Evolution of videolaryngoscopy in pediatric population

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Abstract

Direct laryngoscopy has remained the sole method for securing airway ever since the inception of endotracheal intubation. The recent introduction of video-laryngoscopes has brought a paradigm shift in the pratice of airway management. It is claimed that they improve the glottic view and first pass success rates in adult population. The airway management in children is more challenging than adults. The role of videolaryngoscopy for routine intubation in children is not clearly proven. This review attempts to discuss various videolaryngosocpes available for use in pediatric patients.

Keywords: Airway management, children, infants, intubation, videolaryngoscope

Introduction

Airway management is a vital skill for the anaesthesiologist as it is an intergral part of general anaesthesia (GA). Ever since the inception of endotracheal intubation, direct laryngoscopy (DL) has been an indispensable part of routine and difficult airway (DA) management. However, it was realized over the course of time that airway related adverse perioperative events are an important contributor to the morbidity and mortality.[1] Introduction of video-laryngoscope (VL) is an important technological advancement that has facilitated endotracheal intubation (ETI) and has the potential of decreasing its adverse consequences.[2]

Nowadays, VL is emerging as a tool of choice for ETI as they provide better view and higher success rate especially in difficult intubation situations and they can be used as a tool for teaching. In addition to this, a faster learning curve as compared to DL obviates the need of an experienced laryngoscopist.[3,4]

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VL involves indirect visualization of laryngeal structures during intubation using optical and video technology that helps the anaesthetist see around corners in the upper airway and obtain a clear glottic view. VL's eliminate the need for a direct line of sight to visualize the airway, reduce the force required to visualize the airwary structures, causes less local tissue distraction and reduce the stress response.[2,5]

The first generation of VLs were developed based on the technology used in rigid fibreoptic laryngoscopes like Upsher scope (UL), the Bullard (BL) and the Wuscope.[6] The need of long training periods and the high incidence of complications made them obscure.[7] In 2001, a new type of VL arrived in the shape of the Glidescope (Verathon Company, USA). Subsequently, the following VLs with adequate complement of pediatric sizes were introduced: The Storz videolaryngoscopy (SVL) original version direct coupled interface (DCI), C-MAC, Glidescope, TruView-PCD, Airtraq, McGrath series 5, KingVision.

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There is ample evidence in favor of VL over direct laryngoscopy (DL) for intubation in adult patients with normal and DA.[2,3,8] Difficult airway society guidelines[9] have also recommended VL for initial intubation and management option.

In contrast to adults, airway management in children—particularly in neonates and infants—can be more challenging. The overall incidence of difficult laryngoscopy (Cormack and Lehane Class ≥ III) is significantly higher in infants (4.7% vs. 0.7%) as compared to older children.[10] This may be due to various anatomic factors such as the more anterior and cephalad larynx, large overhanging epiglottis, large tongue, shorter mandible and prominent occiput which complicate airway management particularly in infants. Moreover, apnoea time is greatly reduced in children, as compared to adults, and awake intubation may not be feasible.[1,10]

VLs which have been introduced in paediatric practice are generally the scaled down version of the adult devices. It is a well recognized fact that airway related complications in children can be mitigated if the number of intubations attempts are restricted.[11] VLs are a promising option in this regard as they have been shown to improve glottic view and first attempt success rates especially in difficult airway scenarios.[12,13] Though VLs have shown encouraging results in various randomized controlled trials (RCTs) conducted in paediatric patients, their exact role at present remains unclear in this population. A meta-analysis[12] comparing the clinical efficacy of paediatric VL with DL demonstrated that VLs improved glottis view. However, they had cautioned that further studies are required to explicitly recommend its routine clinical use.

A Cochrane metanalysis[13] of VL assisted intubation in neonates concluded that there was insufficient evidence to recommend or refute the use of VL for endotracheal intubation in neonates. Well-designed, adequately powered trials are necessary to address efficacy and safety of VL for endotracheal intubation in neonates. The current review is intended to highlight the evolution of different types of paediatric specific VLs, their advantages, limitations and comparison of various devices in pediatric population.

Search Strategies

The measures adopted included extensive scrutiny of literature evidence from internet resources, journals and textbooks in the PubMed database using the key words "video laryngoscopy", "video laryngoscope", "GlideScope®", "Airtraq", "C-MAC", "TruView", "KingVision", "children", "Paediatric", "infants", "indirect-laryngoscopes", "rigid-fibreoptic scope", "bonfils" and various internet-based databases carrying the detailed information related to paediatricsVLs. The strategies included exploration of full text articles and abstracts from various search engines such as PubMed, Medscap, Google Scholar Medline Scopus, EMBASE, Science Direct, Yahoo and many others.

Classification

VLs may be categorized either by the method used to produce the image (video, fibreoptic or mirror/prism) or by the means used to deliver the tube. Various classifications have been proposed but most commonly used system is as follows:[14,15]

1. **Non-channeled:** The tube is steered into position by the anaesthetist, usually on a curved stylet [e.g., Glidescope (Verathon Inc.), McGrath (Aircraft Medical), C-MAC (Karl Storz)]. These VL may be based on Macintosh design which provides an additional advantage that both DL and VL features are available, especially for those familiar and experienced with the Macintosh blade. e.g., McGrath Mac, Storz V- Mac and C- Mac VLs.[16] Some of these VLs have a hyperangulated curvature which significantly improves glottis visualization with negligible neck flexion and head extension e.g., Glidescope (GVL), McGrath Series 5 and Storz C-Mac D- blade.[2,16] However, it is often difficult to intubate and a precurved stylet is often required for intubation.
2. **Channeled:** The laryngoscope incorporates a channel to deliver the tube [e.g., Airtraq (Airtraq), Bullard (Gyrus Medical)]. They do not require stylet and often have a groove for housing ETT and directs it towards the center of the image viewed.
3. **Optical stylet:** The tube is preloaded over the stylet [e.g., Bonfils (Karl Storz), Clarus Shikani and Levitan (Timesco)].

Technique of Videolaryngoscopy

Laryngoscopic technique varies between devices but with the exception of optical stylets, most are introduced along the midline of the mouth, over the tongue. As the device is advanced, the anaesthetist looks at the screen rather than at the tip of the scope until the larynx is visualized. This 4-step 'in-out' technique of videolaryngoscopy was first described for Glidescope VL but is applicable to all VLs:[17]

1. Insertion of the VL blade into the oral cavity under direct visualization (look 'in')
2. Look at the projected image on the screen for optimal laryngeal viewing (look 'out')

3. Direct visualization of the ETT entering the centre of mouth till it enters the pharynx (look 'in')
4. Look at the projected image for further guiding of the ETT towards glottis for intubation (look 'out').

Bird's eye view

If the the blade is kept too close to the glottis opening, intubation will be difficult. So, the blade should be withdrawn slightly to provide more of a bird's eye view. This will decrease the angle along with facilitating the tube insertion.

Storz Videolaryngoscopes (SVL)

"Karl Storz endoscopes" have developed direct coupled video intubation system (DCI) that can be connected to a variety of intubating devices. The original version is Berci- Kaplan VL or V- Mac and its next generation are Boedeker Dorges VL or C-MAC. Others are Bonfils intubating endoscopes and flexible intubation fibrescopes.

Elucidation of the Device

Storz DCI VL integrates the camera with an ergonomic handle which can be attached to a series of blades in paediatric size. The video lens is situated by the light source near the end of the blade and provides an angle view of 80°. The latest version of storz DCI VL is the C-MAC.

C- MAC (Karl Storz® SE and Co. KG, Tuttlingen, Germany)

The C- MAC is analogous to Macintosh and Miller blades connected to a rectangular handle. It's a modification of the older V-MAC device. The tip of the blade has a 320 × 240 pixel complementary metal oxide semiconductor video chip and fog resistant lens. The video system is mounted on a small mobile cart and supports an 7-8 inch monitor mounted on the patients left side.[18] It may also have a 2.4-inch pocket monitor. Different paediatric blade sizes which are available include Miller 0, 1, Macintosh 2 and C-MAC D-blade size 2 [Figure 1]. The various advantages and disadvantages of C-MAC VL have been summarized in Table 1.

Technique of Insertion

C-Mac blade introduced via midline approach takes lesser time.[19] C–Mac is introduced like a conventional laryngoscope via right side, tongue swept to the left by the blade flange, advanced into the epiglottic vallecula and then raised to obtain laryngeal view. In case of poor laryngeal view, optimization maneuver can be performed (OELM and blade position adjustment).

Figure 1: CMAC with pediatric Miller blade

Literature Appraisal and Evidence

Various prospective randomized trials [Table 2] showed the Storz VL provided better laryngoscopic views as assessed using percentage of glottic opening (POGO) scores and on Cormack-Lehane scores (CL)[21,22] as compared to DL in children (infancy through adolescence).

Donoghue *et al*. compared C-MAC to direct laryngoscopy in mannequins (neonate, infant, and adult) and found improved POGO scores with VL.[23] Fiadjoe *et al*., performed a study in an infant mannequin with limited neck extension using conventional and C-MAC Miller blades. They found C-MAC Miller blade improved glottis view by at least one CL grade in 78% patients, with no difference in time to intubation and resulted in fewer failed intubations.[24]

The largest published study[25] (descriptive case series) in neonates (weight 530 g-6795 g) found successful intubation with VL in all the 5 patients that could not be intubated using DL. In 6 cases, video assistance helped to prevent repeat attempts probably due to improved anatomic view. The diagnosis of vocal cord paresis could also be made on VL, that could be perhaps missed on the DL.

In infants with normal airway, C-MAC has fared better in terms of faster intubation time and ease of use, when compared to the TruView Infant EV02.[26]

C-MAC VL also had a lower IDS score (intubation difficulty score) when compared to conventional Miller blade due to improved CL grade, reduced laryngeal pressure and decreaesed lifting force.[27] In a Prospective randomized trial on intubation in lateral position in infants (n = 64), CMAC VL decreased the time to intubation 6.1 s (1.7-10.4) and reduced the IDS as compared to conventional Miller blade.[28]

Table 1: Advantage and Disadvantage of C-MAC

Advantages	Disadvantages
It can be used both as VL and DL	Reusable blades require sterilization between each patient
It provides very good high resolution views on the remote video screen and can be a good teaching tool[20]	The equipment as well as its mantainence is costly and maintenance is both specialized and expensive
Video storage and review can be done on a removable secure digital card[20]	Its large handle is difficult to manipulate than smaller DL handles used in infant
C-Mac view includes the blade tip that allows for guiding the tip into the vallecula under vision	It is relatively expensive

Moussa *et al.*[29] conducted a study on 34 novice paediatric residents for intubation in infants (32 weeks) with a median weight of 1500 g. They deduced a higher intubation success rate (75%), rapid learning curve (2nd vs 7th intubation) and a need for longer time to intubation with C-MAC (57 vs 47 s) than DL. Soft tissue trauma was observed more with conventional laryngoscopy.

Bonfils (Karl Storz GmbH, Tuttlingen, Germany)

The use of the Bonfils Retromolar Intubation Fiberscope was first described by the Bonfils in 1983. The retromolar approach was used to intubate the tracheas of children with Pierre Robin syndrome.[30] The adult version is a rigid straight fiberoptic device with a curved tip of 40-degree for targeted intubation, a length of 40 cm and outer diameter (OD) of 5 mm. The necessary overview is ensured by the 110-degree angle of view. There is a central channel through which oxygen can be insufflated and local anaesthetics can be instilled. The eyepiece is mounted at the proximal end of the handle that can be connected to a camera, video monitoring system or can be viewed directly. A portable battery powered light source can be attached to the handle (stylet). For children, 2 other sizes with a 2-mm (for ETT 2.5-3.5 mm ID; shaft length 22 mm) or 3.5 mm OD are available (suitable for ETT 4.0-5.5 mm ID; shaft length 35 mm) [Figure 2]. The various advantages and disadvantages of Bonfils intubation fiberscope (BIF) have been summarized in Table 3.

Technique of Insertion

A chin-lift/tongue-jaw lift is performed by grasping the tongue and mandible and lifting them verticlally upwards away from the posterior pharynx to expose the laryngeal inlet. The scope is introduced alongside the molars from the right side of the mouth and forwarded underneath the epiglottis and the scope is cautiously guided to visualize the tracheal rings and the Bonfils tip is then positioned safely. Thereafter, the ETT is railroaded into the trachea after releasing it from the holder using corkscrew motions.

In the mid-line technique, the scope is advanced to reach the epiglottis and when the ETT passes the vocal cord, ETT is advanced into the trachea. For a beginner, this approach is easy and

Figure 2: Pediatric Bonfils intubation scope

also instead of chin-lift maneuver, one can do DL that increases the retropharyngeal space for the introduction of the bonfils.[31]

Literature Appraisal and Current Evidence

Bein *et al.*[33] reported a first attempt success rate of 72.7% and overall success rate of 89.1% with the paediatric Bonfils device (outer diameter of 2 mm and 3.5 mm) by an experienced operator in children (6 months-4 years) with normal airways. All the 6 failed intubation attempts were because ofcopious secretions badumbrating the view. The authors concluded that Bonfils fiberscope has significant drawbacks when used for intubation of normal pediatric airways due to its high failure rate and prolonged intubation times.

Houstan *et al.*,[34] conducted a randomised cross over trial in healthy children (2-4 years) to compare bonfils with conventional laryngoscopy. In the Bonfils group, first DL followed by Bonfils aided intubation and vice versa in the conventional group. After 2 attempts, the success rate was 92.3% for the bonfils group and 100% for the DL group, respectively. They concluded that though the Bonfils fiberoscope improved glottic visualization as compared to DL, but there was a higher incidence of failure to intubate. Bonfils has been shown to provide a better image quality, easier to operate, constant view of the tracheal tube passage, and lead

Table 2: Summary of manikin studies and clinical evidence of CMAC videolaryngoscope

Authors, year	Design and Control group	Number of subjects, age group	Glottic view scores	Mean TTI (sec)	Success rate (CMAC)	First attempt success rate (CMAC)	Complications/remarks
Mannequin studies:							
Donoghue *et al*.[23]	Cross-sectional study manikin study; control: DL	Neonate, infant, and adult mannequins	Improved POGO scores (newborn-89% vs 64%; infant-82% vs 59%)	NR	88% in the newborn and 79% in infant simulators	Neonate: 92%; infant: 71%;	SVL did not significantly improve the first-attempt success rate vs DL for newborn and infant simulators but, POGO score was significantly improved with SVL in both simulators
Fiadjoe *et al*.[24]	Cross sectional randomized comparative manikin study; control: DL	Infant mannequin with limited neck extension	Improved Cormack and Lehane grades by at least one CL grade in 78%	No difference in TTI	100% with SVL	NR	Intubation using DL required significantly higher number of requests for assistance as compared to SVL
Clinical studies							
Moussa *et al*.[29]	Nonblinded randomized controlled trial; control: DL	Infants (32 weeks) with a median weight of 1500 g	NR	Longer TTI with C-MAC (57 vs 45s)	Higher intubation success rate (75% vs 63%)	NR	34 novice paediatric residents, rapid learning curve (2nd vs 7th intubation), ↑ soft tissue trauma was observed with DL
Mutlak *et al*.[26]	Retrospective observational study; TruView Infant EV02& DL	Infants and children (<10 kg) with normal airway	CL grades were comparable in the three groups	TTI much less with CMAC compared to TruView (28 sec vs 52 sec)	100% in all three groups	NR	C-MAC was considered easier to use due to its similarity to conventional DL blade.
Vanderhal AL *et al*., 2009[25]	Descriptive case series	42 Neonates (w: 530 g-6795 g)	NR	NR	Successful intubation with VL in 5 patients who couldnot be intubated using DL	Only 3 intubations required more than 2 attempts	Improved anatomic view in 6 patients, prevented repeat attempts, diagnosis of vocal cord paresis could also be made on VL
Jain D *et al*., 2017[28]	RCT; control: DL (miller blade)	Infants (in lateral position) (n=64)	Improved CL grade and POGO score	Decreased TTI with CMAC (32 vs 38 s)	100% with both	Comparable	Reduced IDS as compared to DL, fewer patients needed OELM
Gupta A[27] *et al*., 2018[31]	RCT, Truview-PCD	Infants	Improved CL grades (CL I/II after OELM in all)	Decreased TTI (22 vs 26s)	Improved success rates (100% vs 92.5%)	97.5% with CMAC vs 90% with TruView	No complication with CMAC, CMAC was easier to use

Table 3: Advantages And Disadvantages Of Bonfils

Advantages	Disadvantages
Light- weight, durable and portable Slim profile makes it useful in ptswith limited mouth opening &cervical spine movement Rigid structure improves maneuverability and allows insertion nbeyond soft tissue obstruction The endoscopic orientation of the Bonfils is better than the flexible Fibreoptic bronchoscope One- hand maneuver is required, for better translation of hand to scope movement Wide angle of view allows an assessment of any aberrant anatomy to govern the feasibility of intubation Preparation requires less time Visualization of the ETT passing between the vocal cords reduces the risk of injury Less expensive and faster to assemble than the FOB	Limited view due to blood, secretion, fogging and tissue contact Nasal intubation is not possible Can cause direct trauma and barotrauma Success is operator dependant Requires more time than traditional laryngoscopy Expensive Large training curve is required compared to others due to less availability May cause inadvertent esophageal intubation or arytenoids injury if the tip is placed at the laryngeal aperture outside trachea before advancement of the ETT[32]

Table 4: Summary of literature on use of bonfils in children

Authors	Design	n	Age	Success rate BIF	Complications/ remarks
Bein[33] *et al*.	Case series	55	6 month-4 yrs (normal airways)	After 3 attempts was 89%	Failure 6, Bronchoscpam 1 Obstructed view due to secretions 5
Houston[34] *et al*.	RCT (control: DL)	50	2-14 yrs (normal airways)	After 2 attempts: 92.3% vs 100% with DL	2 failures with BIF easily intubated with DL
Kaufmann *et al*.[35]	Prospective controlled trial (control: FOB)	26	0-18 yrs (DA)	100% with both in first attempt	Faster and easier intubation, better image quality with BIF
Vlatten *et al*.[36]	RCT (manikin)	150	Infant difficult airway manikin	98% vs 90% in DL	Times to intubation comparable to DL while glottic views were significantly improved
Laschat M[37] *et al*.	Case report	1	Neonate with mosaic trisomy	Successful intubation with DL in place and manipulating BIF	Cormack grade 3 with DL
Aucoin S[38] *et al*.	Case report	1	Child with Hurler syndrome	Kept laryngoscope in place, BIF directed underneath the epiglottis after full of glottis view for endotracheal intubation	No complications

to faster times to intubation when compared to Fiberoptic bronchoscope in children with difficult airway.[35]

Vlatten *et al*. compared Bonfils fiberscope with DL in simulated difficult infant intubation in manikin and found that Bonfils was easier to use and gave better laryngeal views, but did not improve intubation success rates and intubation times.[36]

There are many case reports advocating the use of the Bonfils in children with difficult airway, especially in children with decreased intraoral space, where Bonfils has a distinct advantage over LMA, Glidescope VL, Airtraq and DL.[37,38] The literature in relation to use of Bonfils fiberscope has been summarized in Table 4.

Glidescope Video Laryngoscope (GVL)

GVL is the first VL that was introduced by John Pacey (Canadian Surgeon) in 2001. It is non-channelled VL that was one of the first introduced in adult and pediatric size, and subsequently all spectrums of pediatric versions accessible since 2005. The non-channelled GVL is essentially a camera mounted on a specially shaped laryngoscope handle with an acutely angled blade (It is available in sizes 3 and 4 only and shape is similar to MAC blades). The adult GVL have height of 16 mm (max) at the mouth and its blade angles to 60 degrees with inbuilt camera at the inflection point. It provides real-time continuous image that is illuminated by a light-emitting diode and can be seen on a separate color monitor.

The GlideScope Cobalt comes in an infant size with a smaller height (10 mm) laryngoscope blade, which permits its use in neonates. There are a variety of other GlideScope products available, including fully portable and reusable designs, but all are variations on the above-described device [Figure 3].

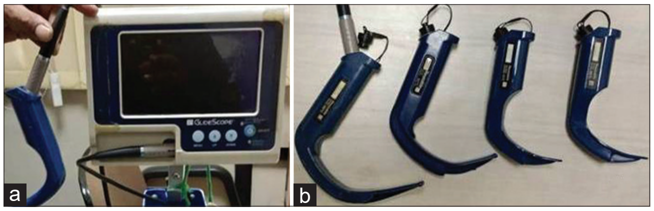

Figure 3: Glidescope with monitor (a) and various blade sizes(b)

The primitive reusable GVL2, evinced to be vain in small children[39] and was superseded by the cognate Glidescope Cobalt. Other models with pediatric sizes include the AVL (advanced videolaryngocope), the Titanium and the Ranger. Nowadays, AVL 2 reusable, modified version of GVL 2 is also available though they are not usable in neonates and small children. GVL Ranger is portable device with an antireflective screen for use in daylight (apt for use in the field) and can store upto 60-minute video recording.

The AVL-S and Cobalt have reusable baton covered by the disposable (same) hard sleeve made up of plastic known as "Stat". The manufactures recommend a weight range of 0.5-28 kg with 4 sizes stats available for the pediatric baton. Its various advantages and disadvantages have been summarized in Table 5.

Technique of Insertion

The blade is inserted in the midline, and the ETT is bent to resemble the shape of the blade[48] using a dedicated stylet. The GVL blade is slowly moved by rotating the device along the natural curvature of the base of the tongue into the vallecula. The four step in-out technique as described previously is followed.[17]

Literature Appraisal and Evidence

Various studies with pediatric GVL have reported significantly better view of the glottis.[43-45] Various studies and case reports have demonstrated improved conditions for intubation with the GVL in comparison to DL in normal and predicted difficult airway in children.[44,46,47]

In a prospective randomized trial comparing intubation time with GS cobalt VL and DL with a Miller blade in neonates and infant (n = 60) reported similar intubation time and success rate. It was observed that the GS cobalt provided faster views but prolonged the ETT passage time.[48]

Hyung-jung Kim *et al.*, compared the GVL and DL laryngoscopy for nasotracheal intubation in 80 childrenless than 10 years posted for elective dental or facial surgery and concluded that in GVL provided similar time to intubation in experienced hands.[49]

A large study[25] performed in the neonatal population (530 g to 6795 g) showed that GVL improved glottic view. It helped to diagnose vocal cord paresis in one patient that may have been missed on conventional laryngoscopy and also prevented repeat attempts by trainees in six cases. In 5 patients with failed DL previously, the author observed that VL resulted in successful intubation.

Sylvia *et al.* compared the GVL to DL and found a slightly longer time to intubation (median of 36 seconds vs 23 seconds) with no difference in success rate.[50] In a study of pediatric interns, similar rates of success was seen between GVL and DL, with longer time to intubation when using the VL. In spite of these results, the Glidescope was the elected device among the majority of the participants.[51]

Kim[45] *et al.* conducted the study in 203 children with and without manipulation, i.e., backward, upward and rightward pressure (BURP), comparing the GVL with a DL using Macintosh blade and concluded better laryngoscopic structure, but a longer time to intubation, with GVL (36.0 ± 17.9 vs 23.8 ± 13.9 s).

A recent pediatric difficult intubation registry assessed the efficacy of GVL and DL for intubation in 1295 children with anticipated difficult intubation on intial attempt of DL. GVL had higher success rate than DL without increasing the complications.[52] Though GVL was better than DL but overall success in children less than 10 kg was lower than adults.

TruView Videolaryngoscope

The TruViewPicture Capture Device (PCD) (Truphatek International Limited, Netanya, Israel) is a successor of the TruView Infant EV02. In 2006, the TruphatekTruView EVO2 system was introduced for adult[53] and later on, in 2009, it began to be used in pediatrics.[54] It has an integrated optical lens laryngoscope that can be connected to a videomonitor via a eyepiece on the handle [Figure 4]. There are four paediatric blades (sizes 0, 1, 2 and 3) available for intubation in neonates from more than 800 g to obese children. The blade of the device has a 46 degree anterior refracted angle that allows a wide and magnified image of the larynx without having to align the three axes (oral, pharyngeal, and tracheal axes).

A distinctive feature of the device is an integrated oxygen jet to provide apneic oxygenation (flow 2-5 l/min^{-1}) and anti-fogging of the camera. A special stylet (the OptiShape™) is also

Table 5: Advantages And Disadvantages Of Glidescope

Advantage	Disadvantage
Reusable Macintosh blade design with built in antifogging mechanism	Intraoral injury, when the operator focuses solely on the video monitor due to blind spot of the oropharynx[40-42]
Digital video technology with real time recording	Requires specilaised training
Glidescope Titanium are more familiar Mac-style blades, compatible with already existing blades for Pre-term and small children	Acute angle of the Glidescope requires preformed to facilitate intubation

Figure 4: Pediatric Truview

available with the TruView for better angulation and providing rigidity to the endotracheal tube.

Literature Appraisal and Evidence

A manikin study was conducted with normal and simulated difficult airways in novice operators, and concluded improved glottis visualization with the TruView VL. A long time to intubation was observed in difficult airway scenarios in the TruView than the conventional Macintosh blade and more dental clicks considered as indicative of dental trauma,[55] along with manipulation difficulty due to its bulky nature was noticed in the TruView operators.

In a study by Riveros *et al*., of pediatric cohort ranging from neonates to 10 years of age, the TruView was compared to Glidescope and DL with Macintosh blade.[39] They recorded longer mean intubation times (44 seconds vs 23 seconds) in the Truview group along with similar glottic views as compared to DL. The inbuilt safety feature of oxygen insufflation did not avert fall of oxygen saturation below 90% due to longer intubation times.

A comparative study of the Macintosh laryngoscope, C-MAC VL and the Tru View Infant EV02 PCD in infants (<10 kg, up to 22 months) reported longest median time for intubation with Truview PCD (52 s) than C-MAC (28 seconds) and Macintosh (26 seconds) laryngoscopes though the glottic view was better in the TruView group. Also, the user satisfaction score was lowest with the Truview EVO2 due to non-familiarity with the instrument.[26] Fogging was reported as a hinderance with TruView VL. In parallel to the previous study, the use of TruView EV02 resulted in a fall in SpO_2 related to the longer times to intubate. Similar findings of increased intubation times leading to desaturation and fogging as a cause of intubation failure were reported in another recent study.[27]

Similar findings of improved laryngeal view along with increased intubation times as compared to conventional laryngoscopy were reported in a study on 60 neonates and infants (1-10 kg) and another study on 50 children aged 2-8 years.[54,56]

Although there exists a paucity of literature supporting the utilization of the TruView in the paediatric difficult airway cohort, but there are a few case reports, showing successful intubation in cases where previous intubation had failed.[57,58]

In a randomized trial[59] comparing the Truview, C-MAC, and Macintosh laryngoscope in 150 paediatric patients airway aged 1-6 years, authors concluded that percentage of the glottic view (POGO score) was better with TruView than C-MAC and Macintosh bladebut it still required the longest time to intubate. They highlighted that Truview PCD, gives a better view than conventional Macintosh laryngoscope, on the other hand C-MAC provides high resolution views and is a good teaching tool.

Airtraq Videolaryngoscope

The Airtraq (Prodol Meditec, SA; Vizcaya, Spain) is a channeled disposable optical laryngoscope, available in different sizes with the smallest size 0 infant scope. It has an eye-piece on the handle that can be connected to a 2.8 inch camera that uses Wi-Fi for projecting the image or 7-cm video monitor (external) [Figure 5].

It has 2 channels, the guide channel on the side of the device through which ETT is advanced, and the other is the optical channel containing the lens for indirect viewing. The device has a unique integrated warming system at the light source and

Figure 5: Airtraq Pediatric VL showing the channel to guide endotracheal tube (a) and the power button to swtich on the device(b)

the camera that should be turned on for at least one minute for the anti-fogging system. Recently, 50 times reusable version known as Airtraq Avant with a disposable eyepiece and an optical baton is also now available.

Technique of Insertion

- The device is inserted into the oral cavity in the midline, the flange on the tip of the blade is either passed into the vallecula or lifts the epiglottis. Before intubation, the ETT should be properly lubricated and after visualization of the vocal cords in the center of the field (back-and-up maneuver), it is advanced through the guiding channel. After advancing the tube into the vocal cord, it is kept stationary and the device is dragged laterally to the left to disengage the ETT from the channel and removing the device. In case of difficult scenario, Airtraq can be introduced in the oral cavity like a Guedal airway (upside down) before moving it through 180 degree.[60] The instrument is bulky compared to conventional DL and may pose difficulty in patients with limited mouth opening or small oral cavities.[61]

Troubleshooting

- Passing the ETT through the vocal cords may be difficult.[61,62] Gum elastic bougie, fibreoptic bronchoscopes and stylets can be used in case of troubleshooting[63]
- The Triple maneuver (downward, backwards and upwards) may be done in case of poor laryngeal view. Also, inadequate laryngeal visualization may be due to the device being inserted too far and is ameliorated by gentle withdrawal.[64]

Literature Appraisal and Evidence

A meta-analysis comparing different videolaryngoscopes, including Airtraq, concluded that the quality of the evidence was low.[65] VLs improved visualization of the glottis but prolonged the intubation time in contrast to direct laryngoscopy.

The skilled operators have experienced lack of superiority of the device over conventional laryngoscopy in routine patients,[66] however, in cases with a difficult airway, the device has demonstrated less time to intubation and improved success rate.[67]

Studies have suggested the utilization of the device in patients with unstable or restricted movement of the cervical spines due to less cervical motion as compared to Macintosh DL.[68] It has been also used for awake intubations.[69]

In infants and children under 5 years, Airtraq exhibited better POGO scores but a longer duration of intubation in comparison to conventional laryngoscopy.[70,71]

Airtraq has been used in various difficult airways in pediatrics[21] and also the device has a shorter learning curve for novices, compared to DL.[72]

In 2012, a study compared Airtraq with the airway scope (Pentax) for intubation in an infant manikin simulating cardiopulmonary resuscitation (CPR), where the subject was at rest and found time to intubation and visualization of glottis was longer in Airtraq during CPR and at rest.[73]

Various studies have reported less time to intubation, improved visualization and less number of esophageal intubation with the Airtraqin children.[74,75] However, the evidence regarding the utilization of the Airtraq is mostly on normal airway in pediatric cohort.

McGrath Videolaryngoscope

The McGrath MAC VL (Aircraft M e d i c a l, E d i n b u r g, U n i t e d Kingdom) has a Macintosh style blade which was introduced to clinical practice in 2010. It has a fixed length metal alloy camera stick used with a plastic disposable blade that slides over it. The bladesizes 2,3 and 4 have a maximum blade height of 11.9 mm, thereby minimizing the required mouth opening for its use. The pediatric version of the McGrath series 5 include a Mac 2 sized disposable, portable, single use, non channeled blade for small children and more recently, size-1 blade to facilitate intubation in neonates and infants [Figure 6]. The blade has a unique feature of "vertically aligned optics" that reduces the

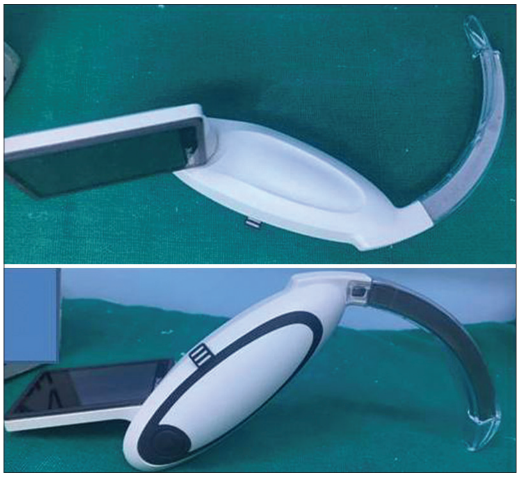

Figure 6: Mc Grath with Pediatric blade

'Blind spot' as described by the manufacturers. It produces a real time color 2.5 inch screen mounted on handle for video-display and has a light source on the tip of the blade. There exist no anti-fogging system, still the McGrath has a hydrophilic optical surface coating to reduce fogging on the light source.

The greatest advantage of this new small videolaryngoscope blade is the magnification of the view of the laryngeal inlet. This provides a further advantage in the demonstration and training of neonatal intubation. The device emulates the traditional Macintosh laryngoscope in both design and the application of an appropriately sized blade to a standard handle. The device can be used similar to Macintosh blade and required less force for intubation on normal and difficult airway.

Technique of Insertion

McGrath Mac can be used akin to conventional laryngoscopy, in that the device can be introduced in the oral cavity under direct vision. The blade tip is placed in the vallecula with the image lying centrally in the upper third of the display.

Troubleshooting

There could be difficulty in directing the ETT through the vocal cords and may require external manipulation or bougie.

Literature Appraisal and Evidence

The McGrath is relatively a recent device, there exist paucity of well- studied literature, especially in difficult airways and evidence of efficacy have been mainly limited to successful case reports.[76-78] The McGrath was used successfully in a 9 yr old child with extensive burn with scarring in face and neck where fibreoptic laryngoscopy had failed and the device provided a Cormack and Lehane grade 1 view.[77] The device was used successfully in a previous failed direct laryngoscopy in a 13 yr old child with Treacher Collins syndrome and here also it improved the view from grade 4 to grade 1 compared with DL.[78]

In a study of 90 paediatric cases aged 4-10 years, the ease of insertion, glottis view was compared with McGrath, TruView EVO2 and Macintosh laryngoscope.[79] The POGO score in the Macintosh laryngoscope group was lower than the other two groups. The requirement of external manipulation was increased in Truview EVO2 group and the intubation difficulty score (IDS) was also significantly more in Truview EVO2. The time of intubation was found to be statistically significantly shorter in the McGrath videolaryngoscopy group while the number of attempts for intubation were similar in all 3 groups.

In 2008, a study was presented at the ASA annual meeting concluding good conditions for intubation in children with a mean age of 63 months with normal airways.[80] Use of the infant blade of McGrath MAC (size 1) has only been documented in a small series of six cases of neonatal intubation by Ross *et al.*, who noted an improved glottic view withthis VL over that obtained under direct laryngoscopy.[81]

Manikin studies have demonstrated encouraging results for McGrath VL. McGrath was considered to be faster and allowed a higher rate of first attempt intubation success rate in paediatric manikin study even during ongoing chest compression.[82]

A paediatric manikin study, comparing McGrath MAC with conventional laryngoscopy in simulated immobilized cervical spine patients, McGrath was recommended as the first intubation option for endotracheal intubation in difficult paediatric emergencies.[83]

KingVision® a Blade Videolaryngoscope

KingVision™ is a curved single-component, wireless, lightweight, portable battery operated reusable device with disposable high angulation non-channeled or channeled blade (Ambu® A/S, Bad Nauheim, Germany). Single-use blades eliminate risk of cross contamination. King Vision laryngoscope (KVL) is ergonomically designed to provide clear image viewing in 160° panoramic field with minimal lifting of soft tissue and impact on teeth. It has 2.4 inch organic light emitting diode display with advanced imaging technology that includes a video-camera (complementary metal- oxide semiconductor).

Recently its paediatric version King Vision a Blade has been introduced for clinical use in children. The device has three pediatric blades: size 1, 2 non-channeled and a size 2 channeled version.

Technique of Insertion

It is introduced in the oral cavity like a Macintosh blade and its tip is positioned in the vallecula. It produces an indirect glottis view without the requirement of oral- pharyngeal tracheal axis alignment.

Troubleshooting

The tip of the channeled blade can go too deep inside the airway resulting in the uploading of the epiglottis leading to difficulty in directing the tube towards the glottis causing longer time to intubation.

Literature Appraisal and Evidence

KVL is a relatively new device and has paucity of literature evidence in its favor or against it. Adult studies have yielded variable results with success rates ranging from 51% to 100% on intubation with KVL.[84] At present, literature is deficient on clinical use of KVL in children. Only one clinical trial has been published on children <2 years of age and the authors found comparable time for intubation with KVL as compared to conventional laryngoscopy using Miller blade.[85]

In a bi-centric randomized comparison of KVL and the C-MAC paediatric D-blade to conventional laryngoscopy for intubation in an infant high-fidelity simulator in normal and difficult airway scenarios,[86] VLs were associated with shorter times to ventilation in both situations. In the DA scenario, both the VLs (KVL > CMAC) attained higher first-pass intubation success rates. These advantages of VL can potentially avoid desaturations and decrease adverse events in pediatric airway management.

A manikin study compared channeled Kingvision VL with non channeled and Macintosh blade and concluded better rate of successful intubation (87%) with the channeled compared to non channeled KVL (47%).[87]

Emerging Roles of VL: Teaching/Training, Safety and Quality Assurance

Improvement of knowledge, technical skills, and cognitive skills are necessary for the education and training of the difficult airway management. Regular seminars, hands-on training session for technical skills, simulation/scenario-based training sessionsare important to attain and mainten the requisite airway management skills. VL play an important role in the teaching and training of endotracheal intubation. VL is associated with a faster learning curve thereby resulting in a higher success rate for intubations and quality assurance by novice physicians.[3,27] VL with macintosh design can assist with the learning of both conventional and indirect laryngoscopy, and this may decrease airway morbidity by preventing additional intubation attempts in case of difficulty. The VLs not only have better effectiveness but the possibility of theentire operating room personnel watching the intubation procedurewhich in turn, could enhance teaching, improve team dynamics, hasten the response in crisis and mayimprove overall patient safety. Due to the better glottic view imparted by VLs, unanticipated difficult intubations may be less frequent if these are used as the first-line approach. Videolaryngoscopy gives us the option of continuous recording of the intubation process particularly valuable in video recording of critical events and procedure.[88] This may help in clinical documentation, quality improvement, research and teaching. They also create an opportunity for remote supervision by a more experienced airway manager, which may be beneficial in rural hospitals and during prehospital emergency airway management.[89] It provides continuous recording particularly valuable in a video recording of critical events and procedure.[88] Although, there exists no large data, but primitive evidence in a paediatric cohort suggested better outcome in patients with normal and difficult airway.[90]

Pitfalls and Hinderances to Routine Use of VL

1. They are much more expensive compared to DL. If VLs become the first line devices for endotracheal intubation, all sites where airway management is anticipated would require stationing of these devices raising overall costs multifold.
2. If VLs become the routine airway management device, existing difficult airway algorithms would need to be modified to begin with videolaryngoscopy failure and the choice of next device would be more complex.[3]
3. VL requires additional training and attainment of learning curveto reach proficiency with each type of device.
4. The number and types of VLs in market are growing exponentially and not all devices are equally effective in all scenarios. Relative efficacy of these devices has not been conclusively proven and this may increase confusion in their selection for management of a particular challenging case.
5. It may difficult to insert ETT especially with an angulated blade VL.

6. VL is difficult to use in patients with limited mouth opening.
7. While inserting a styletted tube, airway soft tissue injury may occur due to operator's focus on the video monitor ('blind spot' related to VL).
8. Use of VLs for routine airway management can possibly reduce the incidence of unanticipated difficult intubation. This might negatively impact the impetus to learn and teach use of alternate airway devices and indirectly affect patient safety in long run.[3]

Conclusion

The emergence of videolaryngoscope has expanded the airway armamentarium and they are being considered as an important tool in paediatric airway management. They have demonstrated encouraging results in improving the glottic views and intubation success in difficult airway scenarios. However, current evidence on efficacy of VL in the paediatric population is not voluminous and further well-designed large clinical trials are needed to conclusively prove their role in the routine clinical practice of this particularly vulnerable cohort.

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Conflicts of interest
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