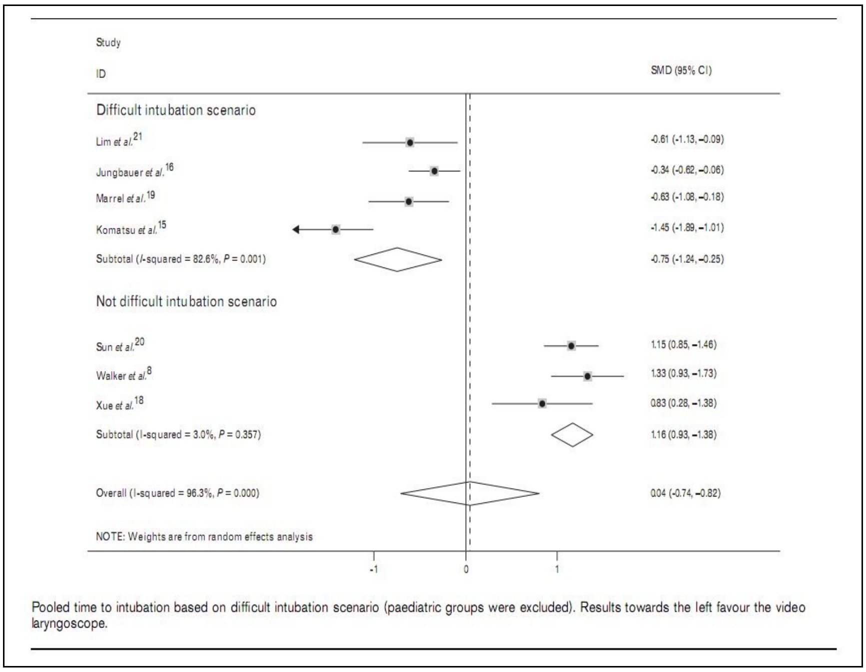


Figure 8: *Subgroup Analysis (Difficult vs Not Difficult Scenarios) of Time to Intubate Using Standardised Mean Differences between Video laryngoscopy and Direct Laryngoscopy for Pooled Trials; results towards LEFT favour the VL (Su et al 2011)*

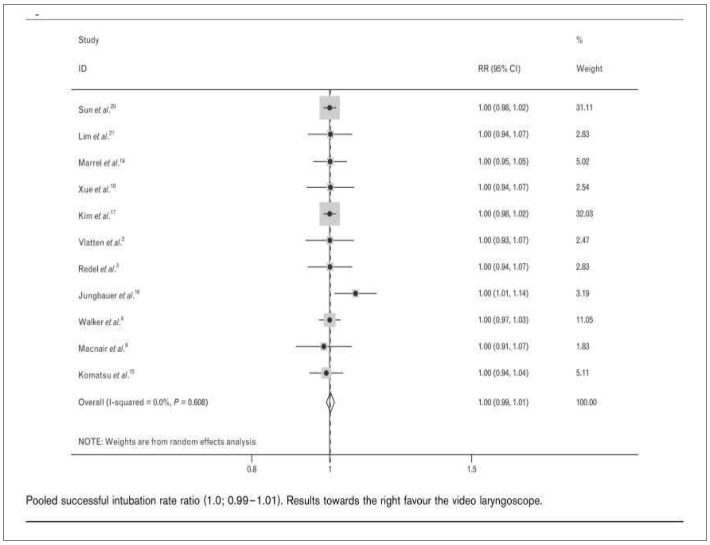


Figure 9: *Ratio of Successful Intubation of Video Laryngoscopy to Direct Laryngoscopy for Pooled Trials (success rate was nearly 100% for both groups in all trial) (Su et al 2011, 1196 Patients).*

Paediatrics:

The paediatric airways contrasts with the adult airway in that an unanticipated difficult airway is exceedingly rare; given the history and appearance of the child almost always alerts the anaesthetist (Best 2012). One accepted approach for the anticipated difficult airway is a gas induction followed by an asleep fibreoptic intubation with or without an LMA as a conduit, given that children are unable to properly comply with a standard awake fibreoptic intubation (*eg* Miller's Anaesthesia, 2009). Maintaining an appropriate skill-level for such a rare event is challenging, even for a paediatric anaesthetist, let alone an anaesthetist with only occasional paediatric exposure. In this context, the advent of the video laryngoscope has generated interest in providing assistance in at least some of these situations, although it is recognised that the occasional need for the fibreoptic scope (while asleep) will almost certainly remain.

Unfortunately, not all manufacturers produce paediatric sized video laryngoscopes given that this population is both a smaller market, and less likely to have a difficult airway. The requirement for a camera also makes these devices more bulky than a standard laryngoscope which complicates their use in the smaller paediatric airway. Nevertheless, the C-Mac does have paediatric blades (Miller Size 0, 1, and MacInstosh Size 2), and these are progressively finding their way into major paediatric teaching hospitals (*eg,* Westmead Children's Hospital, NSW). Other paediatric video laryngoscopes do exist, including the Airtraq, Glidescope, Storz DCI, and Truview PCD, and for a full review the reader is referred to Holm-Knudsen (2010).

A particular challenge is the confined space available within the paediatric airway where it may be difficult or impossible to manouvre the endotracheal tube, with the stylet in situ, to the glottis and/or through the cords where the stylet is then removed. Holm-Knudsen (2010) proposes a variation of the standard technique whereby instead of withdrawing the stylet, the endotracheal tube is advanced off the "stabilised" stylet and towards the glottis; Figure 10 below shows this more clearly. This technique has applicability to adult airways as well, especially in the situation of a narrow adult airway, as well as when using the D-blade, as will be discussed in a later section.

A study contrasting a (GlideScope) video laryngoscope with standard direct laryngoscopy using a paediatric patient simulation model with graded difficulty showed no benefit in intubation success, along with a greater period of time required for the video laryngoscope, (Rodriquez-Nunez et al. 2010); although it is unclear how well their “in simulator” results would translate into clinical practice.

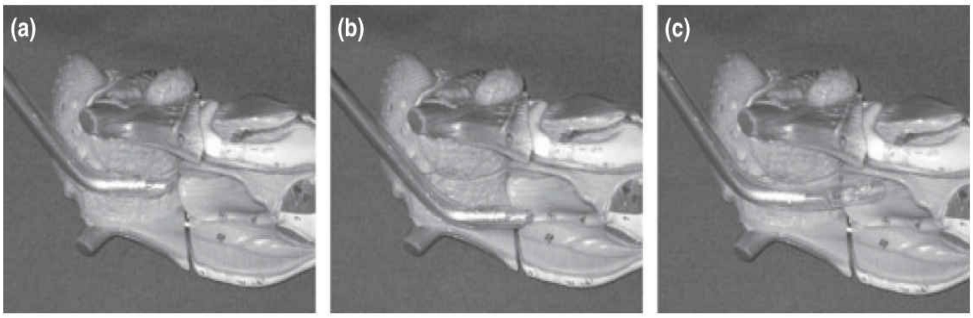


Table 2 The four steps in indirect laryngoscopy

Step 1. Looking in the mouth. The laryngoscope is inserted into the mouth and gently advanced toward the root of the tongue.
Step 2. Looking at the screen. The position of the laryngoscope is optimized.
Step 3. Looking in the mouth. The endotracheal tube with the stylet is inserted gently and placed as close to the tip of the laryngoscope as possible.
Step 4. Looking at the screen. The endotracheal tube is directed toward glottis and between the vocal cords.

Figure 10: *The “Sliding Off Stylet” Technique (from* Holm-Knudsen 2010)

As experience with these devices accumulates, their limits and strengths will become further defined. For example, Oakes et al. (2013) found that they were unable to intubate a 9yo child with Klippel-Feil Syndrome with the C-Mac and a Size 2.0 MacInstosh blade as the bulky handle abutted the patient's chest and prevented full insertion of the blade (see Figure 11). Interestingly, this problem was not apparent with the smaller profile of the paediatric handle on a conventional laryngoscope, although this also proved insufficient for the purpose, and the patient was eventually intubated with the use of a flexible fibreoptic scope via the nasal route.

(a) C-MAC handle abutting the patient's chest

(b) easier insertion of the blade using a conventional paediatric handle.

Figure 11: *C-Mac vs Conventional Handle in Paediatric Setting (from Oakes et al. 2013)*

In terms of practicalities, Seal (2009) suggests that a common problem with video laryngoscopes in a paediatric context is the tendency to push the blade too deeply, and he advises that carefully withdrawing the blade allows the proceduralist to take advantage of the wider field of view afforded by the distal camera than is available on a direct view. In a similar way, and for similar reasons, he advises that in the setting of an anterior larynx (only the arytenoids or posterior glottis visible at the top of the monitor screen) that external laryngeal manipulation (ELM) may be of greater assistance than simply pushing the blade further inwards, as the latter will inevitably narrow the camera's available field of view.

Obstetric:

The obstetric population is also an at-risk group for failed intubation, and has attracted interest in the use of video laryngoscopy, although there have been limited specific studies. Aziz et al. (2012) audited their use of conventional direct laryngoscopy (DL) and video (Glidescope) laryngoscopy (VL) over a 3 year period in an Obstetric Unit and found that DL resulted in a successful first attempt intubation in 157/163 patients, while the VL resulted in a successful first attempt intubation in 18/18 patients; noteably the failed direct laryngoscopies were all rescued with the video laryngoscope. It is difficult to draw any conclusions regarding the VL arm (18 patients) with such an underpowered study, although the authors did suggest that the video laryngoscope was a useful adjunct in the setting of failed intubation; clearly more work needs to be done in the obstetric context.

Obesity:

The proportion of patients presenting with comorbid obesity is increasing throughout the developed world, with implications for the management of anaethesia (Figure 12).

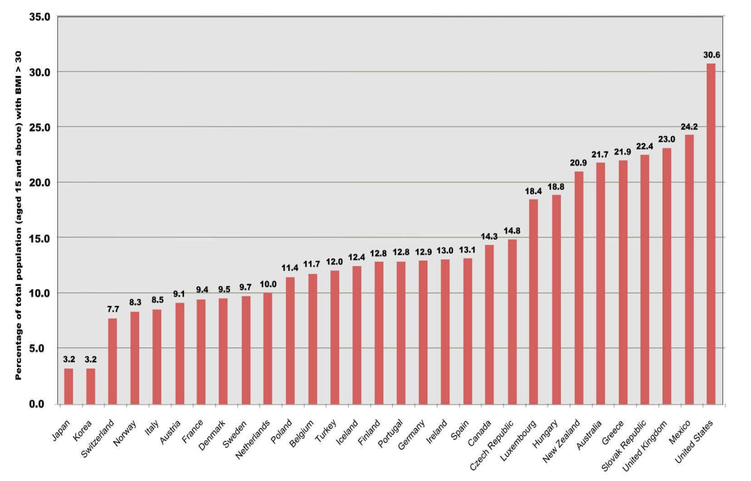


Figure 12: *Proportion of Population Obese by Country (1996-2003) (based on OECD Health Data 2005)*

Specifically, obesity is associated with difficult mask ventilation, rapid desaturation, and difficult intubation (El-Orbany et al. 2009; Jense et al. 1991). Surprisingly, obesity on its own is a weak predictor of failed intubation, although it is a marker for the presence of associated problems that are predictive of difficulties, such as a large neck circumference or poorer average Mallampati score (Brodsky et al. 2002). In particular, Gonzalez et al. (2008) found that the obese with thick short necks had a large amount of oropharyngeal fat limiting the oropharyngeal space which impeded adequate visualisation of the glottis; which can be readily seen in Figure 13 (modified from Cattano & Hagberg 2010). Complicating any difficulty is that the obese become hypoxic more quickly due to the poor pulmonary oxygen store available in the reduced functional residual capacity (Hunter et al. 1998, Cattano & Hagberg 2010).

To cater to the special needs of this increasingly large proportion of patients, many institutions have acquired devices such as hover mats and troop elevation pillows for ease of positioning and transfer (Figure 14). Other techniques, such as apnoic oxygenation, have been found useful in the obese in order to increase the available time to complete an intubation, and this is discussed in more detail in a later section.

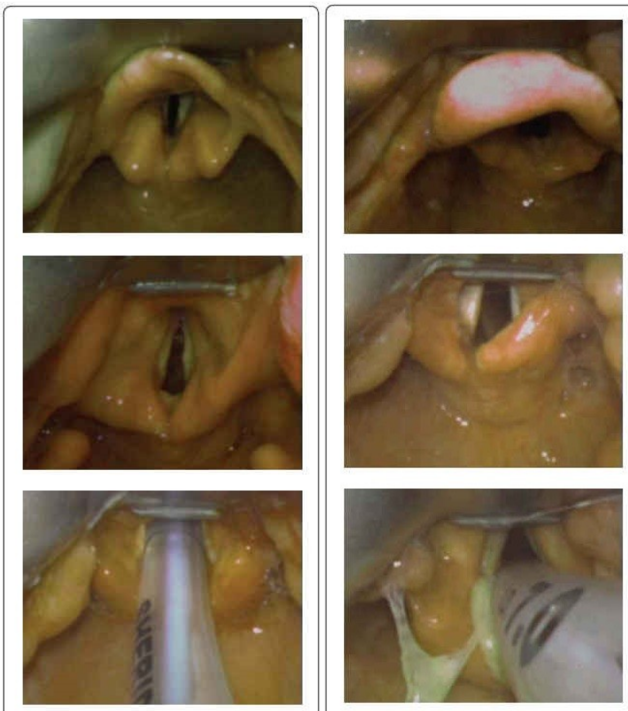


Figure A Airway images of an average weight patient obtained through video laryngoscopy.

Figure B Airway images of a morbidly obese patient obtained through video laryngoscopy.

Figure 13: *Comparison of Typical Lean Airway (Left) and Obese Airway (Right) (modified from Cattano & Hagberg 2010)*

Our own interest is in the use of video laryngoscopes in this population, although the number of specific studies remains surprisingly small. Some studies have suggested the benefit is marginal, for example, Abdallah et al (2011) randomised 105 morbidly obese patients (BMI ≥ 35 kg/m^2) to be intubated with either the Pentax AWS video laryngoscope or a standard Macinstosh #4 blade and found the Pentax took longer with no appreciable improvement in the likelihood of successful intubation. An interesting study by Ydemann et al. (2012), randomised 100 morbidly obese patients (BMI ≥ 35 kg/m^2) to be intubated with either an LMA Fastrach (effectively a blind technique) or GlideScope (VL), but found very little difference in either their endpoints of time to intubation or success in intubation.

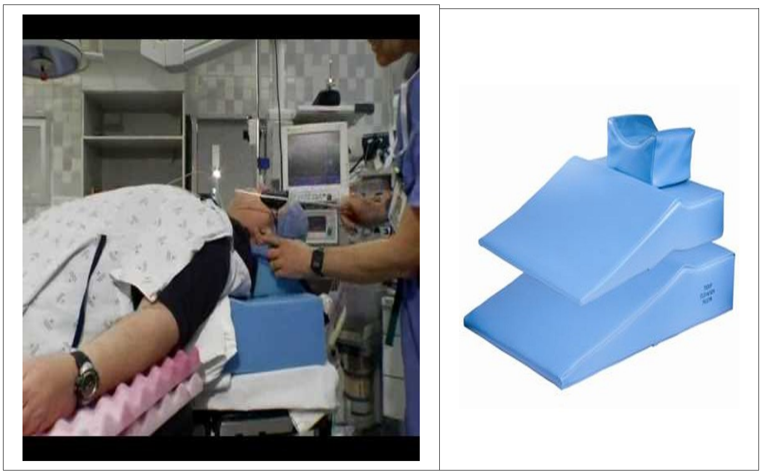


Figure 14: *Troop Elevation Pillow (Left – In Action, Right – Components)*
(from Troop, C. 2013).

Conversely, Marrel et al. (2007) found that better Cormack-Lehane views were obtained in this population using the video laryngoscope than found with direct laryngoscopy. Similarly, Frappier et al. (2004) found up to 16% (19 of 118) of morbidly obese patients had Cormack-Lehane Grade III or IV views during direct laryngoscopy (DL). This correlates with the personal experience of many clinicians in that while difficulty is not always seen in intubating the obese, it does seem to be encountered more often and, when it occurs, is more difficult to manage (*eg* Doyle et al. 2009).

Emergency:

Most high quality studies comparing DL and VL have been in the context of the controlled environment of the operating theatre (eg Griesdale et al. 2012) and the evidence for the use of VL in the Emergency Room derives mostly from observational studies (eg Wayne et al 2010, Platts-Mills et al. 2009, Brown et al. 2010) or from retrospective studies (eg Sakles et al. 2011, 2012). Greenland et al. (2011) provides an editorial on the evolving role of the VL in the Australian context of Emergency Medicine and summarises the state of play by recommending its use as a rescue device when conventional intubation with direct laryngoscopy with a stylet or bougie has failed, as long as adequate oxygen saturations are maintained. He specifically cautions against task fixation on the video laryngoscope screen rather than the deteriorating condition of the patient; a reflection of this subtle but important shift in attention.

The evidence-base in the Emergency context has been recently improved by the high quality study of Yeatts et al. (2013) who randomised 623 consecutive adult patients requiring intubation in their trauma receiving unit to either the Glidescope or conventional direct laryngoscopy. They found no difference in terms of first pass success in intubation; although as in other studies the time to intubation was longer with the video laryngoscope. Interestingly, one of their endpoints was whether either device was a marker for long term survival and discharge from hospital, and although they did not find any clear relationship, they did make the troubling observation that a smaller subgroup of severely head injured patients did appear to have a trend towards a greater incidence of hypoxia below 80% and increased mortality when randomised to the Glidescope arm of the study, although this did not reach significance. They concluded that the use of a DL was not inferior to VL in the emergency context, but that further studies were warranted to ensure that its use did not in fact result in a disservice to specific subpopulations.

Awake Video-Assisted Intubations:

Difficult tracheal intubation is a known contributor to severe patient morbidity and death, as has been extensively documented in many studies of closed claims (*eg* Runciman et al. 1993, Hove et al. 2007) and national audits (*eg* NAP4; Cook et al. 2011). In specific situations of an *anticipated* difficult tracheal intubation the use of a flexible fibreoptic scope with an awake patient has often been the preferred instrument, if not the *gold standard*, for achieving this endpoint safely. However, the maintenance of the relevant psychomotor skills and knowledge for fibreoptic intubation (FOI) is a longstanding challenge for the practicing anaesthetist, given they may only rarely encounter the need to use this device (*eg* Mason 1992). In this context, there has been increasing interest in the use of video laryngoscopes to achieve intubation safely in an *awake* patient as an acceptable alternative to flexible fibreoptic scopes (Case Reports: Doyle 2004, McGuire 2009). The clear advantage of Video Laryngoscopes is that most of them are used in a relatively similar fashion to conventional laryngoscopes, and thus rely on a familiar psychomotor skill set.

One interesting trial by Rosenstock et al. (2012) randomised ninety-three patients to either FOI or awake intubation with the McGrath Video Laryngoscope (MVL). The trial used only experienced airway experts and each arm had identical topicalisation. The endpoints of successful intubation, and time to intubate, were practically identical for both FOI and MVL arms, with only one patient failing FOI and requiring intubation with MVL. However, the investigators did accept their trial was underpowered to fully assess the utility of the device for awake intubation and as such their results should be considered informative rather than definitive. Of note is that the investigators used trans-tracheal injection of lignocaine (along with an oropharyngeal lignocaine spray and a low-dose remifentanil infusion) rather than the traditional "spray as you go" technique as it was thought that the pressure of the MVL blade on the tongue and laryngeal structures would cause too much discomfort without prior topicalisation. While common is some countries, it may well be that transtracheal injection is not an acceptable (or commonly used) method for Australian anaesthetists which again qualifies this technique of awake VL intubation.

Use in Teaching:

The experience required to learn manual skills is a well studied area; in the setting of anaesthesia many procedural skills, including tracheal intubation, require over 50 repetitions to have over a 90% success rate; Konrad et al. (1998) has produced "learning curves" which are reproduced in Figure 15. Mulcaster et al. (2003) has replicated these findings through studying 438 direct laryngoscopic intubations by 20 novices, to derive that 47 intubations are required for a >90% success rate; they found that proper insertion of the laryngoscopic blade and correct lifting were critical to competency.

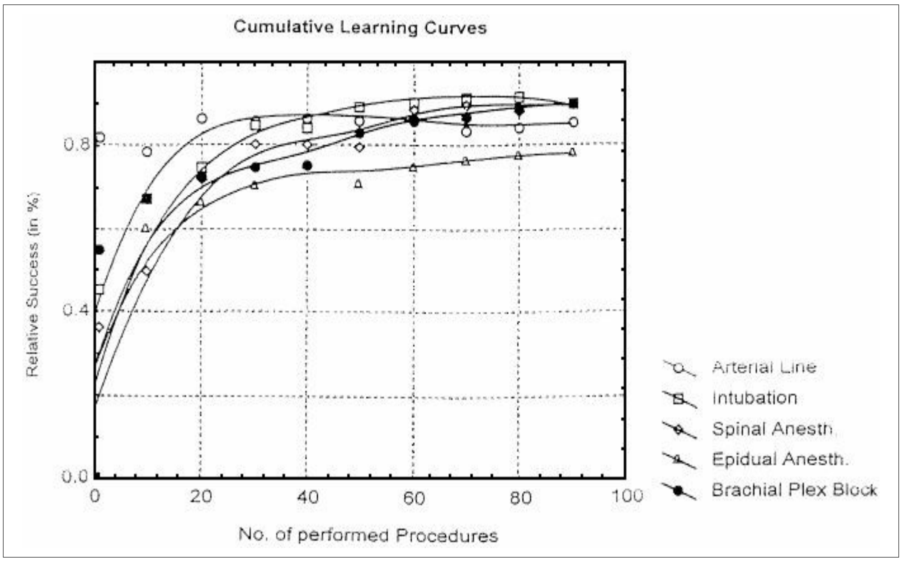


Figure 15: *Cumulative Learning Curves for Common Anaesthetic Procedures (from Konrad et al. 1998)*

However, these learning curves do not apply to all anaesthesia-related manual skills; for example, the number of repetitions required to insert a laryngeal mask with modest success has found to be significantly smaller than that required for more difficult skills such as tracheal intubation (*eg*, Pennant & Walker 1992), and this correlates with our everyday observation of teaching these skills to registrars.

In a similar way, there is a small controlled trial comparing a video laryngoscope (Airtraq) and a standard Macinstosh blade which showed substantially better success with novices after only 5 intubations, with Grade I views found in 87% vs 46% of cases respectively (Di Marco et al. 2011). This may be specific to the Airtraq given that as a channeled video laryngoscope it delivers the endotracheal tube directly to the glottic aperture once it is obtained in the camera's field of view.

Apart from a potentially accelerated learning curve, a video laryngoscope allows the laryngeal structures to be visible to the operator (*eg* registrar), teacher (*eg* consultant), and other support staff (*eg* anaesthetic nurse), which allows the effect of various manipulations (*eg* external laryngeal manipulation) to be immediately evident to all, which can facilitate coordinating a successful intubation.

Known Complications:

The benefits of any new technology need to be weighed against the disadvantages, and video laryngoscopes are no exception. The introduction of a video screen provides additional complications beyond those already identified for standard direct laryngoscopy, and awareness of these complications can allow the user to develop strategies to avoid them.

A common error results from the proceduralist focusing their attention on the video screen during insertion of the laryngoscope or endotracheal tube rather than using conventional line of sight techniques for the insertion. Not surprisingly, this risks injury to the palatal arch and other structures (*eg* Malik & Frogel 2007). A general principle of use should be that during insertion of any device in the mouth or nose that the anaesthetist should focus attention directly on the patient rather than viewing the video screen; the utility of the video screen is at the final stages of passing the ETT through the cords.

This common error may explain some apparent anomalies in the C-Mac trials discussed above, *eg* the greater incidence of minor complications with the C-Mac vs conventional laryngoscopy in the trial by Aziz et al (2012). It would seem intuitive that the combination of direct and indirect views afforded by the video laryngoscope should reduce the minor complication rate relative to conventional laryngoscopy, but this is premised on *the equipment being used properly*.

Further, video laryngoscopes can often provide an excellent view of the larynx but this is no guarantee of being able to pass a tracheal tube through the glottic opening. The point of differentiation is that with direct laryngoscopy a good view represents a fairly straight passage for the ETT, whereas with indirect laryngoscopy the ETT may have to negotiate a significant curvature to reach the glottic opening. To assist with the required manoeuvres, the use of a Stylet is a common feature of the (unchanneled) video laryngoscopes. The damage possible with a Stylet is well known (*eg* Fan et al. 2004), but this is compounded by the lack of direct vision as previously discussed.

Cooper (2007) retrospectively examined the complication rate in over 2000 Glidescope intubations and established that there were only 21 (1%) traumatic laryngoscopies. Minor complications included lip and gum lacerations, while more serious complications included two dental injuries, vocal cord trauma, tracheal injury, and a case of tonsillar perforation. One solution is to avoid the use of the Stylet, and various series (*eg* Maassen *et al*. 2009) have found a relatively good success rate in these cases. However, the unknown factor is whether these cases would have been straightforward with conventional laryngoscopy, and whether choosing not to use the Stylet for all cases may then remove any advantage of the device for the much less common difficult airway. Clearly, further research needs to be done to answer these questions.

One not uncommon problem with conventional laryngoscopy is the force on the maxillary incisors, which can result in dental damage, the most common cause of claims against anaesthetists (Newland et al. 2007). Reassuringly, the study be Lee *et al* (2012) has shown that video laryngoscopes, and particularly the C-Mac series, substantially reduce these forces as shown in Figure 16.

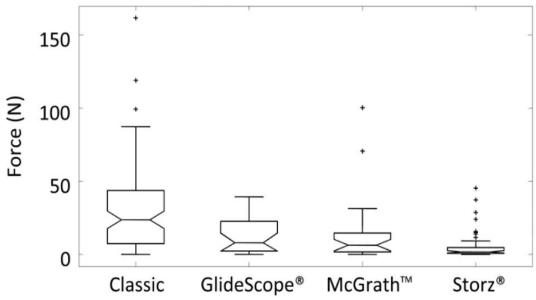


Fig. 2. Comparison of forces (N) during endotracheal intubation for three video laryngoscopes and Macintosh laryngoscope. Box and whisker graph indicating median, upper and lower quartiles, the extremes of the data, and potential outliers.

Figure 16: *Forces on Maxillary Incisors with Various Video Laryngoscopes (from Lee et al. 2012)*

Practicalities of Use- Tips & Tricks:

The C-Mac Video Laryngscope:

This section focuses on the practical knowledge and skills required to use the C-Mac Video Laryngoscope (Karl Storz, Culver City CA, USA, Figure 17).

The C-Mac is a further development of previous videolaryngoscopes by Karl Storz (viz, MVL, V-Mac) and is marketed as a useful alternative to direct laryngoscopy for both routine and difficult airway management, as well as a teaching tool. The VL comes with a range of MacIntosh-shaped blades, sizes 2, 3, and 4, and recently has extended into paediatric blades (Miller Size 0 & 1). A D-blade is also available, which has the distinguishing features of an elliptically tapered blade shape rising distally, and is based on the Dörges blade (hence the "D"). The D-blade and Size 3 & 4 MacIntosh blades also feature a lateral guide for large suction catheters; this guide can also be used as a conduit for an oxygen catheter and administration of oxygen throughout the entire intubation process. For nasal intubations, or removing foreign bodies, a modified Magill forcep known as the "Boedeker" forcep has been developed which has improved utility for these applications (Boedeker et al. 2012, Figure 18).

Figure 17: *C-Mac Equipment (from Karl-Storz 2013)*

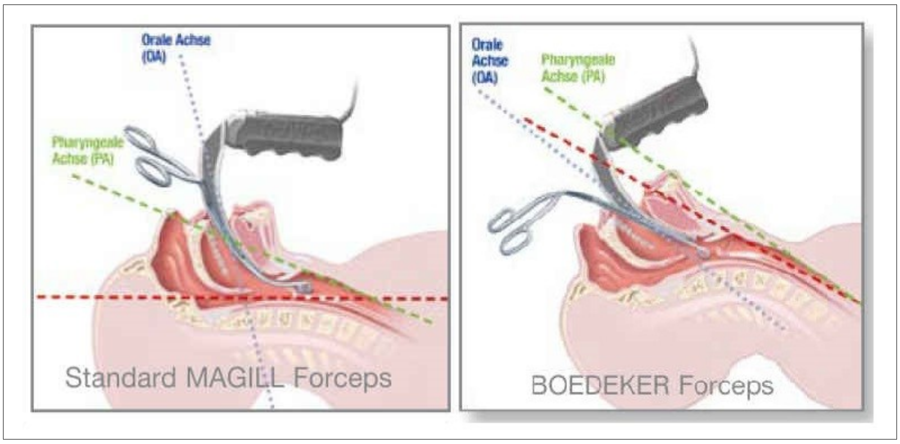


Figure 18: *Standard Magill vs Bodeker Forceps (from Karl-Storz 2013)*

The C-Mac incorporates a small 2mm digital camera (320 x 240 pixels) and a high-power light emitting diode located laterally in the distal third of the blade; this is in departure to earlier models (eg MVL, V-Mac) that made use of a fibreoptic technique and thereby has eliminated the need for white color balance and focusing. In contrast to a range of other video laryngoscopes (*eg* V-Mac, Glidescope, McGrath) the view obtained (aperture angle of 80 degrees) includes the tip of the blade and, therefore, enables visual guidance of the tip into the vallecula (Figure 19). The main angulations of the C-Mac blade Size 3 and 4 are shown in Figure 20; note that the blade angulations are slightly different to conventional MacInstosh blades.

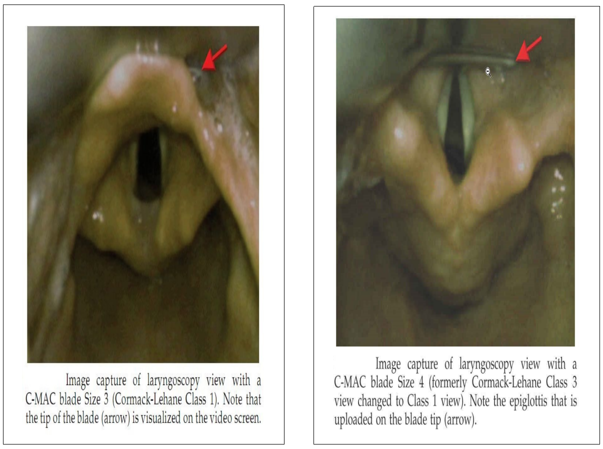


Figure 19: *Typical C-Mac Blade Size 3 and 4 Views (Cavus et al. 2010)*

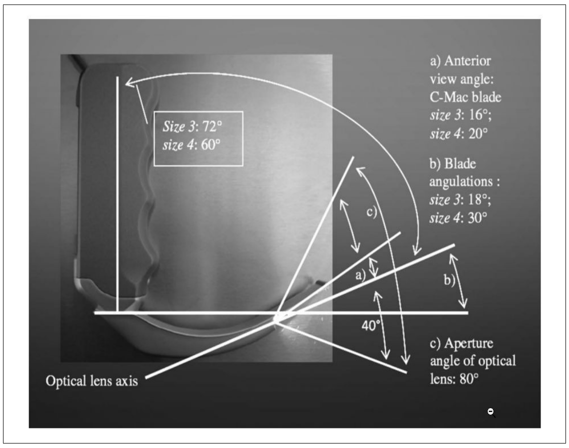


Figure 20: *Main Angulations of C-Mac Blade Size 3 & 4 (Cavus et al. 2010)*

The color image obtained is displayed on a portable, lightweight crystal display monitor (resolution 800 x 480 pixels, 153 x 93mm screen; 7") with lithium-ion batteries that allow approximately 2 hours use prior to requiring a recharge. The image may be recorded as either a picture or video stream using a digital card slot. An additional C-CAM attachment allows the display monitor to be used in combination with a range of other airway devices including the Storz fibreoptic scopes for those situations where a video laryngoscope is not the solution to an airway problem (Figure 21, Left). A recent innovation is a directly attached "pocket monitor" (with a 2.4" LCD screen) which has significantly increased the portability of the C-Mac; the lithium-ion batteries allow one hour of continuous use and require two hours recharge (Figure 21, Right).

Figure 21: *C-CAM and Fibreoptic Scope Attachments (left) and Pocket-Monitor Attachment for increased mobility (from Karl-Storz 2013)*

Intubating with the C-Mac:

In video laryngoscopy certain aspects of the process work best using direct hand-to-eye coordination while others are best done in the video environment. On this basis, Walls (2009) suggests approaching the use of a the video laryngoscope as a four-step process, viz:

Step1: Introduce the video laryngoscope into the oropharynx

With an appropriately positioned patient, the operator introduces the VL blade into the midline of the oropharynx using the left hand under direct vision, and gently advances the blade tip past the posterior portion of the tongue until the view of the tip is obscured. Note that this step is done with the operator looking directly into the patient's mouth and not looking at the video.

Step 2: Obtain the best view of the glottic opening

With the video laryngoscope blade now inserted,the operator then turns their attention to the video screen in order to manipulate the scope to obtain the best view of the glottic opening. In contrast to conventional laryngoscopy the VL is generally a midline instrument, and no lateral displacement of the tongue is required, although it certainly can be simply used as conventional blade in the conventional manner. Also note that the glottic view may be optimised by either gently advancing or withdrawing the laryngoscope or by increasing the tilt on the blade to seat it at the vallecula or on the posterior surface of the epiglottis. When appropriately seated, the glottic aperture should be visiable in the upper third of the video display. Note that this is all done under video visualisation and not by directly looking into the patient's mouth.

Step 3: Introduce the endotracheal tube

The operator then once again turns their attention to the oropharynx and introduces the endotracheal tube under direct vision until the distal tip of the ETT is sited very near to the distal tip of the laryngoscope blade. During this process the left hand maintains the laryngoscopic position in the mouth while the right hand manipulates the endotracheal tube.

Step 4: Intubate

The operator finally returns their attention to the video screen to see the glottic aperture and, near it, the tip of the ETT. The endotracheal tube is then advanced through the glottic opening under video visualisation.

In summary, this four-step process requires the operator to look “in the mouth”, “at the screen”, “in the mouth”, and “at the screen” in quick succession.

Special Considerations & Adjuncts to Intubation:

There are significant differences between conventional direct laryngoscopy and video laryngoscopy. With direct laryngoscopy the main challenge is obtaining a view of the glottic opening, after which advancing the tracheal tube into the trachea is often (although not always) successful. In contrast, video laryngoscopes, including the C-Mac, are often able to obtain an excellent view of the larynx, even with patients that have known direct Cormack-Lehane Grade III or IV views, but the challenge is then being able to advance the tube into the trachea. The reason for this is readily apparent from Figure 22 which shows a comparison of standard direct laryngoscopy (left) with video-assisted laryngoscopy (right) (Levitan et al. 2011). As can be seen, the optimal position for direct laryngoscopy provides a more direct pathway along the line of sight into the trachea, whereas the curvature with indirect video laryngoscopy results in the glottic view directed at an significant angle relative to the axis of the trachea, which clearly complicates the passage of the endotracheal tube.

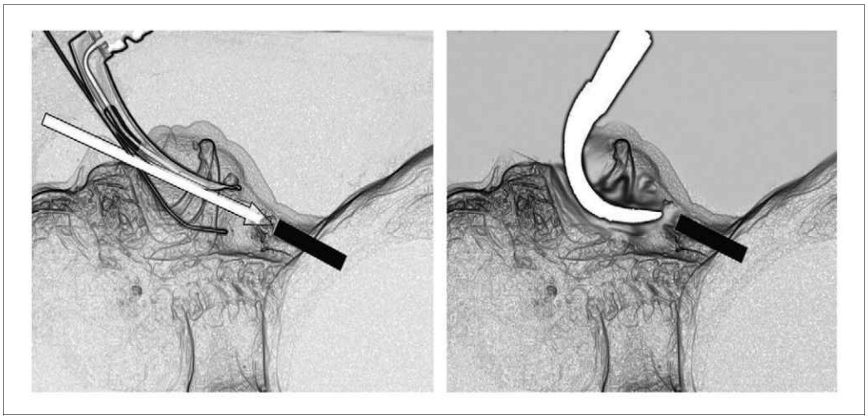
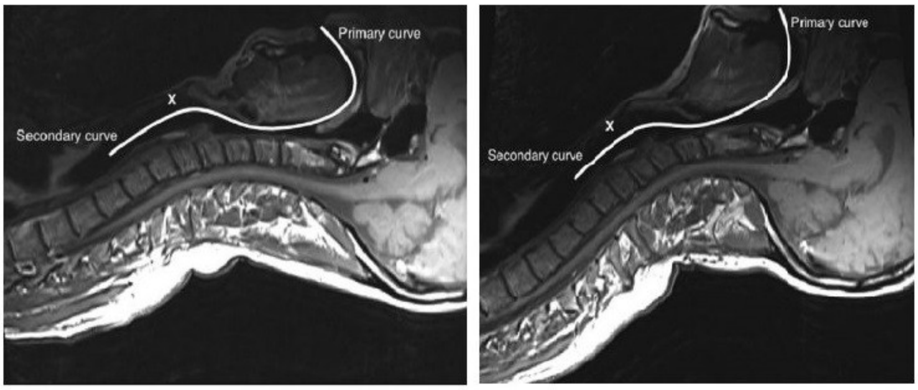


Figure 22: *Tracheal Axes of Standard DL vs Curved VL (after Levitan 2011)*

While we do not propose to delve into various theories of laryngoscopy, it is worthy of note that the situation in video laryngoscopy is in some ways simply an exacerbation of the existing situation with direct laryngoscopy. To understand this, let us briefly consider the well-known three axis alignment theory proposed by Bannister & MacBeth (1944) which suggests that direct laryngoscopy requires alignment of the laryngeal axis, pharyngeal axis and axis of the mouth with the line of vision. In this theory the “sniffing position” (head lift, neck extension) is proposed as a method of achieving this goal, and it has been incorporated as a common practice in anaesthesia. However, Adnet et al. (1999, 2001) showed using MRI that such an alignment is in fact anatomically impossible, unless a patient has a “flip top head”, and Greenland et al. (2008, 2010, 2011) has suggested a “Two Curve Theory” (Figure 23) may better explain the anatomy whereby a “primary” oropharyngeal curve is aligned with a “secondary” pharyngo-glotto-tracheal curve with the point of inflection being the base of the epiglottis (although see comments by Lee 2011). In this latter theory, head lift flattens the secondary curve while neck extension flattens the primary curve, and the sniffing position achieves both of these manouvres. Note that Figure 23 is in fact incomplete in that these are MRI-scans of awake volunteers in the sniffing position: in an anaesthetised patient undergoing intubation the presence of laryngeal blade would mechanically move the tongue away from the line of sight and flatten the primary curve allowing a more direct view of the glottic opening. While neither theory is complete, they remain useful as a conceptualisation of the necessity of having some sort of anatomical alignment from mouth to trachea to enable the passage of a tracheal tube, at least with direct conventional laryngoscopy: the poorer this alignment the poorer not only the laryngeal view but the "more anterior" the larynx, and the more difficult it will be to pass the endotracheal tube. Understanding the relevant anatomy also allows us to anticipate and counter some of the problems not only with direct laryngoscopy but also with indirect video laryngoscopy.



MRI scans showing airway configuration in the neutral and sniffing positions. 'X' marks the likely area that a polyvinyl chloride endotracheal tube will impact on the anterior wall of the subglottic space.

Figure 23: *The Two Curve Theory with Neutral (Left) and Sniffing (Right) positions (from Greenland & Brown 2011)*

With this imaging and theory it becomes clear that while the video laryngoscope may allow a good view of the larynx, negotiating the primary curve with an ETT and then passing it through the glottic aperture into the secondary curve can be challenging. This is particularly true when those curves are particularly acute such as with difficult anatomy or when using the D-blade of the C-Mac (or other highly curved blades, *eg* Glidescope).

Various strategies to deal with this problem include using a stylet in the ETT shaped to blade of the video laryngoscope as shown in Figure 24 (in this case the Glidescope). However, McElwain et al. (2010) studied the utility of various Stylets (no stylet, stylet, Parker Flex-It, hockey-stick) in a SimMan manikin with progressively more different laryngoscopy scenarios and established that the hockey-stick (Figure 25) performed best in the most difficult scenarios while there was little difference in the easier scenarios. An alternative or additional approach is to "reverse load" the endotracheal tube on the stylet (Dow & Parsons 2007), which involves mounting the tracheal tube on the rigid stylet in a direction opposite to its natural curve or alternatively reshaping a malleable stylet so that the imposed curve is opposite to its natural shape. When the stylet is withdrawn the ETT will tend to descend into the trachea. However, in our experience, it can be difficult to maintain this reverse loading, as the ETT tends to twist around the stylet to conform to its natural shape. Finally, it is apparent from our discussion of the two curve theory above that even though indirect laryngoscopy does not require alignment of the primary and secondary axis, it may well be that passage of the endotracheal tube will be improved once these axis are better aligned. We would thus suggest that when encountering this problem it is reasonable to employ our conventional direct laryngoscopy techniques with the specific purpose of improving the likelihood of passage of the tracheal tube rather than to obtain a direct laryngoscopic view: this would include the usual tongue sweep and lift manouvre, as well as insisting on the best possible "sniffing" position prior to induction.

Figure 24: *Shaping Stylet to the Video Laryngoscope (from Baker 2013)*

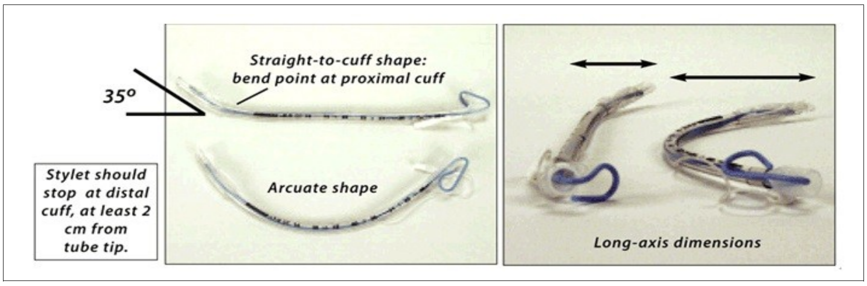


Figure 25: *Hockey-Stick vs Arcuate Stylet Shapes (from Baker 2013)*

While the use of stylet is generally straightforward, most anaesthetists would resort to the use of a bougie in conventional direct laryngoscopy and given its familiarity it is useful to consider whether the bougie has some utility with video laryngoscopy. To this end, we should firstly establish a common language and history for the bougie, as not all bougies have equal utility in either direct or indirect laryngoscopy. In brief, the bougie was first used for airway management by Sir Robert Macintosh in 1943, and went into commercial production in 1949 by Eschmann Healthcare and was thus called the "Eschmann bougie". Our current reusable bougie, the reusable Eschmann Tracheal Tube Introducer [Smiths Medical International, Hythe, UK] derives from a modification by Venn in the 1970s to have two layers: a core of tube woven from polyester threads (fibreglass) and an outer resin layer; it is approximately 60cm in length with a 38º coude distal tip (El-Orbany et al. 2004). In terms of nomenclature, this is sometimes called a "gum elastic bougie" (GEB), although this is a misnomer as it is neither made of gum, nor elastic, and strictly speaking is not a "bougie" as this term is historically used for a dilator; the confusion derives from Sir Robert Macinstosh's early bougie being a borrowed urinary catheter used for the dilation of urethral strictures. In more recent times concerns about infection control have driven the introduction of single-use equipment with significantly different performance and properties.

However, while there is considerable literature to show the Eschmann introducer is a highly effective device (Kidd et al. 1988, Nolan et al. 1992, Latto et al. 2002) with a low potential for airway trauma (Hodzovic et al. 2004), the single-use bougies have variable success rate for tracheal placement (eg Marfin et al. 2002) and a high potential for airway trauma (Hodzovic et al. 2003, 2008, 2010). Further, the single-use bougie is less likely to maintain a preformed curve (has less "memory") than the Eschmann bougie, and many models do not have a coude tip (Rucklidge & Patel 2004). For these reasons, a number of authors suggest that only an Eschmann or equivalent bougie is used, until single-use bougies can demonstrate similar performance characteristics (Hodzovic et al. 2010).

In the setting of video laryngoscopy the ability to shape the bougie is of paramount importance in negotiating the primary curve; while the coude tip is an important feature in passing the bougie through the glottic aperture, thus favouring the use of the classic Eshmann bougie. Once through the glottic opening further confirmation of tracheal placement can be obtained by the "clicks" of the distal tip on the tracheal rings, as well as through eliciting the "hold up" sign by pushing the bougie until it encounters the carina or main bronchi, as is consistent with the Difficult Airway Guidelines (Henderson et al. 2004). However, some authors suggest not using the "hold up" sign given reports of perforation (*eg* Prabhu et al. 2003), particularly with the new single-use and Frova bougies (Marson et al.

2012): if it is used ensure that the sign is elicited gently, and that the bougie is pulled back a short distance so that the adjacent abutted airway does not receive the high pressures that result from railroading the tracheal tube over the bougie (Higgs & Goddard 2009).

Video laryngoscopy does not protect against encountering many of the same common problems as with direct laryngoscopy, such as the endotracheal tube wedging on the aryepiglottic fold or other structures while being railroaded over the bougie, as shown in Figure 26. As is the case in direct laryngoscopy, this problem can often be solved with a counter-clockwise rotation of the ETT, although an advantage of video laryngoscopy is that we can observe this manouvre indirectly on the video screen which may improve its success rate.

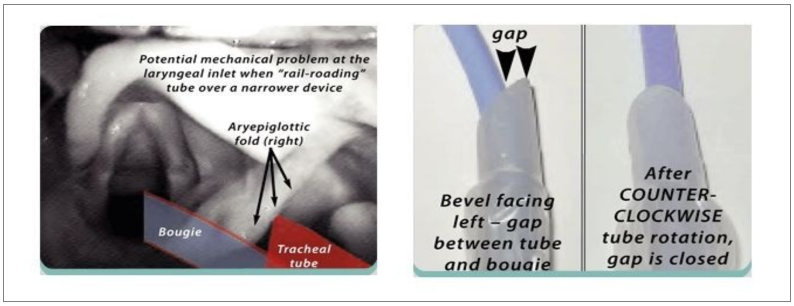


Figure 26: *Bougie & Railroading Problems (from Baker 2013).*

One challenge with video layngoscopy is an increase in the amount and sophistication of equipment which can increase the demands on an assistant, particularly if a bougie is then also involved. We can ameliorate this in part by having "ownership" of the bougie through the "Kiwi Grip" shown in Figure 27 which allows control of the proximal end of the bougie, maintains curvature, and allows the endotracheal tube to be preloaded (after Baker 2013).

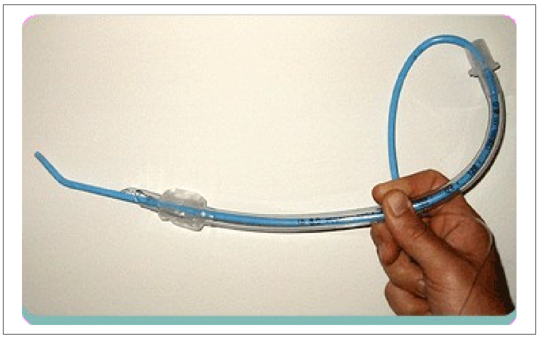


Figure 27: *The "Kiwi Grip" on the Bougie (from Baker 2013)*

A separate problem is readily visualised through the two curve theory, as we can see that the greater the primary curve, and the more the misalignment with the secondary curve, the more likely it is that the endotracheal tube will impact on the anterior tracheal rings (marked as an "x" in Figure 28). With the video laryngoscope this situation is exacerbated by the lack of any requirement to align the primary and secondary curves to obtain a reasonable view of the glottic opening. As with conventional direct laryngoscopy this results in the likelihood of the bevel of a standard endotracheal tube engaging with the anterior tracheal rings, as seen in Figure 28, and interfering with the smooth passage of the trachel tube. One solution is to rotate the endotracheal tube clockwise to disengage the tip of the ETT from the tracheal rings. An alternative is to use endotracheal tubes that have curved tips, such as the Parker ETT or the reinforced ETT that comes with the LMA Fastrach.

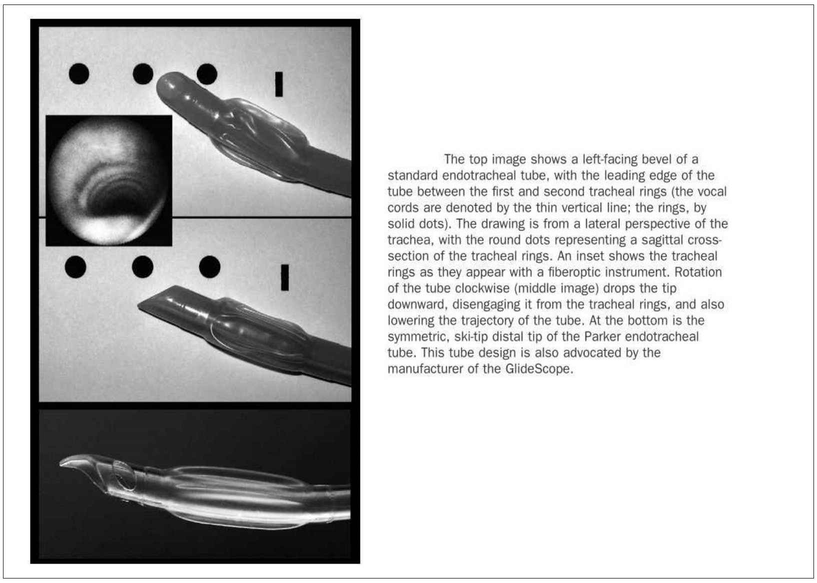


Figure 28: *Tracheal Rings & Endotracheal Tube Bevel (from Baker 2013)*

How to buy time- apnoic oxygenation:

As discussed earlier, the meta-analysis by Su et al. (2011) shows that video laryngoscopy can suffer from a greater time to intubation relative to conventional direct laryngoscopy, at least for less difficult airway scenarios. For more difficult scenarios, both direct and indirect (video) laryngoscopy is likely to take additional time. As mentioned previously, Yeatts et al. (2013) reached the troubling conclusion that trauma patients with severe head injury intubated with a video laryngoscope appeared to have a greater incidence of hypoxia and mortality, relative to those intubated with conventional techniques, although this did not reach clear significance.

While standard techniques such as preoxygenation with 100% oxygen are the mainstay of mitigating against this problem, it is also useful to consider “apnoic mass movement oxygenation” as a method of extending the available time to intubate prior to the patient encountering hypoxia. The basis of this technique is the recognition that when experiencing apnoea a patient's alveoli extract a greater volume of oxygen than is replaced by carbon dioxide (which is more soluble) and thus a pressure gradient forms between the alveoli (intrathoracic) and ambient pressure (extrathoracic). With a closed-airway, desaturation will occur relatively rapidly, as is our common experience, but with a patent airway, oxygen will diffuse along the pressure gradient into the apnoic lung and maintain oxygenation for a substantial period of time (see Figure 29, from Sirian & Wills (2009), who provide an excellent overview of the theory and application of this technique).

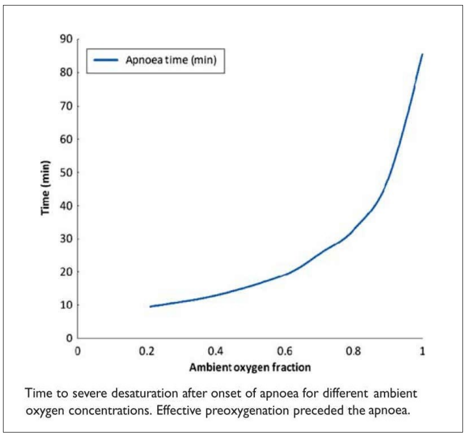


Figure 29: *Time to Severe Desaturation with Onset Apnoea for a Patent Airway (from Sirian & Wills 2009).*

This technique has implicitly been considered in the design of the C-Mac with the formation of a lateral guide on the Size 3, 4 and D-blades that can act as a conduit for an oxygen catheter, as discuss earlier. However, while promising, in practice it is cumbersome to have an oxygen catheter directly connected to the video laryngoscope, and there is the risk of eye trauma when the catheter inevitably drapes over the patient's face. A common alternative is to simply attach nasal prongs to the patient, although this relies on a patent nasopharynx; however, these are easily dislodged during intubation and not only fall inconveniently into the field but are associated with an increased risk of eye trauma. An elegant solution is proposed by Heard (2012) and shown in Figure 30, who attaches an oxygen catheter to a Size 3.5 Paediatric South-Facing RAE (Ring, Adair, Elwyn) Endotracheal tube and tapes it to the left side of the patient's mouth; he calculates that this is sufficient to maintain oxygenation for an extended period.

Figure 30: *Apnoic Oxygenation in Video Laryngoscopy (from Heard 2012)*

As a parting comment it should be emphasised that while the purpose of video laryngoscopy is to improve the likelihood of intubation, we should recollect that failing to intubate *per se* does not represent a problem so long as we maintain oxygenation. This goal is emphasised in the Difficult Airway Algorithms (2004) whereby other options such as laryngeal masks, bag-mask ventilation, waking the patient, or even surgical airways are considered. The anaethetist should not depart from the primacy of oxygenation even if they have obtained an excellent glottic view with the video laryngoscope, but are unable to pass an endotracheal tube through the glottic aperture. In this situation other options should be considered as would be the case with any failed direct laryngoscopy.

Assessing Airway Devices:

The variety of Video Laryngoscopes on the market has grown dramatically in the last few years, resulting in difficult procurement decisions for both the individual practicising anaesthetist and anaesthetic department(s). Unfortunately, many of these devices have little or no evidence to support either their safety or clinical use, in part due to the lack of a statutory requirement for published trials prior to the marketing of airway devices (this situation contrasts sharply with the extensive trials required prior to the introduction of new drugs onto the market). In response to this uncertainty, the Difficult Airway Society (DAS) introduced a process whereby the anaesthetic community can critically evaluate the clinical efficacy and safety of a new device; a process often informally described as “separating the tools from the toys” (Pandit et al. 2011).

The DAS formed an Airway Device Evaluation Project Team (ADEPT) who quickly realised that it was impractical to seek legislative changes across multiple jurisdictions to enforce a requirement that an adequate evidence-base exists prior to the introduction of new airway devices. Their pragmatic alternative was to recognise that they could influence what was *bought*, even though they could not restrict what was sold, and their subsequent guidelines reflect this approach. An inevitable consequence of this “bottom up” approach is the decentralisation of the decision-making process to local committees, and with this in mind, they developed a number of guiding strategies which are worthy of exploration.

Firstly, the guidelines encourage anaesthetists to contribute to the “procurement committees” for new airway devices, and suggest the particular procurement pathway shown in Figure 31. While they recognised that a Randomised Control Trial would be the *optimum* evidence base on which to guide decisions, it was clear that the limitations of time, resources, effort and expense would not always justify the results gained, and as such they sought to identify what would be a *satisfactory* evidence base. The result was to advise that a historical control study (Level 3b, see Table 3) should be viewed as the minimum standard, and that all lower levels of evidence, which include expert opinion (alone), a case report, or case series, are simply not sufficient, and that devices should be rejected on this basis.

Secondly, the DAS felt that to facilitate this process it should transform itself into an organisation that can assist in the coordination of dedicated research into airway devices, rather than simply distilling what was already known in the area. Figure 32 provides an overview of the anticipated role of the DAS; and their guidelines go into detail as to the funding and direction of a secretariat to support these activities, which is outside the scope of this review.

While not specifically mentioned by the DAS Guidelines, Su et al (2012) provides guidance on on what would be the useful study characteristics and measurements to include in any trials of video laryngoscopes, with the view of incorporating them into future meta-analyses, and these are shown in Table 2 below.

Table 5 **Desirable determinants for clinical trials investigating video laryngoscopes**

Determinants	Descriptions
Study characteristics	
Types of video laryngoscope	The manufacturers, brand names and specific types
Intubators	Physicians (attending physicians or residents; anaesthesiologists or non-anaesthesiologists) or non-physicians (e.g. paramedics or nursing specialists)
Intubation condition	Emergency situation (e.g. prehospital or emergency department) or non-emergency situation (e.g. scheduled surgical interventions)
Intubation scenario	Difficult airway or not
Measurements	
Time to intubation	Start when the intubator takes the laryngoscope and stop when the position of the tube is confirmed by capnography
Time to visualise the vocal cords	Start when the intubator takes the laryngoscope and stop when the vocal cords are inspected by the intubator
Time from visualisation of vocal cords to intubation	Start when the vocal cords are inspected by the intubator and stop when the position of the tube is confirmed by capnography
Number of attempts	Numbers of trials to achieve a successful intubation
Failed intubations	More than two attempts by the same intubator
Glottic view	C&L grade and/or POGO score
Complications	Numbers and types of complications
Statistical methods	Parametric methods, non-parametric methods or survival analysis should be addressed

C&L, Cormack and Lehane; POGO, percentage of glottis opening.

Table 2: *Desirable Determinants for Trials on Video Laryngoscopes*
(from Su et al. 2012)

Level of evidence	Type of study
1a	Systematic review of RCTs
1b	Single RCT
1c	All-or-none study (i.e. when all patients died before the therapy became available, but some now survive on it; or when some patients died before the therapy became available, but none now die on it)
2a	Systematic review of Level 2b cohort studies
2b	Single cohort study or low-quality RCT
2c	Outcomes studies that investigate outcomes of healthcare practices using epidemiology to link outcomes (e.g. quality of care, quality of life) with independent variables such as geography, income or lifestyle, etc
3a	Systematic review of Level 3b studies
3b	Single case-control or historical-control study
4	Case report or case series
5	Expert opinion or ideas based on theory, on bench studies or first principles alone

RCT, randomised controlled trial.

Table 3: *DAS Levels of Evidence*
(from Pandit et al. 2011)

Finally, the DAS concluded that if these strategies were generally adopted, and successful, that industry itself would be incentivised to provide evidence of at least Level 3b prior to attempting to market a product, given the inevitability of early rejection by purchasing committees in the absence of such evidence.

While the ultimate success of these ambitious guidelines remains to be seen, they nevertheless provide a constructive and pragmatic framework for the practicing anaesthetist to form their own judgements regarding purchasing decisions of new airway devices.

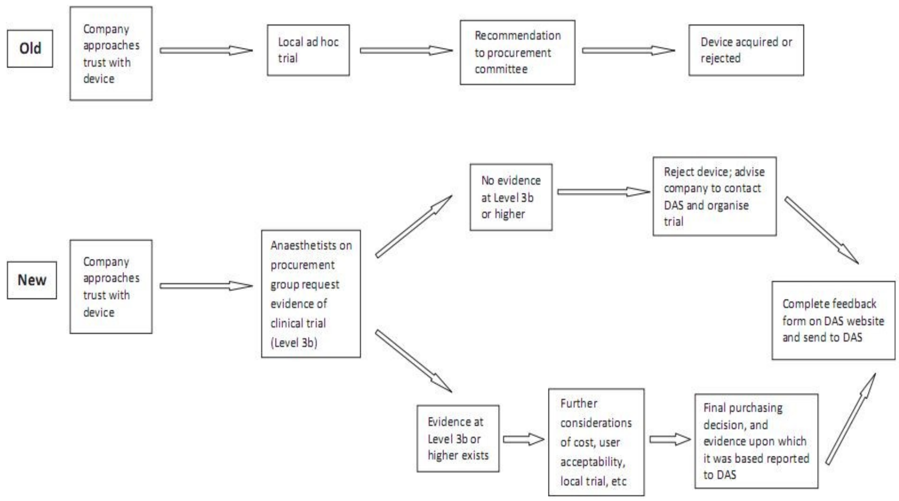


Figure 1 Procurement pathways for the current (Old) way in which devices are procured by trusts, and for the proposed (New) method, if the Difficult Airway Society (DAS) guidance on minimum evidence are adopted.

Figure 31: *Procurement Pathways for Airway Devices (from Pandit et al. 2011)*

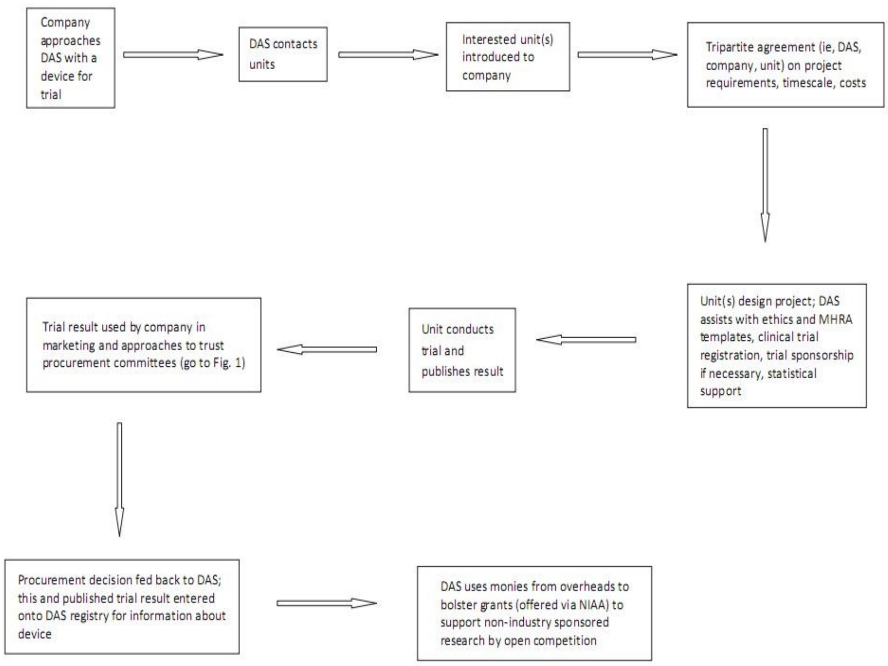


Figure 2 Anticipated pathway for how airway equipment will be evaluated via the network developed by Difficult Airway Society (DAS). The 'units' refers to groups of clinicians in individual trusts who form a research-active unit, prepared to undertake the clinical trial. MHRA, Medicines and Healthcare products Regulatory Agency; NIAA, National Institute for Academic Anaesthesia.

Figure 32: *DAS Facilitated Network for Evaluation of Airway Devices (from Pandit et al. 2011)*

Future Developments:

The role of the video laryngoscope in clinical practice continues to evolve; nevertheless, it would appear inevitable that they will become a common place tool for the practicing anaesthetist, given the trend of increasing minituarisation and cost efficiencies. However, this role remains to be fully clarified, and further study, perhaps under the trial guidance of the Difficult Airway Society, will help elucidate the remaining unknowns.

Meanwhile, it is intriguing to consider Fiadjoe & Litman (2012) who imply that the direct laryngosope may find its way eventually into the museum during our lifetime (Figure 33).

Figure 33: *Video Laryngoscope in the Museum (after Fiadjoe & Litman 2012).*

List of Figures:

List of Tables:

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