Technoleg Iechyd Cymru
Health Technology Wales

Evidence Appraisal Report

Video laryngoscopes for people who require airway management in pre-hospital settings

Executive summary

- This report aims to identify and summarise evidence that addresses the following question: what is the clinical and cost effectiveness of intubation using video laryngoscopy for people who require airway management in pre-hospital settings?

- Emergency services are required to respond to situations where patients cannot maintain an airway and airway management in the pre-hospital setting is needed. In severe cases pre-hospital intubation is necessary to allow transfer of a patient to hospital. The causes of a patient being unable to maintain an airway are varied but can be broadly divided into situations where major trauma has occurred and other medical causes, in particular cardiac arrest.

- Intubation can be done using direct or video laryngoscopy to visualize the upper airway in to order to allow passage of a tracheal tube.

- We identified one systematic review with meta-analysis (Savino et al. 2017) and three randomised control trials (RCTs) comparing video versus direct laryngoscopy in pre-hospital settings (Ducharme et al. 2017, Kreutziger et al. 2019, Macke et al. 2020).

- Systematic review with meta-analysis:
  - They reported pooled estimates for the relative risk of successful overall and first-pass intubation with video versus direct laryngoscopes stratified by professional background and by study type (i.e., doctors, RCTs vs nurses/paramedics, observational).
  - Included RCTs suggested that video had worse first-pass and overall intubation success rates whereas observational studies suggested the reverse.

- RCTs comparing video laryngoscopes versus direct laryngoscopes:
  - All three most recent RCTs suggested that there was no difference between video and direct laryngoscopes or that video laryngoscopy had modest benefits that would be unlikely to translate into improved clinical outcomes.

- Meta-analysis of this report:
  - We performed a meta-analysis involving individual study data for overall and first-pass intubation rates across six RCT studies(Arima et al. 2014, Ducharme et al. 2017, Kreutziger et al. 2019, Macke et al. 2020, Trimmel et al. 2016, Trimmel et al. 2011).

- The CI for both outcomes of individual RCT studies had poor overlap indicating the presence of statistical heterogeneity due to clinical and methodological diversity among the studies. Thus, we performed a sub-group analysis for both outcomes based on the population requiring airway management (i.e., cardiac arrect or major trauma).

- Sub-group analysis for first-pass and overall intubation success rates by population:
    - Studies involving cardiac arrest population suggested that the video laryngoscopy had worse fist-pass and overall intubation success rates compared to direct laryngoscopy (Arima et al. 2014, Ducharme et al. 2017, Trimmel et al. 2016). There was moderate heterogeneity (I2 = 59%) in terms of first-pass success rates, while considerable heterogeneity (I2 = 97%) regarding overall intubation success rates.
    - The only study involving major trauma population suggested that first-pass intubation success rates was higher for video compared to direct laryngoscopy, while the overall intubation success rates did not differ between the two devices (Macke et al. 2020). Heterogeneity for the major trauma group was not applicable to be calculated for both first-pass and overall intubation success rates, since only one study was included in this sub-group analysis.

- Economic evaluation:
    - The economic analysis suggests that video laryngoscopes are considerably more expensive than direct laryngoscopes.
    - There is no relative benefit associated with the use of video laryngoscopes and cost minimisation analysis based on providing video laryngoscopes for all out-of-hospital intubations in Wales suggests that video laryngoscopes are not a cost-effective intervention.
    - A scenario of the cost minimisation analysis where video laryngoscopes are used in EMRTS show that video laryngoscopes would remain more expensive, but the additional expense would be lower.

1. Purpose of the evidence appraisal report

This report aims to identify and summarise evidence that addresses the following question: what is the clinical and cost effectiveness of intubation using video laryngoscopy for people who require airway management in pre-hospital settings?

Evidence Appraisal Reports are based on rapid systematic literature searches, with the aim of published evidence identifying the best clinical and economic evidence on health technologies. Researchers critically evaluate this evidence. The draft Evidence Appraisal Report is reviewed by experts and by Health Technology Wales multidisciplinary advisory groups before publication.

2. Health problem

Emergency services are required to respond to situations where patients cannot maintain an airway and airway management in the pre-hospital setting is needed. In some cases, basic airway techniques may provide temporary provision of oxygenation and ventilation. However, in more severe cases pre-hospital intubation is required to allow transfer of a patient to hospital (Crewdson et al. 2018). Where intubation is needed, it has been suggested that ensuring the first attempt is successful is a high priority as multiple attempts can cause complications relating to both damage from the laryngoscope and hypertensive responses. In addition, reduced time to intubation reduces the likelihood of complications from continued hypoxia (Crewdson et al. 2018). The causes of a patient being unable to maintain an airway are varied but can be broadly divided into situations where major trauma has occurred and other medical causes, in particular cardiac arrest (Crewdson et al. 2018).

Cardiac arrest is considered an unexpected loss of the heart function, breathing and consciousness (Patel & Hipskind 2021). It constitutes a life-threatening condition requiring immediate measure to prevent sudden death (Patel & Hipskind 2021, Crewdson et al. 2018). In the UK, NHS Ambulance Services attempt resuscitation in approximately 30,000 people annually (Perkins et al. 2021, Hawkes et al. 2017). Most of cardiac arrest incidents occur in adults between 64 to 68 years of age, either in their home or workplace (Hawkes et al. 2017). Major trauma is considered an injury or a combination of multiple injuries where there is a strong possibility of prolonged disability or death (Kehoe et al. 2015, Krug et al. 2000, Roberts et al. 2020). It might include serious injuries on the head, neck, chest, spine, limbs, abdomen and pelvis which have a wide range of causes, including accidents, violence, recreational activities, or medical issues (Thompson et al. 2019). In England and Wales, trauma is a leading cause of death, with individuals between 16 and 20 years of age and men particularly overrepresented (WHO 2021, NHS Wales 2021).

In Wales, people requiring airway management in the pre-hospital setting are cared for by the Emergency Medical Retrieval and Transfer Service Cymru (EMRTS) and the Welsh Ambulance Service NHS Trust (WAST). Experts reported that there are key operational differences between EMRTS and WAST and that patients with cardiac arrest and major trauma would receive different responses. EMRTS is formed of consultants, from emergency medicine, anaesthesia, and intensive care backgrounds, and specialised critical care practitioners (EMRTS 2022). They have a remit to provide pre-hospital critical care with a focus on interventions outside of standard paramedic practice. EMRTS would be most likely to manage major trauma patients in Wales and for this group, they would deliver rapid sequence induction of anaesthesia and intubation prior to transfer to hospital. EMRTS would also respond to some cases of cardiac arrest requiring intubation. WAST responds to more routine emergency calls in Wales and ambulance crews consist of paramedics and emergency medical technicians (WAST 2022). As such, WAST would be more likely to deal with cardiac arrests that require pre-hospital intubation in Wales.

There appears to be ongoing debate about the optimal approach to airway management in the pre-hospital setting. This debate centres around outstanding questions about the cohort of patients who require pre-hospital intubation and the differing technologies that are available. In particular, there is uncertainty around whether video laryngoscope provides additional benefits over direct laryngoscope and video laryngoscope may have different benefits for differing populations (Bacon et al. 2015, Maldini et al. 2016).

3. Health technology

Laryngoscopy refers to the direct or indirect visualization of the upper airway to allow passage of a tracheal tube (Collins 2014, Rodgers & McGahren 2006).

Direct laryngoscopy constitutes one of the most common strategies for endotracheal intubation, involving the use of a rigid laryngoscope to display the laryngeal inlet under direct or line-of-sight visualisation to enable the placement of tracheal tube beyond the vocal folds (Collins 2014). Direct laryngoscopes are classified in three different types based on blade characteristics: (1) straight blade (e.g., Miller laryngoscope), (2) curved blades (e.g., Macintosh laryngoscope) and (3) blade with articulating tips (e.g., McCoy laryngoscope) (Collins 2014, Maldini et al. 2016). It is considered as an effective strategy to secure the airway (Rodgers & McGahren 2006), but requires training and expertise for professional competence (Maldini et al. 2016).

An alternative approach, video laryngoscopy, involves the use of a video camera rather than line-of-sight visualization (Bacon et al. 2015, Maldini et al. 2016). Video laryngoscopes gather enhanced images of the airway via a camera and these can be observed on a monitor attached (Smith et al. 1999). Currently, there are several different video laryngoscopes available to the market (Bacon et al. 2015, Healy et al. 2012, Maldini et al. 2016). Video-laryngoscopes are classified into three different broad categories: (1) Macintosh blade-shape (e.g., McGrath MAC, C-MAC), (2) angulated blade rigid (e.g., GlideScope, TrueView) and (3) channelled rigid (e.g., Airtraq, King Vision) devices (Bacon et al. 2015, Maldini et al. 2016). The most commonly used video laryngoscopes are the C-MAC and GlideScope (Cook & Kelly 2017, Bacon et al. 2015). Research has suggested that video laryngoscopy is associated with faster learning curve, higher success rate for difficult airways and better visualization of glottis leading to higher intubation success rate by novice professionals and minimal manipulation of head, neck or both (Carlson & Brown 2014, Cooper 2007, Niforopoulou et al. 2010). However, to date, the majority of research on video laryngoscopes has taken place in the emergency department or other hospital settings and it is unclear whether video laryngoscopes would improve care for patients requiring intubation in the pre-hospital setting.

The NICE guideline for assessment and initial management of major trauma (NICE 2016) recommends use drug-assisted rapid sequence induction (RSI) of anaesthesia and intubation as the definitive method of securing the airway in patients with major trauma who cannot maintain their airway and/or ventilation. However, it does not provide comment on use of direct versus video laryngoscope. Expert highlighted that video laryngoscopy is already used with EMRTS. It does not appear to be widely used within WAST, but some experts suggested video laryngoscope was available for some crews. No other guidance from HTA programmes or Wales-specific policy was identified.

4. Clinical effectiveness

A range of primary and secondary evidence was identified by the systematic literature search. A recent systematic review and meta-analysis comparing video versus direct laryngoscopy in pre-hospital settings was considered the highest priority evidence (Savino et al. 2017). In addition, three randomised control trials (RCTs) comparing video versus direct laryngoscopes in pre-hospital settings, published after the latest search in Savino et al. (2017), are included (Ducharme et al. 2017, Kreutziger et al. 2019, Macke et al. 2020). More detail on the evidence identification and selection process is available in Section 11.

Savino et al. (2017) conducted a systematic review and meta-analysis comparing video and direct laryngoscopes in pre-hospital settings for people requiring intubation due to cardiac arrest or major trauma. Studies were eligible if they reported exclusively on the pre-hospital setting, used only living human participants, and included sufficient data to calculate overall success rate of intubation, first-pass success rate, or both. The review included three RCTs, three non-RCTs, and four observational studies using retrospective cohort (n=2) or before and after (n=2) designs. They reported pooled estimates for the relative risk of successful overall and first-pass intubation with video versus direct laryngoscopes stratified by doctors, who were experienced in intubation, and non-doctors, who had less experience. This stratification scheme also led to stratification by study type, with data for doctors coming from the three RCTs and data for non-doctors coming from the four observational studies. In addition, the I^2 test for heterogeneity was performed for each pooled estimate. Egger's test was also performed and funnel plots created evaluating the presence of publication bias in the selected studies. Further details on the systematic review and its findings are reported and summarised across Tables 1 and 3.

Ducharme et al. (2017) conducted a randomised, crossover, non-blinded trial comparing King Video and direct laryngoscopy in 82 adult intubations mostly during cardiac arrest. The trial was conducted in four suburban and two rural ground ambulance bases across two emergency medical services (EMS) in Pennsylvania in the United States and each base was randomised to King Video or direct laryngoscope. Bases were then crossed over to the other study arm at six-month intervals. All intubations were completed by an experienced paramedic and/or experienced emergency technician and while professionals in bases randomised to the King Video arm were encouraged to use this device when intubation was indicated, they were also able to revert to direct laryngoscope if they felt this was needed for patient safety. Most of the participants were male, 70 years old or older and their estimated weight ranged from 76 to 150kg. The study reported outcomes on overall and first-pass intubation success rate, glottic view as measured by Cormack-Lehane grade and percentage of glottic opening (POGO) scores as well as device complications.

Kreutziger et al. (2019) conducted an open-label, patient-blinded RCT comparing McGrath Video and direct laryngoscopy in 514 adult intubations during both cardiac arrest and major trauma cases. Individual patients were randomised to video or direct laryngoscopy using a pre-specified schedule and intubation was delivered by experienced doctors in a helicopter EMS (Austria) over 18 months. Switching between the devices was allowed if intubation failed and a maximum of four intubation attempts were permitted. Most of the participants were male, 18 years old or older and their estimated body mass index was between 26 and 27. The study reported outcomes on intubation success, total number of intubation attempts, first end-tidal Co2 and time until passage of the tracheal tube through the glottis.

Macke et al. (2020) conducted an RCT comparing C-MAC PM video laryngoscopy and direct laryngoscopy in 152 adult intubations during mostly major trauma incidents. Patients were randomised at the individual level and assigned to video or direct laryngoscopy took place after the decision to intubate was made. The intubation was delivered by experienced doctors and paramedics in air ambulances (Germany) over 21 months and video laryngoscopes had been in routine use for a period of time prior to initiation of the study. Switching between devices was permitted if there was failed intubation. Most of the participants were male, with median age 68 years old, and the study reports that most intubations took place on a stretcher (n = 79, 52%) or on the ground (n = 72, 47.45%). The study reported outcomes on first-pass success, visualization of glottic view as measured by Cormack-Lehane grade and POGO-scores as well as comparison of success rate between experienced and less experienced doctors.

Details of the three RCTs and their finding are reported and summarised across Tables 2 and 3.

We performed a meta-analysis for first-pass and overall intubation success rates for video versus direct laryngoscopy to further examine the moderate to considerable outcome heterogeneity reported by Savino et al. (2017). For the purpose of this meta-analysis, we included three RCTs (Arima et al. 2014, Trimmel et al. 2011, Trimmel et al. 2016) from Savino et al. (2017), as well as the three more recent RCTs (Ducharme et al. 2017, Kreutziger et al. 2019, Macke et al. 2020), involving 1395 participants in total. In line with the previous meta-analysis, we found considerable heterogeneity for both outcomes in analyses that included all identified trials. To further examine this, we performed a sub-group analysis for these outcomes among RCT studies, involving mostly cardiac arrest (Arima et al. 2014, Ducharme et al. 2017, Trimmel et al. 2016) and mostly major trauma populations (Macke et al. 2020) (n= 669). Two studies (Kreutziger et al. 2019, Trimmel et al. 2011) excluded from the sub-group analysis, as they had a more equal distribution of participants from both populations. Details of the meta-analysis and sub-group analysis methods are reported and summarised in Section 11.

Table 1. Systematic review and meta-analysis: Savino et al. (2017)

Included studies	Inclusion criteria	Quality and Risk of Bias	Observation/notes
Number of studies: 8 studies **Total number of patients:** 3552 **Publication year:** 2017 **Setting:** ground ambulance (n=3), air ambulance (n=4) and both (n=1) **Intubation operator:** doctors (n=3) and non-doctors (i.e., nurses and/or paramedics) (n=5) **Population:** cardiac arrest and major trauma	**Review period:** No time period limit **Review purpose:** To compare overall and first-pass success for video versus direct laryngoscopy in patients requiring intubation in the prehospital hospital setting. **Included study designs:** RCTs, non-RCTs and observational studies **Included age groups:** Two studies (25%) included participants of all ages, five studies (62.5%) included participants ≥18 years old and one study (12.5%) included participants ≥6 years old. **Included outcome measures:** Pooled effect sizes (random-effects model) for overall intubation, first-pass intubation, or both.	**Tool:** Cochrane Collaboration's tool structured into eleven fixed set of domains of bias, focusing on different aspects of trial design, conduct and reporting used. **Risk of Bias:** Summary of risk of bias ratings provided. **Adjustment for publication bias:** Egger's test was used, finding no publication bias for the overall and first-pass success. The funnel plot supported the findings of the later, but for the former it found some potential publication bias.	The review included studies comparing several different video versus direct devices for intubation. Video laryngoscopy devices included Airway Scope (n=1), C-MAC (n=2), King Vision (n=1), Airtraq (n=2), GlideScope Ranger (n=2). The overall intubation success data of Selde et al. (2014) was not included in the meta-analysis as they used a different definition for overall intubation success. The review did not report an overall pooled result for video compared to direct laryngoscopy, due to high heterogeneity. Results were stratified according to intubation by doctors and non-doctors and this also led to stratification by study type with only RCTs available for doctors and only observational studies available for non-doctors.

RCT: Randomised controlled trials.

Table 2. Randomised controlled trials: design and characteristics

Reference	Study Design	Intervention and Comparator	Relevant outcomes	Additional notes / Comments on applicability
Ducharme et al. (2017)	Cross over, non-blinded RCT Multicentre (n= 6, USA) **Enrolment period:** Dates not reported (34 months) **Follow-up:** Immediate **Total number of intubations:** 82 **Population:** mostly cardiac arrest	**Intervention:** The King Video Laryngoscope has a reusable video display with disposable blades that are available in three different sizes. **Comparator:** Direct laryngoscopy using the Macintosh or Miller blade according to professional preference.	• Overall intubation success • First attempt intubation success rate based on device, clinician experience and clinical scenario • Visualization of glottic view as measured by (1) Cormack-Lehane grade and (2) POGO-score • Device Compilations	Participant were excluded if they were believed to be under 18 years of age. The operators were instructed to use the intended device (i.e., video or direct) for the first intubation attempt. Any following intubation attempts could be performed via any device the operator chose. The authors report that three complications occurred in the King Video arm due to a design issue with the channelled blade. These blades were replaced with conventional blades after three months of recruitment and no further complications due to this issue occurred. Sensitivity analyses censoring this period of recruitment did not alter findings.
Kreutziger et al. (2019)	Prospective, open-label, patient-blinded RCT Multicentre (n=10, Austria) **Enrolment period:** April 2017 and July 2018 **Follow-up:** Immediate **Total number of intubations:** 514 **Population:** mixed (i.e., cardiac arrest and major trauma)	**Intervention:** The McGrath Video Laryngoscope is a pocket size device with integrated monitor and Macintosh-style single use blade with adjustable length. There is no anti-fog system and it requires standard AA batteries. **Comparator:** Direct laryngoscopy using the Macintosh-style blade All intubations were delivered by experienced doctors in a helicopter EMS.	• Intubation success for each method • Total number of endotracheal intubation attempts • First end-tidal Co2 • Time until passage of the tracheal tube through the glottis	Participants were excluded if they were under 18 years of age or if survival was unlikely. The operators were either certified anaesthesiologists or EMS doctors with four or more years of postgraduate training and inpatient anaesthesia experience.
Macke et al. (2020)	Prospective, consecutive RCT	**Intervention:** The C-MAC PM has a pocket size monitor and multi-reusable blades (Macintosh II-IV,	• First-pass success • Visualization of glottic view as measured by (1)	Participants were excluded if they were under 18 years of age

Reference	Study Design	Intervention and Comparator	Relevant outcomes	Additional notes / Comments on applicability
	Enrolment period: April 2017 and January 2019 **Follow-up:** Immediate **Total number of intubations:** 152 **Population:** mostly major trauma	D-Blade). It has two batteries with charging unit. **Comparator:** Treatment as usual (i.e., traditional direct laryngoscopy using the Macintosh blade). All intubations were delivered in air ambulances by doctors with a background in trauma surgery and additional qualification in prehospital care. Paramedics supported intubation and the study protocol by completing documentation, drug administration and time measurement.	Cormack-Lehane grade and (2) POGO-score • Comparison of success rate of experienced and less experienced doctors.	Doctors who carried out <100 intubations were classified as less experienced, while those with >100 intubations, as more experienced.

EMS: emergency medical services, POGO: percentage of glottic opening, RCT: randomised controlled trial.

4.1 First-pass intubation success

In the systematic review and meta-analysis, all eight studies were included in the analysis for first-pass intubation success (Savino et al. 2017). As outlined above, first-pass intubation success was reported according to intubation by doctors or non-doctors and this also stratified the outcomes by study type. Based on three RCTs, the review reported that doctors had a lower rate of first-pass success with video laryngoscopy compared to direct laryngoscopes (RR = 0.32, 95%CI = 0.23 to 0.44). Based on five observational studies, the review reports that use of video laryngoscopy was associated with a higher rate of first-pass intubation success compared to direct laryngoscopy (RR = 1.83, 95%CI 1.18 to 2.84). There was minimal heterogeneity among doctor studies (I^2 = 28.9%) and substantial heterogeneity among non-doctor studies (I^2 = 84.9%).

Of the RCTs, Ducharme et al. (2017) found that first-pass intubation success was comparable for direct compared to video laryngoscopy (RR = 0.94, 95%CI 0.68 to 1.29). Similarly, Kreutziger et al. (2019) reported that first-pass intubation success was higher for direct compared to video laryngoscopy (RR = 0.92, 95%CI 0.84 to 1.02) but this difference did not reach significance. However, Macke et al. (2020) found that fist-pass intubation success was higher for video compared to direct laryngoscopy (RR = 1.20, 95%CI 1.06 to 1.36).

4.2 Overall intubation success

In the systematic review and meta-analysis, seven out of the eight studies were included in analyses on overall intubation success (Savino et al. 2017). As outlined above, overall intubation success was reported according to intubation by doctors or non-doctors and this also stratified the outcomes by study type. Based on three RCTs, the review reports that doctors had lower rate of success with video compared to direct laryngoscopy (RR = 0.05, 95%CI 0.01 to 0.18). Based on four observational studies, the review reports use of video laryngoscopy was associated with higher rates of overall success compared to direct laryngoscope (RR = 2.28; 95%CI 1.00 to 5.20). There was moderate heterogeneity among doctor studies (I^2 =46.1%) and considerable heterogeneity among non-doctor studies (I^2=76.6%).

Of the RCTs, Ducharme et al. (2017) reported that direct laryngoscopy was associated with comparable rates of overall success compared to video laryngoscopy (RR = 0.90, 95%CI 0.70 to 1.14). Similarly, Kreutziger et al. (2019) reported that overall success did not differ between video and direct laryngoscopy (RR = 1.00, 95%CI 0.97 to 1.02). Macke et al. (2020) also reported that overall success did not differ between video and direct laryngoscopy groups (RR = 1.00, 95%CI 0.97 to 1.03).

4.3 Overall intubation attempts

Ducharme et al. (2017) found that the median number of intubation attempts did not differ across groups (median attempts, 1 vs. 1, p = 0.98) and Kreutziger et al. (2019) replicated this finding (median attempts, 1 vs. 1, mean attempts, 1.1 vs. 1.2 p = 0.76). Macke et al. (2020) did not report overall intubation attempts.

4.4 Intubation success of subsequent attempts

Kreutziger et al. (2019) and Macke et al. (2020) also reported the intubation success rate of subsequent attempts with video and direct laryngoscopes. Specifically, Kreutziger et al. (2019) found that success of 2nd, 3rd and 4th intubation attempts had no significant difference between video and direct laryngoscopes arms with absolute difference of 1.47% (99 CI -3.68 to 6.63), 0.41% (99%CI -2.89 to 3.70) and 0.40% (99%CI -2.58 to 3.39) respectively. Macke et al. (2020) found that the success of 2nd intubation attempts was not higher for video compared to direct laryngoscopes (p = 1.0), although this is highly likely to be influenced by the higher first-pass intubation success seen in this study.

4.5 Intubation time

Kreutziger et al. (2019) report both time until passage of the tracheal tube through the glottis and time to first end-tidal CO_2 as measures of the time needed for intubation. They report that significant differences between the video and direct laryngoscope groups were not found for passage through the glottis (median time, 12 seconds vs 14 seconds, $p = 0.05$) or for first end-tidal CO_2 (median time, 25 seconds vs 30 seconds, $p = 0.10$). Macke et al. (2020) reported that the median time for the first intubation attempt of video and direct laryngoscopy was 15.5 seconds and 18.5 seconds, respectively and this difference was significant ($p = 0.01$). From the reporting in the study, it is unclear how this outcome was operationalised and it is unclear whether this related only to successful attempts or all attempts.

4.6 Glottic view

Ducharme et al. (2017) found that video and direct laryngoscopy were similar in terms of Cormack-Lehane grade ($p = 0.19$) and POGO-scores ($p = 0.31$). However, Kreutziger et al. (2019) reported that video laryngoscopy led to a significantly better glottic view in terms of Cormack-Lehane grade ($p < 0.0001$). Macke et al. (2020) also found better Cormack-Lehane grade ($p < 0.001$) and POGO-scores ($p < 0.001$) for video laryngoscopy.

4.7 Perceived difficulty of intubation

Kreutziger et al. (2019) reported on doctors' subjective assessment of the difficulty of intubation from a 4-point scale. They report that differences in perceived difficulty of intubation were not significantly different between the video and direct laryngoscopy arms (median difficulty, 2 vs. 1, $p=0.6$; mean difficulty, 1.9 vs. 1.9).

4.8 Technical problems

Kreutziger et al. (2019) reported on technical problems for video and direct laryngoscope including impaired sight due to fogged camera lens, monitor reflexes, and ambient light. Video laryngoscope had significantly higher problems compared to direct laryngoscopes (26.5% vs 4.2%, $p < 0.0001$).

4.9 Adverse Events

Ducharme et al. (2017) reported complications in four of 82 intubation attempts. One complication occurred because the batteries were not working not and the device could not be turned on. Three of the complications occurred due to design issues because of the device's channelled blades. This was reported by the operators during the first three months of the trial. After the request of paramedics, all channelled blades were replaced with a traditional (non-channelled) blade and no additional complications related to this issue with recorded. Kreutziger et al. (2019) reported that intubation injuries were comparable between the groups with six (2.1%) in the direct group and eight (2.7%). There was one injury to teeth in each group and all other injuries were superficial dermal or mucosal abrasions.

4.10 Clinical outcomes and mortality

No studies reporting on clinical outcomes or mortality after transfer to hospital were identified.

4.11 Health service utilisation

No studies reporting on health service utilisation (e.g., procedures after transfer to hospital, admission to critical care, length of stay) were identified.

4.12 Outcomes according to age

None of the identified studies compared outcomes according to age. The included RCTs excluded patients believed to be below the age of 18. Studies included in the systematic review and meta-analysis either also excluded those under age of 18 or did not report according to age.

4.13 Outcomes according to professional background

None of the identified studies directly compared outcomes according to whether professionals were doctors or paramedics or people from other professional backgrounds. Savino et al. (2017) did stratify outcomes by professional background and found divergent results for doctors and other professionals. However, these findings are confounded by the fact that all studies with doctors were RCTs and all studies for other professionals were observational.

In terms of experience level, Macke et al. (2020) reported that experienced and less experienced doctors were equally distributed in the two arms (video, 48%, direct, 54%, $p = 0.6$) and no difference between the experienced and less experienced doctors were found on any outcome. More detailed results for this are not reported by the study.

4.14 Outcomes according to type of emergency service

None of the identified studies compared outcomes according to use in ground and air ambulance services.

Table 3. Video laryngoscopes compared to direct laryngoscopes: outcomes

Outcome	Evidence source	Number of studies, number of participants	Setting and Professionals	Absolute effect	Relative effect
Intubation success					
First pass intubation success	Savino et al. (2017)	3 RCTs, 647 participants	Air and ground Doctors	NR	RR= 0.32 (95% CI 0.23 to 0.44) Favours direct
	Savino et al. (2017)	5 non-RCTs, 2905 participants	Air and ground Nurses and paramedics	NR	RR = 1.83 (95% CI 1.18 to 2.84) Favours video
	Ducharme et al. (2017)	1 RCT, 82 participants	Ground Paramedics	Video: 25/40 (62.5%) Direct: 28/42 (66.7%)	RR = 0.94 (95%CI 0.68 to 1.29) Favours direct
	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 180/247 (83%) Direct: 211/267 79%	RR = 0.92 (95%CI 0.84 to 1.02) Favours direct
	Macke et al. (2020)	1 RCT, 152 participants	Ground Doctors	Video: 72/76 (95%) Direct: 60/76 (79%)	RR = 1.20 (95%CI 1.06 to 1.36) Favours video
Overall intubation success	Savino et al. (2017)	3 RCTs, 647 participants	Air and ground Doctors	NR	RR = 0.05 (95% CI 0.01 to 0.18) Favours direct
	Savino et al. (2017)	4 non-RCTs, 2775 participants	Air and ground Nurses and paramedics	NR	RR = 2.28 (95% CI 1.00 to 5.20) Favours video
	Ducharme et al. (2017)	1 RCT, 82 participants	Ground Paramedics	Video: 29/40 (72.5%) Direct: 34/42 (81%)	RR = 0.90 (95%CI 0.70 to 1.14) Favours direct
	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 251/256 (98.1%) Direct: 254/258 (98.5%)	RR = 1.00 (95%CI 0.97 to 1.02) Favours neither

Outcome	Evidence source	Number of studies, number of participants	Setting and Professionals	Absolute effect	Relative effect
	Macke et al. (2020)	1 RCT, 152 participants	Ground Doctors	Video: 76/76 (100%) Direct: 76/76 (100%)	RR = 1.00 (95%CI 0.97 to 1.03) Favours neither
Time to intubation					
Time to passage through glottis	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 14 seconds Direct: 12 seconds	$p = 0.05$ Favours neither
Time to first end-tidal CO_2	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 30 seconds Direct: 25 seconds	$p = 0.10$ Favours neither
Time to intubation for first-attempt	Macke et al. (2020)	1 RCT, 152 participants	Ground Doctors	Video: 15.5 seconds Direct: 18.5 seconds	$p = 0.01$ Favours video
Glottic view					
Percentage of POGO score, median	Ducharme et al. (2017)	1 RCT, 82 participants	Ground Paramedics	Video: 82.5% Direct: 85%	$p = 0.31$ Favours neither
	Macke et al. (2020)	1 RCT, 152 participants	Ground Doctors	Video: 100% Direct: 65%	$p < 0.001$ Favours video
Cormack and Lehane score, median	Ducharme et al. (2017)	1 RCT, 82 participants	Air Doctors	Video: 2 Direct: 2	$p = 0.19$ Favours neither
	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 1 (1.5) Direct: 1 (2)	$p < 0.0001$ Favours video
	Macke et al. (2020)	1 RCT, 152 participants	Ground Doctors	Video: 1 Direct: 2	$p < 0.001$ Favours video

Outcome	Evidence source	Number of studies, number of participants	Setting and Professionals	Absolute effect	Relative effect
Perceived difficulty and technical problems					
Perceived difficulty of intubation (4-point scale), median (mean)	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 1 (1.9) Direct: 2 (1.9)	p = 0.41 Favours neither
Technical problems (i.e., fogged camera lens, monitor reflexes, ambient light)	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 78/294 Direct: 12/285	P < 0.0001 Favours direct
Device safety					
Adverse events	Ducharme et al. (2017)	1 RCT, 82 participants	Ground Paramedics	Video: 4 Direct: NR	NR
	Kreutziger et al. (2019)	1 RCT, 514 participants	Air Doctors	Video: 8/294 Direct: 6/285	p = 0.63 Favours neither

CI: confidence interval, POGO: percentage of glottic opening, NR: not reported, RCT: randomised controlled trial, RR: relative risk.

4.15 Meta-analysis

For the purposes of the meta-analysis, we combined individual study data for overall and first-pass intubation rates across six RCT studies (Arima et al. 2014, Ducharme et al. 2017, Kreutziger et al. 2019, Macke et al. 2020, Trimmel et al. 2016, Trimmel et al. 2011). Details of the meta-analysis methods are reported and summarised in Section 11.

4.15.1 First-pass intubation success

We conducted an analysis for the RCTs that included first pass intubation success rate comparing video versus direct laryngoscopy (Figure 1). Six studies, three RCTs (Arima et al. 2014, Trimmel et al. 2016, Trimmel et al. 2011) from Savino et al. (2017) and three most recent identified RCTs (Ducharme et al. 2017, Kreutziger et al. 2019, Macke et al. 2020), were included with a total of 1395 participants. The use of direct laryngoscopes had higher rates of overall intubation success compared to video laryngoscopes (RR = 0.77, 95%CI 0.58 to 1.01). There was considerable heterogeneity within this analysis (I^2 = 95%).

	VL		DL			Risk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI
Arima 2013	26	56	40	53	14.8%	0.62 [0.45, 0.85]
Ducharme 2017	25	40	28	42	14.8%	0.94 [0.68, 1.29]
Kreutziger 2019	180	247	211	267	18.0%	0.92 [0.84, 1.02]
Macke 2020	72	76	60	76	17.7%	1.20 [1.06, 1.36]
Trimmel 2011	50	106	105	106	16.8%	0.48 [0.39, 0.58]
Trimmel 2016	104	168	152	158	17.8%	0.64 [0.57, 0.73]
Total (95% CI)		**693**		**702**	**100.0%**	**0.77 [0.58, 1.01]**
Total events	457		596			

Heterogeneity: Tau² = 0.11; Chi² = 91.20, df = 5 (P < 0.00001); I² = 95%
Test for overall effect: Z = 1.88 (P = 0.06)

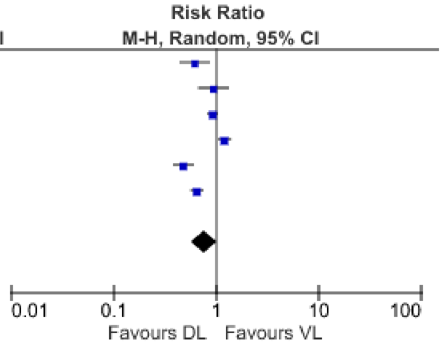

Figure 1. Comparison of first-pass intubation success rates for VL versus DL. Weight is the relative contribution of each study to the risk ratio (random effects model with 95%CI). CI: Confidence interval, DL: Direct laryngoscopy, VL: Video laryngoscopy.

4.15.2 Overall-intubation success

We also conducted an analysis for the RCTs that included overall intubation success rate (Figure 2). Six studies, three RCTs (Arima et al. 2014, Trimmel et al. 2016, Trimmel et al. 2011) from (Savino et al. 2017) and three most recent identified RCTs (Ducharme et al. 2017, Kreutziger et al. 2019, Macke et al. 2020), were included with a total of 1395 participants. The use of direct laryngoscopes had higher rates of overall intubation success compared to video laryngoscopes (RR = 0.81, 95%CI 0.67 to 0.99). There was considerable heterogeneity within this analysis (I^2 = 99%).

Study or Subgroup	VL Events	VL Total	DL Events	DL Total	Weight	Risk Ratio M-H, Random, 95% CI
Arima 2013	54	56	53	53	18.1%	0.97 [0.91, 1.03]
Ducharme 2017	29	40	34	42	14.3%	0.90 [0.70, 1.14]
Kreutziger 2019	251	256	254	258	18.4%	1.00 [0.97, 1.02]
Macke 2020	76	76	76	76	18.4%	1.00 [0.97, 1.03]
Trimmel 2011	28	63	58	58	13.4%	0.45 [0.34, 0.59]
Trimmel 2016	108	174	215	224	17.3%	0.65 [0.57, 0.73]
Total (95% CI)		**665**		**711**	**100.0%**	**0.81 [0.67, 0.99]**
Total events	546		690			

Heterogeneity: Tau² = 0.05; Chi² = 444.13, df = 5 (P < 0.00001); I² = 99%

Test for overall effect: Z = 2.10 (P = 0.04)

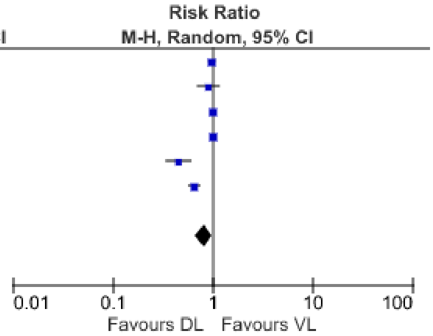

Figure 2. Comparison of overall intubation success rates for VL versus DL. Weight is the relative contribution of each study to the risk ratio (random effects model with 95%CI). CI: Confidence interval, DL: Direct laryngoscopy, VL: Video laryngoscopy.

The CI for both outcomes of individual RCT studies had poor overlap indicating the presence of statistical heterogeneity due to clinical and methodological diversity among the studies (Higgins et al. 2021). Savino et al. (2017) also highlighted this on their meta-analysis. Considering all the above as well as the comments received from experts regarding the influence of the population during intubation, we performed a sub-group analysis for both outcomes based on the population requiring airway management.

4.15.3 Sub-group analysis for first-pass and overall intubation success rates by population

For the purposes of the sub-group analysis, we combined individual study data for first-pass and overall intubation success rates by population (i.e., cardiac arrest or major trauma) across four studies (Arima et al. 2014, Ducharme et al. 2017, Trimmel et al. 2016, Macke et al. 2020) with a total of 669 participants. Most studies included cardiac arrest population (Arima et al. 2014, Ducharme et al. 2017, Trimmel et al. 2016), while only one RCT included major trauma population(Macke et al. 2020). Two studies (Kreutziger et al. 2019, Trimmel et al. 2011), were excluded since they had included a more equal distribution of populations. Details of the sub-group analysis methods are reported and summarised in Subsection 11.

4.15.3.1.First-pass intubation success by population

We conducted a sub-group analysis for the studies that included first-pass intubation success rates comparing video versus direct laryngoscopy by population (Figure 3). Studies involving cardiac arrest population suggested that the video laryngoscopy had worse fist-pass intubation success rates compared to direct laryngoscopy (RR = 0.70, 95%CI 0.56 to 0.88), while the only study involving major trauma population suggested that first-pass intubation success rates was higher for video compared to direct laryngoscopy (RR = 1.20, 95%CI 1.06 to 1.36). There was moderate heterogeneity for the cardiac arrest group (I^2 = 59%), while the heterogeneity for the major trauma group was not applicable to be calculated as only one study was included in this sub-group analysis.

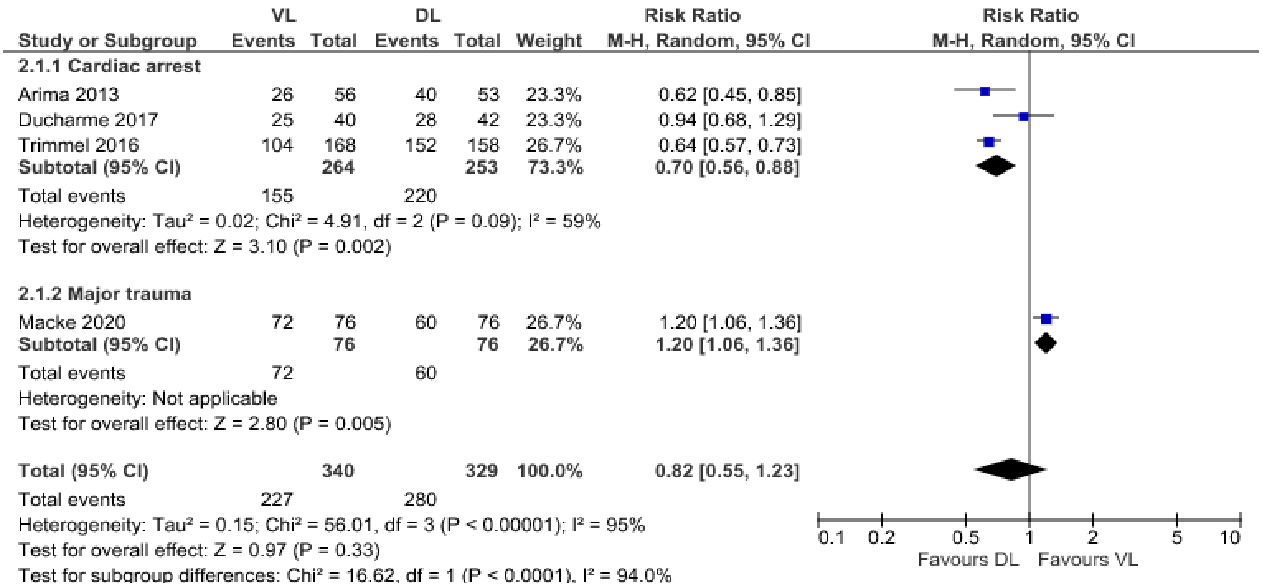

Figure 3. Comparison of first-pass intubation success rates by population. Weight is the relative contribution of each study to the risk ratio (random effects model with 95%CI). CI: Confidence interval, DL: Direct laryngoscopy, VL: Video laryngoscopy.

4.15.4 Overall-intubation success by population

We conducted a sub-group analysis for the same RCTs studies that included overall intubation success rates comparing video versus direct laryngoscopy by population (Figure 4). The overall intubation success rate was different between video and direct laryngoscopy during cardiac arrest and major trauma. Studies involving cardiac arrest population suggested that the video laryngoscopy had worse overall intubation success rates compared to direct laryngoscopy (RR = 0.82, 95%CI 0.53 to 1.28), while the only study involving major trauma population suggested that overall intubation success rates did not differ between the two devices (RR = 1.00, 95%CI 0.97 to 1.03). There was considerable heterogeneity for the cardiac arrest group (I^2 = 97%), while the heterogeneity for the major trauma group was not applicable to be calculated as only one study was included in this sub-group analysis.

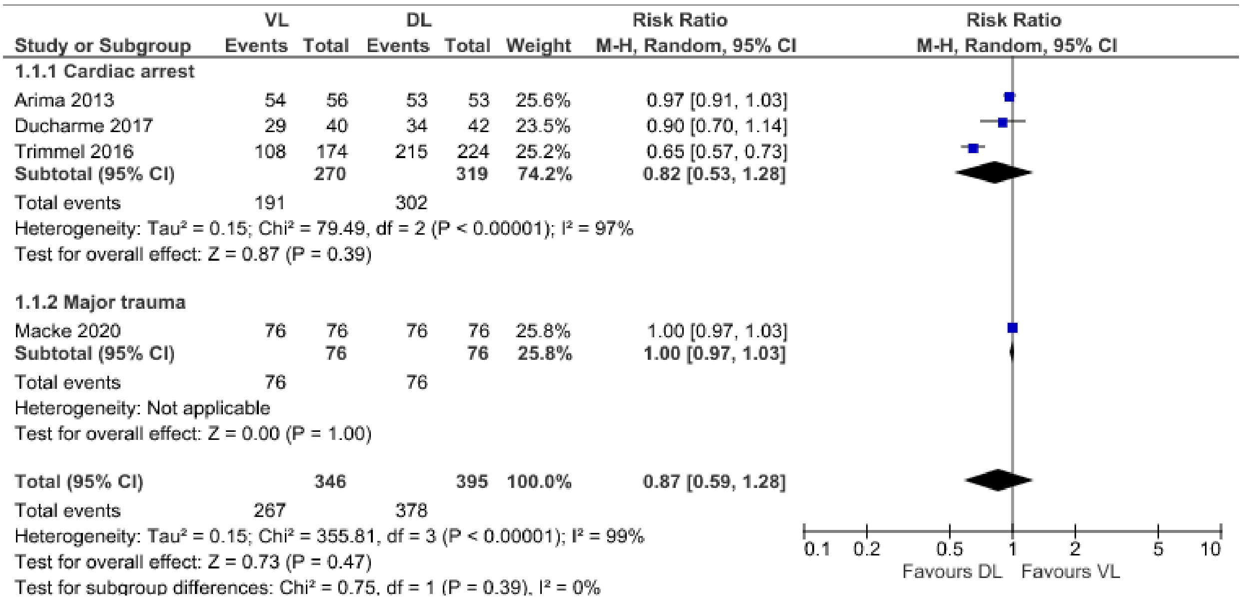

Figure 4. Comparison of overall intubation success rates by population. Weight is the relative contribution of each study to the risk ratio (random effects model with 95%CI). CI: Confidence interval, DL: Direct laryngoscopy, VL: Video laryngoscopy.

To sum up, the results of our overall meta-analysis comparing video versus direct laryngoscopy suffered from substantial heterogeneity similarly to the Savino et al. (2017) meta-analysis. The performance of sub-group analysis for first-pass and overall intubation success rates by population was able to partially address the heterogeneity for the cardiac arrest population. Specifically, the heterogeneity of the first-pass intubation success rate for this population was moderate (I^2 = 59%). Thus, there is an indication that this population favours direct compared to video laryngoscopy. We were not able to draw any conclusions regarding the overall intubation success rates for cardiac arrest population, because the heterogeneity was still substantial (I^2 = 97%). Although it was not possible to calculate the heterogeneity for both outcomes for the major trauma population, there is an indication that this population favours video versus direct laryngoscopy during intubations requiring airway management.

4.16 Ongoing trials

One ongoing RCT was identified during the search. It aims to evaluate the effectiveness McGrath video and Macintosh (direct) laryngoscopes for adult tracheal intubation in the prehospital setting. This RCT is funded by the Assistance Publique - Hôpitaux de Paris in France. The trial registration reports that final data collection of the primary outcome measure (i.e., first-pass intubation success rate) is anticipated in December 2021. Details of the ongoing RCT and its primary and secondary outcomes are reported and summarised in Table 4.

Table 4. Ongoing Trials: design and characteristics

Study information	Status	Research questions & outcome measures
Registration: NCT01635660 **Country**: France **Target recruitment:** 150 participants **Follow-up:** Immediate	In Progress (not yet recruiting)	This RCT aims to compare the McGrath video and direct laryngoscopy for tracheal intubation in the prehospital setting. **Population:** ≥ 18 years old requiring intubation / airway management **Intervention:** McGrath video laryngoscope **Comparator:** Macintosh laryngoscope

Study information	Status	Research questions & outcome measures
		Operator: Experienced professionals in use of McGrath **Relevant outcomes:** first-pass intubation success rate, number of intubation attempts, intubation time, device failure reasons of the first-pass intubation success, visualisation of glottic view (Cormack-Lehane grade and POGO-score), proportion of decision of device switch in case of failure, number and type of device complications per and post-intubation, mortality.

5. Economic evaluation

No studies that compared the cost-effectiveness of video and direct laryngoscopes were identified. The current clinical evidence suggests that use of video laryngoscopes compared to direct laryngoscopes does not lead to significant improvements in first-pass intubation success or overall intubation success. A cost minimisation analysis approach is adopted due to the clinical equivalence between video and direct laryngoscopy. The costing approach takes a limited UK NHS and personal social services (PSS) perspective which focuses on the relative initial technology procurement costs. Costs are reported in 2020 (GBP) base year. No discounting is applied.

5.1 Cost of standard care

Medtech innovation briefing 167 (MIB 167), published by NICE in 2018 offers a detailed review of the comparative costs of direct and video laryngoscopes used within the NHS. The report assesses the use of video laryngoscopes for intubation of individuals with difficult airways in emergency or secondary healthcare settings. Whilst the indication does not exactly match the HTW review, the devices listed are selected as to be generalisable.

MIB 167 identified 363 devices and consumables under the search term 'laryngoscope' offered on the NHS supply chain catalogue. Direct laryngoscopes broadly consist of a handle and a blade, either or both may be once use or reusable. The combination of these characteristics and associated price ranges are reported in Table 5. To offer 2020 GBP values, a bank of England consumer price inflation index is multiplied by the 2018 prices.

Table 5. Direct Laryngoscopy costs

Direct Laryngoscope	Lowest price	Highest price
Reusable handle with disposable blade	£10.46	£92.53
Single-use handle with disposable blades	£4.52	£82.64
Single-use handle with reusable blade	£2.71	£41.32
Reusable handle with reusable blade	£17.64	£29.31

Expert input has reported that ambulance services in Wales use a single-use handle with a disposable blade. A Polaris fibre optic disposable laryngoscope represents the single-use handle and disposable blade style used within Wales; this item costs £7.45 (MedTree 2022).

5.2 Cost of intervention

Video Laryngoscopes differ from direct laryngoscopes as they typically have an integrated display unit and camera. A sample of video laryngoscopes listed in MIB 167 in table 6 below. The reported devices have been chosen due to their prevalence in the clinical trial data. Devices broadly consist of the reusable camera display unit and blades; the blades can be either reusable or disposable. Table 6 reports the range of video laryngoscope costs, values have been inflated to 2020 (GBP).

Table 6. Video Laryngoscopy costs

Device (Company)	Item Description	List price (2020 GBP)
King Vision aBlade (Ambu Ltd)	King Vision display	781
	aBlade size 1, 2 or 2c, box (10)	125
C-MAC System (KARL STORZ)	C-MAC pocket monitor set	3538
	Disposable blades (10)	214
McGrath MAC (Medtronic)	Video laryngoscope	1666
	Disposable blades: Mac sizes 1 to 4 (10)	68
Glidescope (Verathon Medical UK Ltd)	GlideScope Go monitor kit	2394
	LoPro S3 or S4, box (10)	281
Airtraq Avant / Airtraq SP (Prodol Meditec)	Reusable optics	No Charge
	SP single-use laryngoscope box (10)*	492
Note * Airtraq blades sold in box of 6, adjusted figure to offer comparable blade number (10)		

Table 6 shows the range of cost from a representative sample of video laryngoscopes, each display unit reported along with 10 disposable blades. The costs range from £492 for the Airtraq series to £3752 for the C-MAC system. The lowest price video laryngoscope option is roughly five times the most expensive direct laryngoscope. Procurement arrangements reported in Table 6 for the Airtraq device is based on the reusable optics being provided at no charge and the disposable laryngoscope blade component incurring costs. It is unknown whether this payment structure would be extended to all settings regardless of expected use levels. Experts have reported that EMRTS currently use the McGrath Mac EMS video laryngoscope, for cost comparison purposes the McGrath Mac unit is used.

5.3 Cost comparison

The cost comparison between standard care and intervention is requires a usage level to be applied due to the multi-use/single-use items. The cost comparison assumes a base case of ten uses. Table 7 reports the differing cost comparison scenarios. Video laryngoscopy is associated with an increase of £1,659.50 for ten uses. The marginal cost of each use is very slightly less for the video laryngoscope, 100 uses results in an increase of £1,601.

Table 7. Laryngoscopy cost comparison

Device (Company)	Item Description	List price (2020 GBP)
McGrath MAC	Multi-use handle unit	1,666
	Disposable blades (10)	68
Polaris fibre optic direct laryngoscope	Disposable handle and blade (10)	74.50
	Cost difference	1,659.50

5.4 Budget impact

The budget impact analysis offers three temporal components, immediate procurement, a one year and a five-year horizon. Due to triaged approach to emergency response within Wales there are two distinct user groups for out of hospital laryngoscopy, WAST and EMRTS. To estimate the budget impact of procuring and using video laryngoscopes across Wales the number and usage levels need to be calculated. WAST has over 300 ambulances with 925 paramedics or clinical team leaders, expert input stated that each paramedic would likely undertake two to three intubations each year. EMRTS consists of five rapid response vehicles and four air ambulances. EMRTS reported figures of 620 intubations in 2021. The disparity between the number of intubations per vehicle is due to the severity of triaging within emergency services.

Two adoption scenarios are assessed, firstly, a routine adoption of video laryngoscopes across Wales. The second approach deploys video laryngoscopes only to EMTRS vehicles. The budget impact analysis assumes that the lifecycle of the technology exceeds the five-year budget impact horizon. No volume related contracts are included in this analysis. Each vehicle requires a device with usage per vehicle based on an X+2 to account for stock of disposables items, where X is the number of intubations undertaken within the duration. WAST was estimated to undertake 2,312 intubations yearly (925 * 2.5) this is the amount of first responders multiplied by 2.5 intubations yearly. Table 8 presents the initial purchase cost for the first budget impact scenario. Tables 9 and 10 offer the one year and five-year horizons respectively.

Table 8. Budget impact: routine adoption initial cost

Time horizon	WAST		EMRTS		Total (£GBP)
	Devices	Blades	Devices	Blades	
Video Laryngoscope					
Units	300	600*	9	18*	
Cost * Units	499,800	4,080	14,994	122	518,996
* (300*2) supply per ambulance. (9*2) supply per ambulance					

Table 9. Budget impact: routine adoption one year

Time horizon	WAST		EMRTS		Total (£GBP)
	Devices	Blades	Devices	Blades	
Video Laryngoscope					
Units	300	2,912*	9	638*	
Cost * Units	499,800	19,802	14,994	4,338	538,934
* (2,312 yearly intubations + (300*2) supply per ambulance). (620 yearly intubations + (9*2) supply per ambulance).					

Table 10. Budget impact: routine adoption five years

Time horizon	WAST		EMRTS		Total (£GBP)
	Devices	Blades	Devices	Blades	
Video Laryngoscope					
Units	300	12,160*	9	3,118*	
Cost * Units	499,800	143,888	14,994	21,202	679,884
* (2,312*5) yearly intubations + (300*2) supply per ambulance). (620*5) yearly intubations + (9*2) supply per ambulance).					

The second adoption scenario, where WAST uses direct laryngoscopy and EMRTS uses video laryngoscopes of offered by tables 11, 12, and 13 below. Direct laryngoscopes are reported as ‘devices’ as they are purchased as the single-use handle and disposable blade.

Table 11. Budget impact: partial adoption initial cost

Time horizon	WAST		EMRTS		Total (£GBP)
	Devices	Blades	Devices	Blades	
Video Laryngoscope					
Units			9	18*	
Cost			14,994	122	15,116
Direct Laryngoscope					
Units	600*				
Cost	4,470				4,470

Time horizon	WAST		EMRTS		Total (£GBP)
	Devices	Blades	Devices	Blades	
				Total cost	19,586
* (300*2) supply per ambulance.					

Table 12. Budget impact: partial adoption one year

Time horizon	WAST		EMRTS		Total (£GBP)
	Devices	Blades	Devices	Blades	
Video Laryngoscope					
Units			9	638	
Cost			14,994	4,338	19,332
Direct Laryngoscope					
Units	2,912*				
Cost	21,694				21,694
				Total cost	41,026
* (2,312 yearly intubations + (300*2) supply per ambulance).					

Table 13. Budget impact: partial adoption five years

Time horizon	WAST		EMRTS		Total (£GBP)
	Devices	Blades	Devices	Blades	
Video Laryngoscope					
Units			9	3,118	
Cost			14,994	21,202	36,196
Direct Laryngoscope					
Units	12,160*				
Cost	90,592				90,592
				Total cost	126,788
* (2,312 yearly intubations + (300*2) supply per ambulance).					

The budget impact analysis demonstrates the range of costs associated with different time horizons and different adoption approaches. The routine adoption of video laryngoscopes would incur an initial cost of £518,996 rising to £538,934 for a year of use and to £679,884 over five years. A scenario where there is partial adoption to the services which have the higher rate of intubation, EMRTS, results in an initial cost of £19,586, rising to £41,026 for a single year of use and to £126,788 over five years. The cost of video laryngoscopes is much higher in comparison to direct laryngoscopes; therefore, the budget impact of routine adoption is higher compared to partial adoption.

6. Organisational Issues

Two studies exploring professionals' views on video laryngoscopy during intubation were identified (Steel et al. 2021, Lenz et al. 2020). Each of these studies related to use of video laryngoscopes in the pre-hospital setting and included professionals from differing clinical backgrounds and different air ambulance services.

Lenz et al. (2020) distributed an online survey to paramedics and nurses in a helicopter EMS in Wisconsin, United States and aimed to explore factors that contribute to the decision-making between video and direct laryngoscopy. Twenty-nine participants responded (18 paramedics, 11 nurses) and referred to 119 total intubations, of which 15 were completed with direct and 104 with video laryngoscopy. Most operators reported that they preferred video to direct laryngoscopy and this guide their choice but they also considered the patient condition. Participants favouring direct laryngoscopy reported higher first-pass intubation success rate compared to those favouring video laryngoscopy, but this finding should be seen in the context of retrospective reporting from a sample that may not be representative.

Steel et al. (2021) evaluated the impact of video laryngoscopy introduction for a doctor-paramedic team in an air ambulance service in the east of England. They also explored the views of the team members regarding the video laryngoscopy introduction via an online survey. The participants reported what they liked and disliked the most about the video laryngoscopy introduction. The dominant themes regarding positive of video laryngoscopy were situational awareness, improved teamwork and improved glottic view. The dominant themes regarding negatives of video laryngoscopy were poor performance in bright ambient light and challenges of passing the trachea regardless of the glottic view. 95% of the participants reported their preference to maintain the use of video laryngoscopy in the service.

Experts working within EMRTS reported that drug assisted intubations occur approximately 150 to 200 times yearly. They also suggested that there is a common subjective view that using video laryngoscopes is preferable to direct laryngoscope as it is easy to use. There is also a subjective perception that use of video laryngoscopes increases the likelihood of intubation success. This is in line with the findings from the qualitative studies (Lenz et al. 2020, Steel et al. 2021) described above, but contrasts with findings from randomised controlled trials where there is uncertainty about whether this is the case.

Experts working within WAST reported that some ambulance services in England (e.g., London, West Midlands) have withdrawn intubation from paramedic practices. Experts highlighted that there are no current plans for WAST to adapt this, but it might be resource waste in case intubations delivered by paramedics is withdrawn in Wales.

Experts reported that both EMRTS and WAST undertake pre-hospital intubation training, however the training varies in terms of structure and duration. EMRTs is formed by doctors and intubations are delivered via general anaesthesia, which is a skill developed in the hospital practise over many years. WAST is formed by paramedics who mostly complete simulation-based training followed by a hospital operating theatre placement to consolidate these skills intubating approximately 25 patients under direct supervision. Some experts suggested that video laryngoscopy should be used for doctors and experienced paramedics only, as they have undertaken the appropriate training and gained skills. Others suggested that video laryngoscopy training should be offered to any professional who is trained to intubate if this can be supported by frequent practice. They have also highlighted that paramedics, who have less intubation experience, might require more time and simulation-based practice for video laryngoscopy training.

7. Patient issues

The HTW public and patient involvement (PPI) standing group assessed that given the nature of major trauma and the necessity of intubation if it is indicated, there would not be value in approaching patient groups for input.

Our literature search did not identify any studies on patient issues and patient experience and in line with the view of the PPI standing group. It appears unlikely that this type of evidence would be available.

8. Conclusions

The aim of this rapid review was to examine the clinical and cost effectiveness of intubation using video laryngoscopy for people who require airway management in pre-hospital settings. Evidence is available from a recent systematic review and meta-analysis and several RCTs, which have been published since this review.

The overall evidence suggests that use of video laryngoscopes compared to direct laryngoscopes does not lead to improvements in first-pass intubation success or overall intubation success and some studies suggest that video laryngoscope may lead to worse outcomes than direct laryngoscopes. Evidence is mixed on whether use of video laryngoscopes improves time to intubation, with several studies suggesting no difference and a single study suggesting video may be quicker. In the study where video does appear to deliver improved intubation time, the difference is minimal and is unlikely to be clinically meaningful considering the time needed to wait for emergency medical service attendance.

There is some evidence that findings for intubation success may differ according to whether video laryngoscopes are used with populations requiring intubation due to out-of-hospital cardiac arrest and populations requiring intubation after major trauma, with more promise for video laryngoscopes in the latter group. This finding should be interpreted with due caution as sub-group analyses relied on studies where one population was predominant but data was aggregated with patients with other indication. Further, only one study that had a predominant population of major trauma was available and several studies were excluded due to the more balanced nature of their populations. Use of individual-level meta-analysis with data from across these studies may help clarify this issue but was not feasible in the context of rapid review.

There is evidence that use of video laryngoscope leads to an improved view of the glottis during intubation and this may explain qualitative evidence and expert opinion that suggests professionals have a preference for video laryngoscopes. However, this improved view may be counterbalanced for some devices by higher potential for technical problems, including fogging of the camera and the need for the specific ambient light. In addition, evidence suggests that improved view does not lead to changes in professionals' perceived difficulty of intubation.

The economic analysis suggests that video laryngoscopes are considerably more expensive than direct laryngoscopes. Overall, the clinical effectiveness evidence suggests there is no relative benefit associated with the use of video laryngoscopes. Cost minimisation analysis suggests that video laryngoscopes are not a cost-effective intervention. Clinical evidence suggests that there may be potential for video laryngoscopes in population requiring intubation after major trauma. The budget impact modelling scenario where video laryngoscopes are only used in EMRTS show that video laryngoscopes would remain more expensive, but the additional expense would be lower than the routine adoption case.

9. Contributors

This topic was proposed by Welsh Ambulance Services NHS Trust.

The HTW staff and contract researchers involved in writing this report were:

- A Evans, PPI Officer - PPI lead
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- E Glarou, Health Services Researcher – clinical author
- E Hasler, Information Specialist – literature searches & information management
- G Hopkin, Senior Health Services Researcher – clinical author
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- K McDermott, Project Manager – project management
- M Prettyjohns, Principal Researcher – quality assurance
- T Winfield, Senior Health Economist – economic author

The HTW Assessment Group advised on methodology throughout the scoping and development of the report.

A range of clinical experts from the UK provided material and commented on a draft of this report. Their views were documented and have been actioned accordingly. All contributions from reviewers were considered by HTW's Assessment Group. However, reviewers had no role in authorship or editorial control, and the views expressed are those of Health Technology Wales.

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11. Evidence review methods

We searched for evidence that could be used to answer the review question: What is the clinical and cost effectiveness of intubation using video laryngoscopy for people who require airway management in pre-hospital settings?

A systematic literature search for evidence was undertaken and was last updated on the 28th of January 2022. Appendix 2 gives details of the search strategy used for MEDLINE. Search strategies for other databases are available on request. The criteria used to select evidence for the appraisal are outlined in the protocol in Appendix 1. These criteria were developed in agreement with the HTW Assessment Group and UK experts.

After the search was conducted, it was clear that there were several systematic reviews, as well as primary studies, comparing direct and video laryngoscopy in the pre-hospital setting. In line with the priority of evidence outlined in the protocol (Appendix 1), the most recent systematic review and meta-analysis focusing exclusively on the pre-hospital setting was selected for inclusion. RCTs that were published since this latest search in this review were also included. Due to the presence of higher priority evidence, observational and non-randomised studies were not included. Appendix 3 summarises the selection of articles for inclusion in the review. A single reviewer screened studies and extracted data from relevant sources. Where there was uncertainty around eligibility for inclusion, studies were discussed with a second reviewer. A formal quality assessment was not conducted but the strengths and weaknesses of evidence are considered throughout.

For the purposes of the meta-analysis and sub-group analysis by population, we combined individual study data for overall and first-pass intubation rates across six RCT and four RCTs studies respectively. The same method followed for both meta-analysis and sub-group analysis by population. Specifically, we used Mantel-Haenszel models for all dichotomous outcomes. A random effects model was used to analyse the pooled data. The results are presented as risk ratios with 95%CI for all outcomes using the Review Manager (RevMan) software for Windows (version 5.4.1, Cochrane Collaboration, 2020). We assessed the statistical heterogeneity using the I^2 methodology. I^2 values >50% were considered to indicate moderate heterogeneity and >75% considerable heterogeneity among the studies (Higgins et al. 2021).

Appendix 1. Inclusion and exclusion criteria for evidence included in the review

	Inclusion criteria	Exclusion criteria
Population	People who require airway management via endotracheal intubation in pre-hospital settings	Manikin, cadaver and simulation studies
Intervention	Intubation using video laryngoscopy (e.g., Airtraq, AP Venerscope, C-MAC, Glidescope, King Vision, McGrath MAC, McGrath series 5, Pentax-Airway Scope, TruView PCD, TruView PCD-R, V-MAC)	Alternative methods for airway visualization (i.e., basic airway adjuncts, supra-glottic devices and surgical airway)
Comparison/ Comparators	Usual care (anticipated to include intubation using direct laryngoscopy, such as the Miller, Macintosh or the McCoy laryngoscopes)	Alternative methods for airway visualization (i.e., basic airway adjuncts, supra-glottic devices and surgical airway)
Outcome measures	Clinical outcomes (e.g., intubation success rate, time to intubation, incidence of difficult intubation, mortality, adverse events) Patient-reported outcomes (e.g., health-related quality of life, patient satisfaction) Healthcare utilisation and economic outcomes (e.g., intervention delivery, type of admission, length of stay, cost-effectiveness)	
Study design	The following study types were prioritised, in the order listed: • Systematic reviews • Randomised controlled trials • Non-randomised controlled trials • Single-arm trials We will only include evidence for "lower priority" evidence where outcomes for each condition/symptom of interest are not reported by a "higher priority" source or where "lower priority" evidence relates to an intervention assessed to be of high potential. • We will also search for economic evaluations or original research that can form the basis of an assessment of costs/cost comparison and for qualitative studies that provide information on patient or organisational issues.	
Search limits	None	
Language limits	English language only.	
Sub-group analysis	Where evidence allows, we will report outcomes separately according to: • Age (i.e., children and/or adolescents, adults) • Professional background of operator (i.e., doctor, paramedics) • Use by ground and air ambulances Training and expertise in use of intubation have been highlighted as important. These were not considered appropriate as sub-groups but information on these issues will be reported for relevant studies	

Appendix 2. MEDLINE search strategy

Ovid MEDLINE(R) ALL 1946 to January 27, 2022		
1	exp *Intubation, Intratracheal/	26683
2	intubat*.ti.	17835
3	intubat*.ab. /freq=2	21020
4	or/1-3	43669
5	*Laryngoscopy/	5352
6	*Laryngoscopes/	2911
7	laryngoscop*.ti.	4179
8	laryngoscop*.ab. /freq=2	4340
9	exp *Video Recording/	12692
10	exp *Video-Assisted Surgery/	6884
11	(video* or digital* or indirect* or optic or optical).ti.	243710
12	(video* or digital* or indirect* or optic or optical).ab. /freq=2	245841
13	(5 or 6 or 7 or 8) and (9 or 10 or 11 or 12)	2545
14	((video* or digital* or indirect* or optic or optical) adj3 laryngoscop*).tw.	2395
15	videolaryngoscop*.tw.	1339
16	(airwayscope or airway scope).tw.	296
17	(Airtraq* or Bullard* or Pentax or Glidescope* or McGrath* or Storz* or Venner* or King Vision* or Vividtrac* or CoPilot VL* or UEScope or TruView* or C-MAC* or CTrach*).tw,kw.	4534
18	or/13-17	7440
19	4 and 18	2767
20	((video assisted or indirect) adj3 (intubating or intubation)).tw.	90
21	19 or 20	2797
22	limit 21 to english language	2488
23	exp animals/ not exp humans/	4949774
24	22 not 23	2479

Appendix 3. Flow diagram outlining selection of relevant evidence source