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Systematic review/Meta-analysis

SYSTEMATIC REVIEW/META-ANALYSIS

Airway management of adult epiglottitis: a systematic review and meta-analysis

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Abstract

Background: Adult epiglottitis is a life-threatening airway emergency where airway protection is the immediate priority. Despite its importance, the optimal approach to airway management remains unclear. We performed a systematic review of the airway management for adult epiglottitis, including meta-analysis of trends over time.

Methods: We systematically searched PubMed, Ovid MEDLINE®, and Embase® for adult epiglottitis studies that described the airway management between 1980 and 2020. The primary outcome was the prevalence of airway intervention. Secondary outcomes were prevalence of tracheal intubation, tracheostomy, and failed intubation. A random-effects model meta-analysis was performed with subgroups defined by decade of study publication. Cases that described the specific method of airway intervention and severity of epiglottitis were included in a separate technique summary.

Results: Fifty-six studies with 10 630 patients were included in the meta-analysis. The overall rate of airway intervention was 15.6% (95% confidence interval [CI] 12.9–18.8%) but the rate decreased from 20% to 10% between 1980 and 2020. The overall rate of tracheal intubation was 10.2% (95% CI 7.1–13.6%) and that of failed intubation was 4.2% (95% CI 1.4–8.0%). The airway technique summary included 128 cases, of which 75 (58.6%) were performed awake and 53 (41.4%) involved general anaesthesia. We identified 32 cases of primary technique failure.

Conclusion: The rate of airway intervention for adult epiglottitis has decreased over four decades to a current level of 10%. Tracheal intubation is a high-risk scenario with a 1 in 25 failure rate. Specific technique selection is most likely influenced by contextual factors including the severity of epiglottitis.

Keywords: adult epiglottitis; airway intervention; epiglottitis; intubation; tracheostomy

Acute epiglottitis is characterised by localised cellulitis and oedema of the supraglottic structures, in particular the epiglottis.[1–3] Progressive airway obstruction represents a life-threatening emergency with potential for catastrophic outcomes.[3–5] Airway protection is the immediate management priority.[6–8] Epiglottitis was predominantly an infectious disease of childhood, caused by *Haemophilus Influenzae* type B (HIB). However, since the introduction of the Haemophilus vaccine in 1985 the epidemiology has changed.[4,9] It is now three times more common in adults with an annual incidence of 3 per 100 000 and ongoing mortality of ~1%.[6,7,10,11]

The presentation and management of epiglottitis is different in adults compared with children.[4,11] In children, inflammation is localised to the epiglottis and has a classic acute presentation.[11,12] Emergent tracheal intubation with general anaesthesia in the operating theatre is standard.[11] In adults, the inflammation affects the surrounding supraglottic structures and is often referred to as supraglottitis.[6,11] The presentation is subacute with nonspecific features and disease

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progression is often unpredictable.[5,7,9,12,13] In adults, there is no consensus about the optimal method or timing of airway intervention, which creates several dilemmas.[7,12–14] In less severe cases, adults can be managed conservatively, but fulminant epiglottitis can lead to rapid and fatal airway obstruction.[7,11,13,14] Airway technique selection is controversial because of the risk of precipitating complete airway obstruction.[3,15]

A recent systematic review and meta-analysis found that the rate of airway intervention in adult epiglottitis decreased from 18.8% to 10.9% after HIB vaccine introduction.[16] However, airway equipment and techniques have undergone significant advances since the vaccine was introduced.[17] It is unclear how the rate and type of airway intervention has changed over this time.[9,12] The evidence to guide optimal airway management for this high-risk disease remains limited.[4,8]

We performed a systematic review and meta-analysis of trends over time to determine how the airway management for adult epiglottitis has changed since introduction of the HIB vaccine. Our primary outcome was the rate of airway intervention. A secondary aim was to determine if an optimal airway management technique exists.

Methods

This systematic review and meta-analysis evolved from a structured narrative review of the same topic, which was submitted to the *British Journal of Anaesthesia* (BJA) in October 2020 but not accepted for publication. We performed a systematic review and meta-analysis based on feedback from the BJA submission. A timeline for the evolution of this work is outlined as follows. A protocol for the initial narrative review was developed in July 2018. A structured literature search was completed in April 2019, which resulted in the selection of 124 titles containing 10 308 cases for review. Data from these studies were extracted and collated into a Microsoft Excel spreadsheet. The systematic review and meta-analysis process commenced in February 2021. The protocol was written in July 2021 and the search was performed on 24 July 2021. Data extraction commenced in August 2021 and was incorporated with data from the previous excel spreadsheet. Data synthesis commenced in September 2021. The protocol was amended in November 2021 to omit mortality from meta-analysis. Mortality was a very rare outcome (<30% of studies reported mortality, of which most were from early decades) and identified as a source of bias for pooled estimates with limited accuracy. We were unable to register this systematic review with PROSPERO, because data extraction had already commenced with the previous structured review (a PROSPERO requirement from 2019).

Search strategy

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Supplementary Fig. S1).[18] Three separate databases were used in the search to identify relevant studies: PubMed, Ovid MEDLINE®, and Embase®. Search terms included 'epiglottitis' or 'supraglottitis' or 'epiglottic abscess' or 'adult epiglottitis' and 'Airway Management' and 'adult'. The reference sections of the selected articles were also manually searched for additional studies. The protocol, amended protocol, search strategy, and PRISMA checklist are provided in Supplementary Content S1.

Study selection

The inclusion criteria for study selection were as follows:

- Adult patients with epiglottitis or supraglottitis (infectious or non-infectious)
- Airway management described
- Studies published between 1 January 1980 and 31 December 2019
- Full text published in English language.

We did not use a particular age that defined adults for inclusion in the review. Articles were included if the original study authors defined their patients as adults. Although the majority of included studies defined adults as 18 or 20 yr old, six included patients younger than 18 yr. Two included 15 yr or older,[19,20] two included 16 yr or older,[21,22] and two included 17 yr or older.[23,24]

Articles were excluded if: (i) a mixed paediatric and adult population could not be distinguished, (ii) the airway management was not defined, or (iii) the study was deemed to be a duplicate by using the same data set as another case series.

Data extraction

Titles and abstracts of articles were screened and, after this, all eligible articles were individually evaluated by two reviewers (KP and AB). Any discrepancy between the reviewers was resolved by discussion, with any remaining disagreement resolved by a third reviewer (KV). If further details were required, article authors were contacted by email for clarification. The selected articles were reviewed, and outcome data were extracted and entered into a Microsoft Excel spreadsheet.

The primary outcome was the rate of airway intervention in patients with adult epiglottitis. Secondary outcomes included the proportion of patients receiving tracheal intubation or tracheostomy and the proportion of failed tracheal intubations.

Studies were considered for meta-analysis of the primary and secondary outcomes if complete denominator data were reported. Specifically, this required every consecutive case of epiglottitis to be documented during the article's reporting period. A study article was excluded from meta-analysis if the number of reported cases was incomplete for the defined study period.

Quality assessment

A modified version of the Joanna Briggs Institute (JBI) critical appraisal tool (JBI Critical Appraisal checklist for studies reporting prevalence data) was used to assess the quality of included studies (Supplementary Table S1).[25] The JBI checklist for prevalence studies is a nine-point scale used to assess the methodological quality of a study and to determine the possibility of bias in its design, conduct, and analysis. Publications with JBI critical appraisal scores greater than and including seven were included in the meta-analysis.

A sample size of $n=70$ was used to assess sample size adequacy of included studies as per the JBI criteria; determined by the sample size required to estimate an airway intervention rate of 20% with a two-sided 95% confidence interval (CI) width equal to 20%.

Meta-analysis

Meta-analysis was performed using a random effects model with DerSimonian and Laird weights to calculate the pooled prevalence with exact 95% CI. Raw proportions were transformed using the Freeman–Tukey double arcsine transformation (FTT); allowing appropriate use of normal approximation procedures for rate estimates close to 0% and used to stabilise the variance. Potential changes in outcome estimates over time were evaluated as a source of heterogeneity, with subgroups defined by decade of study publication. Heterogeneity was measured using the I^2 index; estimated by an inverse variance fixed-effect model. Small study effects (publication bias) were assessed using funnel plots and Egger's test for asymmetry. Meta-regression to further assess for temporal trends in the proportion of airway intervention, intubation, and failed intubation were run using publication date as a continuous covariate, with the start year and end year of data included in each publication run separately as a sensitivity analysis. Meta-analysis was performed in Stata (Version 15) using Metaprop.[26]

Airway techniques

Cases from cohort studies or case reports that described the specific method of airway intervention and severity of epiglottitis were included in a summary of airway techniques. Cases were only included in this airway technique summary when these two criteria were clearly reported or identified. Airway technique data included: severity, the primary technique of airway intervention and its success or failure, any secondary (or subsequent) airway intervention technique and its success or failure, the location where the airway intervention occurred, major morbidity and mortality.

Airway techniques were classified into two main groups, based on the 2013 American Society of Anesthesiologists (ASA) Difficult Airway Practice Guidelines[27]: (i) awake intubation (invasive or noninvasive) or (ii) intubation after the induction of general anaesthesia (spontaneous respiration preserved or ablated). If cases described airway intervention occurring in an unconscious patient (such as cardiopulmonary arrest) without the administration of any anaesthetic agents, they were included in the awake intubation group.

The severity of epiglottitis was staged according to the Friedman criteria for adult epiglottitis using the available clinical details (Supplementary Table S2).[2] If cases required airway intervention after the failure of initial conservative airway management, they were staged using the Friedman criteria according to their clinical status at the time of the airway intervention.

Cases were excluded from the airway technique summary if: (i) no airway intervention was required, (ii) the airway management technique was inadequately described, or (iii) insufficient clinical details prevented staging with the Friedman classification.

Results

The search strategy was performed on 24 July 2021 and found 1834 articles (582 Pubmed, 529 Medline, 723 Embase). There were 984 duplicates, which resulted in 850 titles to be screened. After exclusion by title or abstract of 366 articles, 484 full text articles were reviewed. Thirty titles could not be accessed, and 306 titles were excluded, which resulted in 148 titles meeting the inclusion criteria. Fourteen titles were added after manual search, which resulted in 162 titles included for analysis (Supplementary Fig. S1). All were retrospective cohort studies or case reports, apart from one prospective series. There were no randomised controlled trials identified.

Meta-analysis

There were 61 cohort studies selected for potential inclusion in the meta-analysis. After JBI assessment, five were excluded for low quality (score <7) (Supplementary Table S1).[19,28–31] This left 56 studies that reported the rate of airway intervention in a total of 10 630 patients, which were included in the meta-analysis. Characteristics of included trials are provided in Table 1. Geographically, most studies were North American (n=21), Asian (n=14), or Nordic (n=9).

The overall pooled rate of airway intervention was 15.7% (95% CI 12.9–18.8%), I^2=89.1% (Fig 1). The mean of the effect sizes for each decade were: 20.0% (95% CI 11.7–29.8%) for 1980, 18.7% (95% CI 14.0–23.7%) for 1990, 16.4% (95% CI 11.1–22.5%) for 2000, and 10.6% (95% CI 6.9–15.0%) for 2010. Tests of heterogeneity between groups indicated differences in rate across publication decades (Q [3 degrees of freedom, df]=9.3, P=0.026), with meta-regression (using publication year as the time covariate) suggestive of some evidence of a linear decrease over time on the FTT scale (slope: −0.004 [95% CI −0.008 to 0.000], P=0.050) (Supplementary Table S3, Supplementary Fig. S2). Sensitivity analysis using alternative time covariates of start and end years of patient data included in studies further supported this trend (Supplementary Table S3).

Review of the funnel plot (Supplementary Fig. S3) and Egger's test of asymmetry (Supplementary Table S4) suggested evidence of small study bias for studies reporting airway intervention (intercept=1.21 [95% CI −0.01 to 2.41], t=2.03, P=0.048). Small studies (defined as n<70 for JBI criteria) were noted across all publication decades. The 2010 decade contained only one (8%) small study. However, small studies made up >70% of the other decades. After sensitivity analysis, excluding small studies, the overall pooled rate of airway intervention and heterogeneity remained similar to the main analysis (13.4% [95% CI 10.0–17.1%], I^2=93.3%). The trend over publication decades and heterogeneity between groups (Q [3 df]=11.1, P=0.011) also persisted when small studies were excluded (Supplementary Fig. S4). Although the pooled estimates varied between analyses, trends over publication decades for airway intervention remained similar when small studies were excluded, and because small studies comprised the majority of studies, they were included in analyses.

The overall pooled rate of intubation was 10.2% (95% CI 7.1–13.6%), I^2=94.0% (Fig. 2). Tests of heterogeneity between groups (Q [3 df]=7.9, P=0.047) suggest some evidence of differences between the decade subgroups, with the following mean of the effect sizes for each decade: 8.1% (95% CI 2.7–15.3%) for 1980, 13.3% (95% CI 8.6–18.7%) for 1990, 13.5% (95% CI 6.7–21.9%) for 2000, and 5.9% (95% CI 2.6–10.3%) for 2010. However, results of meta-regression did not suggest evidence of a linear trend in intubation proportion over time (FTT transformed slope: −0.002 [95% CI −0.007 to 0.004], P=0.56) (Supplementary Table S3).

The overall pooled rate of failed intubation was 4.2% (95% CI 1.4–8.0%), I^2=0.0%, calculated from a total of 346 patients in

Table 1 Basic characteristics of studies included for meta-analysis.

First author, year of publication	Country	Year of study start and finish	Study type	Number of patients	Number of airway interventions	Number of intubations	Number of failed intubations	Total number of tracheostomies	Number of deaths
Mustoe,[32] 1983	USA	1965–1981	Retrospective	75	6	0		6	0
Deeb,[33] 1985	USA	1975–1982	Retrospective	80	24	4	0	20	0
Stair,[34] 1985	USA	1974–1983	Retrospective	20	6	2	1	5	1
Mayo-Smith,[35] 1986	USA	1975–1982	Retrospective	56	13	6	1	8	4
Arndal,[20] 1988	Denmark	1974–1985	Retrospective	49	3	3	0	0	0
Murrage,[36] 1988	Canada	1976–1986	Retrospective	26	11	10	0	1	0
Shih,[37] 1988	USA	1963–1987	Retrospective	48	23	2	0	21	1
Stanley,[38] 1988	Singapore	1982–1985	Retrospective	42	2	1	0	1	0
Fontanarosa,[39] 1989	USA	1982–1988	Retrospective	28	2	2	0	0	0
Sheikh,[40] 1989	USA	1983–1985	Retrospective	9	4	4	0	0	0
Carenfelt,[41] 1989	Sweden	1975–1987	Retrospective	138	18	n/a	n/a	n/a	0
Wolf,[21] 1990	Israel	1978–1987	Retrospective	30	0	0	0	0	0
Crosby,[42] 1991	Canada	1983–1989	Retrospective	21	3	3	1	1	0
Andreassen,[43] 1992	Denmark	1965–1991	Retrospective	168	39	37	3	5	2
Ryan,[44] 1992	USA	1979–1991	Retrospective	8	0	0		0	0
Barrow,[23] 1993	USA	1984–1992	Retrospective	46	7	0	0	7	0
Kass,[14] 1993	USA	1987–1990	Retrospective	17	2	2	0	0	0
Dort,[45] 1994	Canada	1982–1992	Retrospective	43	15	15	0	0	1
Frantz,[6] 1994	USA	1986–1991	Retrospective	129	19	12		7	0
Torkkeli,[46] 1994	Finland	1981–1992	Retrospective	32	5	5	0	0	
Berg,[47] 1996	Sweden	1987–1989	Retrospective	502	114	102		12	12
Kucera,[48] 1996	USA	1976–1990	Retrospective	21	5	2	1	4	1
Hebert,[49] 1998	Canada	1989–1994	Retrospective	51	10	10	0	0	0
Park,[50] 1998	USA	1984–1995	Retrospective	35	11	10	1	1	0
Solomon,[51] 1998	Canada	1979–1991	Retrospective	57	9	8	1	1	0
Alho,[52] 1999	Finland	1967–1993	Retrospective	49	19	8	2	12	0
Rizk,[53] 2000	USA	1987–1997	Retrospective	23	2	2	0	0	0
Chan,[54] 2001	Singapore	1992–1999	Retrospective	31	11	10	1	2	1
Nakamura,[24] 2001	Japan	1995–1999	Retrospective	80	5	0		5	1
Wong,[55] 2001	Australia	1988–2000	Retrospective	17	4	4	0	0	0
Wick,[56] 2002	Switzerland	1996–1998	Retrospective	12	5	5	1	0	1
Berger,[7] 2003	Israel	1986–2000	Retrospective	118	25	25	4	4	0
Madhotra,[57] 2004	UK	1988–2000	Retrospective	23	3	3	2	2	0
Chang,[22] 2005	Taiwan	1996–2003	Retrospective	46	4	2	0	2	0
Katori,[58] 2005	Japan	1992–2003	Retrospective	92	8	0	0	8	0
Price,[59] 2005	Canada	1999–2003	Retrospective	54	9	9	1	1	0
Hafidh,[60] 2006	Ireland	2004–2004	Retrospective	10	2	2	0	0	0
Ng,[61] 2008	Hong Kong	1999–2006	Retrospective	106	7	7	1	1	0
Berger,[62] 2008	Israel	1992–2004	Retrospective	24	7	7	1	1	0
Guldfred,[4] 2008	Denmark	1996–2005	Retrospective	34	10	10	1	1	0
Briem,[63] 2009	Iceland	1983–2005	Retrospective	41	4	4	0	0	0
Cheung,[64] 2009	Hong Kong	2000–2005	Retrospective	80	31	31	1	1	0
Qazi,[65] 2009	Kuwait	2000–2008	Retrospective	42	2	0	0	2	0
Sarkar,[66] 2009	India	2007–2007	Retrospective	12	2	2	0	0	0
Guardiani,[12] 2010	USA	1995–2005	Retrospective	60	13	12	1	2	0
Yoon,[67] 2010	South Korea	1997–2009	Retrospective	123	12	0	0	12	0

Continued

Table 1 Continued

First author, year of publication	Country	Year of study start and finish	Study type	Number of patients	Number of airway interventions	Number of intubations	Number of failed intubations	Total number of tracheostomies	Number of deaths
Bizaki,[68] 2011	Finland	1989–2009	Retrospective	308	45	29		16	2
Riffat,[69] 2011	Australia	1999–2009	Retrospective	169	20	16		4	0
Park,[70] 2012	South Korea	1998–2007	Retrospective	148	0	0	0	0	0
Lee,[71] 2013	South Korea	2006–2012	Prospective	202	3	0	0	3	
Ovnat,[72] 2015	Israel	1990–2013	Retrospective	288	19	19	2	2	1
Suzuki,[73] 2015	Japan	2011–2012	Retrospective	6072	573	106		467	27
Shimizu,[15] 2016	Japan	2004–2013	Retrospective	82	16	1	0	15	0
Shapira Galitz,[9] 2017	Israel	2000–2014	Retrospective	358	16	16	4	4	5
Baird,[74] 2018	Australia	2011–2016	Retrospective	87	24	24	3	3	0
Wu,[75] 2019	Taiwan	2010–2012	Retrospective	108	32	29		3	2

39 studies (Fig 3). In subgroup analysis by decade, the mean of the effect sizes for each decade were: 0.3% (95% CI 0.0–10.8%) for 1980, 3.7% (95% CI 0.0–11.3%) for 1990, 5.4% (95% CI 0.8–12.2%) for 2000, and 8.6% (95% CI 1.4–19.1%) for 2010. Tests of heterogeneity between groups (Q [3 df]=1.5, P=0.68) did not suggest evidence of differences between the decade subgroups and results of meta-regression did not suggest evidence of a linear trend in failed intubation proportion over time (FTT transformed slope: 0.003 [95% CI −0.008 to 0.014], P=0.59) (Supplementary Table S3).

Airway technique summary

There were 103 articles with 128 individual cases that described the method of airway management and severity of epiglottitis in sufficient detail for inclusion into the airway technique summary. Characteristics of included cases are provided in Supplementary Table S5. The maximum number of cases per article was five and 88 articles contained a single suitable case. Of these, 25 cases (19.5%) were classified as Friedman stage 2, 66 cases (51.5%) were stage 3, and 37 cases (29%) were stage 4.

Details of clinical presentation and progression, medical treatment, and the location of airway management were variably reported and summarised according to severity as follows:

(i) Friedman stage 2

Clinical progression was described in 21 of the 25 patients. A prodrome of upper respiratory symptoms was described in nine patients (range several hours to 1 week), with most (n=7) reporting an onset between 1 and 4 days. The most common location for airway intervention was an operating theatre (17 patients, 81%), followed by emergency department (two patients, 10%), intensive care unit (ICU) (one patient, 5%) and the ward (one patient, 5%). Five patients received both steroids and antibiotics, two patients received antibiotics only, three patients received nebulised adrenaline, and one received heliox (oxygen 20%/helium 80%). Rapid progression over several hours was described in two patients despite receiving medical therapy.

(ii) Friedman stage 3

Clinical progression was described in 55 of the 66 patients. A prodrome of minor upper respiratory symptoms was described in 21 patients (range several hours to 1 week). Symptom onset occurred in two main time periods before presentation, either several hours (n=6) or between 1 and 3 days (n=12). The most common location for airway intervention was an operating theatre (38 patients, 70%), followed by emergency department (12 patients, 22%), ICU (four patients, 7%) and the ward (one patient, 2%). Fifteen patients received both steroids and antibiotics, six patients received antibiotics only, and 12 patients received nebulised adrenaline. Rapid progression over several hours was described in 15 patients despite medical therapy. Two patients rapidly deteriorated during transfer to the operating theatre or ICU, of which one required immediate airway intervention.

(iii) Friedman stage 4

Clinical progression was described in all 37 patients. A prodrome of upper respiratory symptoms was described in

Study	Study length (yr)	AWI	Total	ES (95% CI)
1980				
Mustoe	16	6	75	8.0 (3.0–16.6)
Deeb	7	24	80	30.0 (20.3–41.3)
Stair	9	6	20	30.0 (11.9–54.3)
Mayo-Smith	7	13	56	23.2 (13.0–36.4)
Shih	24	23	48	47.9 (33.3–62.8)
Stanley	3	2	42	4.8 (0.6–16.2)
Arndal	11	3	49	6.1 (1.3–16.9)
Murrage	10	11	26	42.3 (23.4–63.1)
Carenfelt	12	18	138	13.0 (7.9–19.8)
Sheikh	2	4	9	44.4 (13.7–78.8)
Fontanarosa	6	2	28	7.1 (0.9–23.5)
Subtotal (I^2=84.5%, p=0.0)				20.0 (11.7–29.8)
1990				
Wolf	9	0	30	0.0 (0.0–11.6)
Crosby	6	3	21	14.3 (3.0–36.3)
Ryan	12	0	8	0.0 (0.0–36.9)
Andreassen	26	39	168	23.2 (17.1–30.3)
Kass	3	2	17	11.8 (1.5–36.4)
Barrow	8	7	46	15.2 (6.3–28.9)
Frantz	5	19	129	14.7 (9.1–22.0)
Dort	10	15	43	34.9 (21.0–50.9)
Torkkeli	11	5	32	15.6 (5.3–32.8)
Berg96	2	114	502	22.7 (19.1–26.6)
Kucera	14	5	21	23.8 (8.2–47.2)
Hebert	5	10	51	19.6 (9.8–33.1)
Park98	11	11	35	31.4 (16.9–49.3)
Solomon	12	9	57	15.8 (7.5–27.9)
Alho	26	19	49	38.8 (25.2–53.8)
Subtotal (I^2=67.9%, p=0.0)				18.7 (14.0–23.7)
2000				
Rizk	10	2	23	8.7 (1.1–28.0)
Chan	7	11	31	35.5 (19.2–54.6)
Nakamura	4	5	80	6.3 (2.1–14.0)
Wong	12	4	17	23.5 (6.8–49.9)
Wick	2	5	12	41.7 (15.2–72.3)
Berger03	14	25	118	21.2 (14.2–29.7)
Madhotra	12	3	23	13.0 (2.8–33.6)
Price	4	9	54	16.7 (7.9–29.3)
Chang	7	4	46	8.7 (2.4–20.8)
Katori	11	8	92	8.7 (3.8–16.4)
Hafidh	0	2	10	20.0 (2.5–55.6)
Ng	7	7	106	6.6 (2.7–13.1)
Guldfred	9	10	34	29.4 (15.1–47.5)
Berger08	12	7	24	29.2 (12.6–51.1)
Cheung	5	31	80	38.8 (28.1–50.3)
Sarkar	0	2	12	16.7 (2.1–48.4)
Briem	22	4	41	9.8 (2.7–23.1)
Qazi	8	2	42	4.8 (0.6–16.2)
Subtotal (I^2=76.3%, p=0.0)				16.4 (11.1–22.5)
2010				
Guardiani	10	13	60	21.7 (12.1–34.2)
Yoon	12	12	123	9.8 (5.1–16.4)
Riffat	10	20	169	11.8 (7.4–17.7)
Bizaki	20	45	308	14.6 (10.9–19.1)
Park12	9	0	148	0.0 (0.0–2.5)
Lee	6	3	202	1.5 (0.3–4.3)
Suzuki	1	573	6072	9.4 (8.7–10.2)
Ovnat	23	19	288	6.6 (4.0–10.1)
Shimizu	9	16	82	19.5 (11.6–29.7)
Galitz	14	16	358	4.5 (2.6–7.2)
Baird	5	24	87	27.6 (18.5–38.2)
Wu	2	32	108	29.6 (21.2–39.2)
Subtotal (I^2=93.2%, p=0.0)				10.6 (6.9–15.0)
Heterogeneity between groups: p=0.026				
Overall (I^2=89.1%, p=0.0);				15.7 (12.9–18.8)

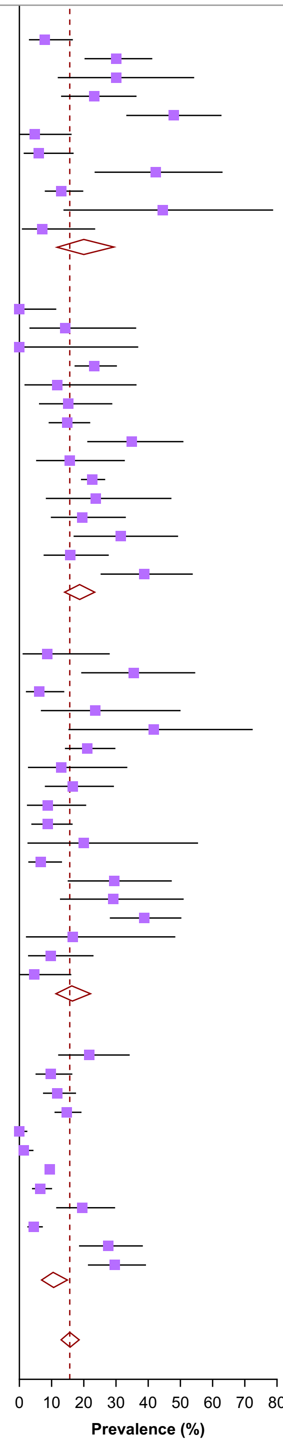

Fig 1. Meta-analysis of the rate of airway intervention with subgroups defined by decade of study publication. AWI, airway intervention; CI, confidence interval; ES, effect size.

Study	Study length (yr)	Intubation	Total	ES (95% CI)
1980				
Mustoe	16	0	75	0.0 (0.0–4.8)
Stair	9	2	20	10.0 (1.2–31.7)
Deeb	7	4	80	5.0 (1.4–12.3)
Mayo-Smith	7	6	56	10.7 (4.0–21.9)
Murrage	10	10	26	38.5 (20.2–59.4)
Stanley	3	1	42	2.4 (0.1–12.6)
Shih	24	2	48	4.2 (0.5–14.3)
Arndal	11	3	49	6.1 (1.3–16.9)
Sheikh	2	4	9	44.4 (13.7–78.8)
Fontanarosa	6	2	28	7.1 (0.9–23.5)
Subtotal (I^2=79.0%, p=0.0)				8.1 (2.7–15.3)
1990				
Wolf	9	0	30	0.0 (0.0–11.6)
Crosby	6	3	21	14.3 (3.0–36.3)
Ryan	12	0	8	0.0 (0.0–36.9)
Andreassen	26	37	168	22.0 (16.0–29.1)
Kass	3	2	17	11.8 (1.5–36.4)
Barrow	8	0	46	0.0 (0.0–7.7)
Torkkeli	11	5	32	15.6 (5.3–32.8)
Dort	10	15	43	34.9 (21.0–50.9)
Frantz	5	12	129	9.3 (4.9–15.7)
Kucera	14	2	21	9.5 (1.2–30.4)
Berg96	2	102	502	20.3 (16.9–24.1)
Park98	11	10	35	28.6 (14.6–46.3)
Hebert	5	10	51	19.6 (9.8–33.1)
Solomon	12	8	57	14.0 (6.3–25.8)
Alho	26	8	49	16.3 (7.3–29.7)
Subtotal (I^2=78.1%, p=0.0)				13.3 (8.6–18.7)
2000				
Rizk	10	2	23	8.7 (1.1–28.0)
Wong	12	4	17	23.5 (6.8–49.9)
Chan	7	10	31	32.3 (16.7–51.4)
Nakamura	4	0	80	0.0 (0.0–4.5)
Wick	2	5	12	41.7 (15.2–72.3)
Berger03	14	25	118	21.2 (14.2–29.7)
Madhotra	12	3	23	13.0 (2.8–33.6)
Chang	7	2	46	4.3 (0.5–14.8)
Price	4	9	54	16.7 (7.9–29.3)
Katori	11	0	92	0.0 (0.0–3.9)
Hafidh	0	2	10	20.0 (2.5–55.6)
Berger08	12	7	24	29.2 (12.6–51.1)
Guldfred	9	10	34	29.4 (15.1–47.5)
Ng	7	7	106	6.6 (2.7–13.1)
Sarkar	0	2	12	16.7 (2.1–48.4)
Briem	22	4	41	9.8 (2.7–23.1)
Qazi	8	0	42	0.0 (0.0–8.4)
Cheung	5	31	80	38.8 (28.1–50.3)
Subtotal (I^2=88.9%, p=0.0)				13.5 (6.7–21.9)
2010				
Guardiani	10	12	60	20.0 (10.8–32.3)
Yoon	12	0	123	0.0 (0.0–3.0)
Riffat	10	16	169	9.5 (5.5–14.9)
Bizaki	20	29	308	9.4 (6.4–13.2)
Park12	9	0	148	0.0 (0.0–2.5)
Lee	6	0	202	0.0 (0.0–1.8)
Ovnat	23	19	288	6.6 (4.0–10.1)
Suzuki	1	106	6072	1.7 (1.4–2.1)
Shimizu	9	1	82	1.2 (0.0–6.6)
Galitz	14	16	358	4.5 (2.6–7.2)
Baird	5	24	87	27.6 (18.5–38.2)
Wu	2	29	108	26.9 (18.8–36.2)
Subtotal (I^2=95.6%, p=0.0)				5.9 (2.6–10.3)
Heterogeneity between groups: p=0.047				
Overall (I^2=94.0%, p=0.0);				10.2 (7.1–13.6)

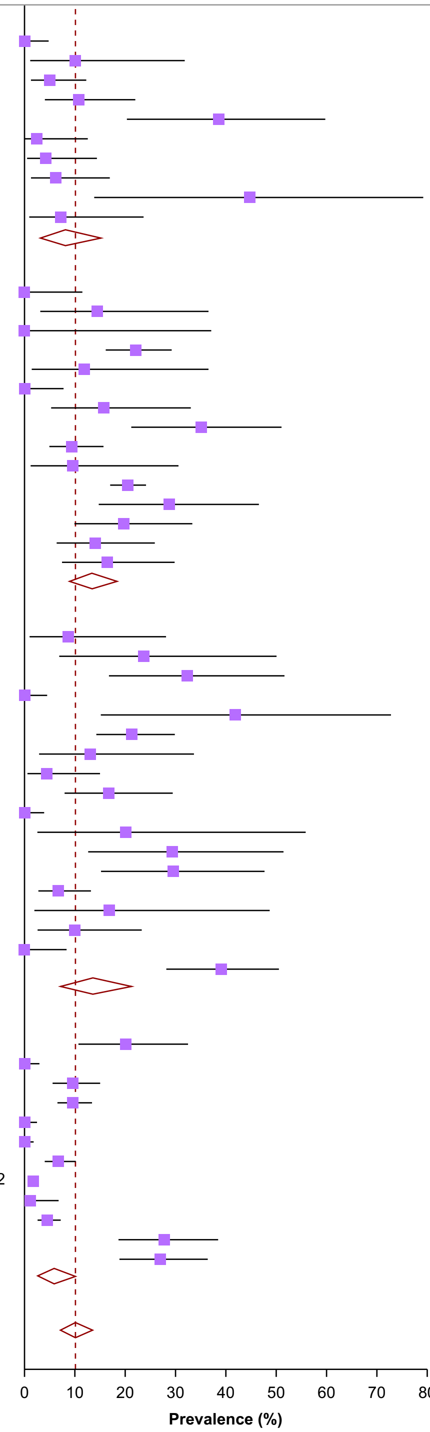

Fig 2. Meta-analysis of the rate of tracheal intubation with subgroups defined by decade of study publication. CI, confidence interval; ES, effect size.

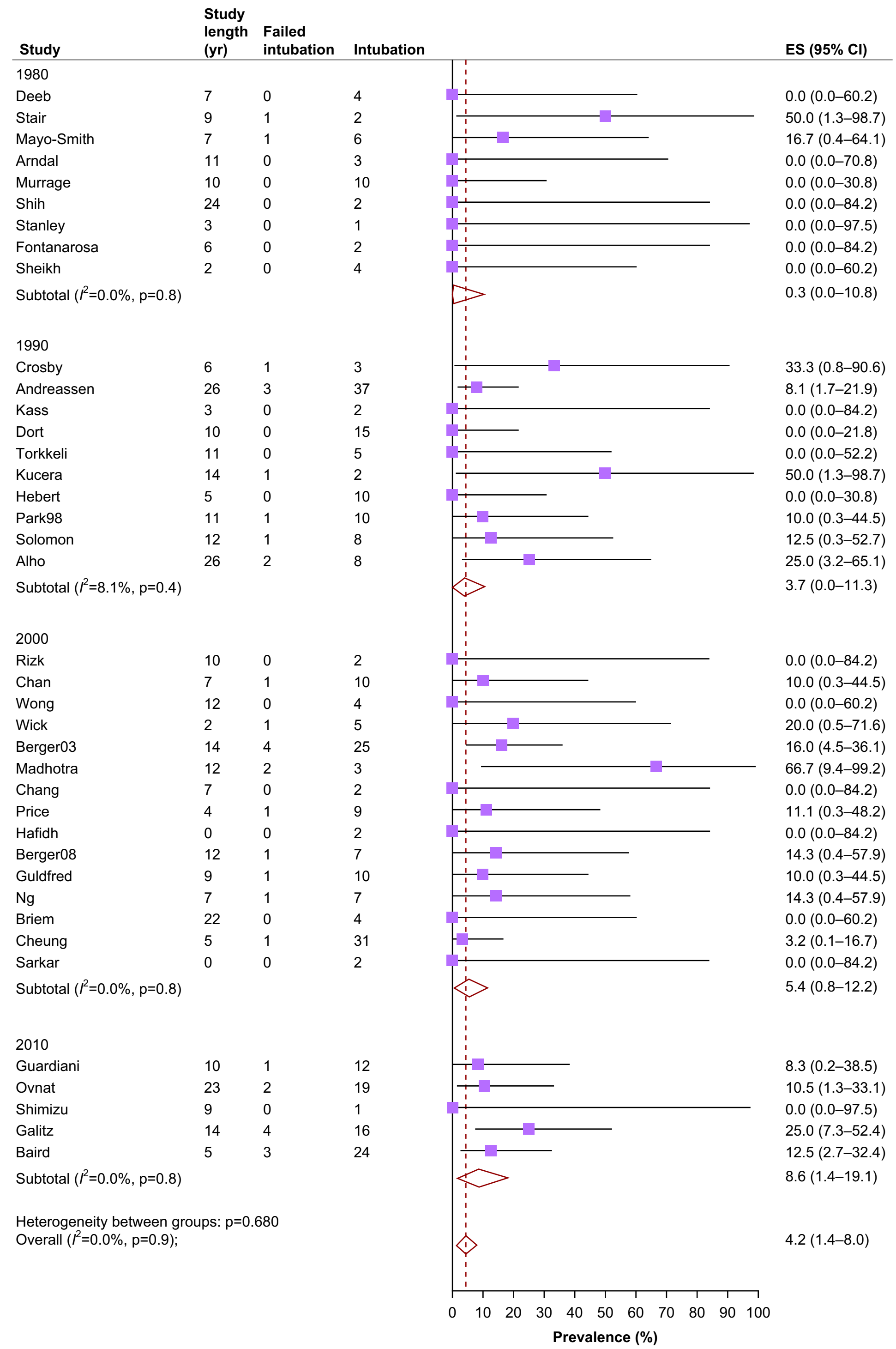

Fig 3. Meta-analysis of the rate of failed tracheal intubation with subgroups defined by decade of study publication. CI, confidence interval; ES, effect size.

20 patients (range 2 h to 6 weeks). Symptom onset occurred in two main time periods before presentation, either several hours (n=9) or between 1 and 4 days (n=9). The most common location for airway intervention was the emergency department (24 patients, 65%), followed by the ward (four patients, 11%), prehospital (three patients, 8%), operating theatre (three patients, 8%), and ICU (three patients, 8%). Eight patients received both steroids and

antibiotics, three patients received antibiotics only, and six patients received nebulised adrenaline. Rapid deterioration and progression to complete airway obstruction was commonly reported in the stage 4 patients in multiple clinical settings despite medical therapy. A total of 28 cases reported respiratory arrest, complete airway obstruction, or both. Of these, eight occurred in a pre-hospital setting (including three in transit to the emergency department), 13 were in the emergency department, one was in an operating theatre (which occurred after indirect laryngoscopy), one was in ICU, and five occurred in the ward (including one during transfer to the operating theatre).

Specific airway techniques and outcomes

Of the 128 cases, 75 (58.6%) reported an awake technique for the primary airway intervention and 53 (41.4%) reported that airway intervention occurred after the induction of general anaesthesia. The primary airway techniques and success rates classified by the Friedman stage of epiglottitis are summarised in Table 2. Details of the airway management for the 32 cases with primary technique failure are presented in Table 3. Airway techniques and outcomes classified by location of airway intervention are presented in Supplementary Table S6. Techniques reported by decade are presented in Supplementary Figure S5. Airway techniques for stage 4 cases classified by arrest status are presented in Supplementary Table S7.

Intubation difficulty was variably reported. Descriptions of the airway during fibreoptic nasendoscopy or laryngoscopy included multiple cases of severe oedema, distorted anatomy, severe glottic obstruction, excessive secretions, or all. Fifteen intubations, although successful were described as difficult, requiring multiple attempts, use of introducers, or reduction in tube sizes. Additionally, one awake fibreoptic intubation required multiple attempts to advance the tracheal tube through the glottis.[101]

Direct laryngoscopy was used during intubation for 70 cases overall, of which 43 (61.4%) were successful. Videolaryngoscopy was used as the primary intubation device for 11 cases overall, of which eight (72.7%) were successful. Videolaryngoscopy was also used after failed direct laryngoscopy in two cases, both of which were unsuccessful.[91,94] Laryngoscopy and clinical outcomes classified by severity are presented in Supplementary Table S8.

Morbidity and mortality outcomes were variably reported. Hypoxic cardiac arrest occurred during airway intervention in zero, one, and six of the stage 2, 3, and 4 cases, respectively. One death was reported in the stage 2 cases (cardiac failure). Four deaths occurred in the stage 3 cases (one hypoxia, two sepsis, one cardiac). There were 11 deaths in the stage 4 cases (all hypoxia) and three patients recovered with neurologic deficits, of which two were severe. The median (inter-quartile range) time to extubation was 2 (2–3) days (n=10), 4 (2–7) days (n=17), and 3 (2–14) days (n=13) for the stage 2, 3 and 4 cases, respectively.

Discussion

We performed a systematic review and meta-analysis of airway management outcomes for adult epiglottitis between 1980 and 2020. Data from 56 studies involving 10 630 patients found the overall rate of airway intervention was 15.6% (95% CI 12.9–18.8%). Airway intervention rates also decreased from 20% to 10% over four decades, after introduction of the HIB vaccine in the 1980s. The overall rate of tracheal intubation was 10.2% (95% CI 7.1–13.6%) and failed intubation was 4.2% (95% CI 1.4–8.0%). No trends over time were demonstrated for these outcomes.

This review updates the previous systematic review and meta-analysis of predictors of airway intervention in adult epiglottitis by Sideris and colleagues.[16] Our focus was airway management techniques and different methodology was applied. The airway management literature for adult epiglottitis consists of exclusively observational studies, which are typically small in size. This introduced a high level of heterogeneity and risk of bias, which was handled differently by each review. Sideris and colleagues[16] excluded small studies and used a non-randomised trial bias assessment tool. In contrast, we included small studies after performing a sensitivity analysis and used a prevalence study quality assessment tool. Consequently, our meta-analysis included twice the number of studies. Our summary estimates for airway intervention remained broadly similar to Sideris and colleagues,[16] who reported an overall rate of 15.0% (95% CI 11.8–18.9%).

Our time trend analysis confirmed that airway intervention has decreased since HIB vaccine implementation in the 1980s.[16] Furthermore, we demonstrated that this reduction has continued with time, up to the current decade. There are several potential explanations for this finding. The

Table 2 Primary airway technique success rates. Data presented as n (%). SGA, supraglottic airway; SV, spontaneous ventilation.

Airway technique	Friedman classification			
	Stage 2 n=25	Stage 3 n=66	Stage 4 n=37	Overall n=128
Awake (n=75)				
Tracheostomy (n=25)	3/3 (100)	18/19 (95)	2/3 (67)	23/25 (92)
Fibreoptic intubation (n=19)	7/7 (100)	12/12 (100)	0	19/19 (100)
Laryngoscopy (n=29)	2/2 (100)	2/3 (67)	11/24 (46)	15/29 (52)
Blind nasal (n=1)	1/1 (100)	0	0	1/1 (100)
SGA (n=1)	0	0	0/1 (0)	0/1 (0)
General anaesthesia (n=53)				
SV preserved (n=42)	8/11 (73)	22/29 (78)	2/2 (100)	32/42 (76)
SV ablated (n=11)	1/1 (100)	3/3 (100)	2/7 (25)	6/11 (55)
Overall (n=128)	22/25 (88)	57/66 (86)	17/37 (46)	96/128 (75)

Table 3 Primary airway technique failures and secondary rescue techniques. AFOI, awake fibreoptic intubation; ARDS, acute respiratory distress syndrome; CPR, cardiopulmonary resuscitation; CT, computerised tomography; ED, emergency department; ENT, ear nose and throat; FMV, face-mask ventilation; FNE, fibreoptic nasendoscopy; FOB, fibreoptic bronchoscope; GCS, Glasgow Coma Scale; HDU, high dependency unit; ICU, intensive care unit; MLT, microlaryngoscopy tube; NMB, neuromuscular block; NPPO, negative pressure pulmonary oedema; OOHA, out of hospital arrest; OT, operating theatre; RSI, rapid sequence induction; SGA, supraglottic airway; VL, videolaryngoscopy.

First author, year of publication	Primary technique	Friedman stage	Scenario and location	Reason for failure	Secondary technique	Outcome
Warden,[76] 1984	Awake direct laryngoscopy	Stage 3	Respiratory distress in ED	Complete airway obstruction and respiratory arrest occurred during laryngoscopy	Repeat direct laryngoscopy and intubation successful after administration of suxamethonium	Elective tracheostomy, recovery
Love,[77] 1984	Inhalation induction	Stage 3	OT	Complete airway obstruction during induction	NMB, successful intubation	Recovery
McNelis,[78] 1985	Awake direct laryngoscopy	Stage 4	Rapid deterioration on ward, complete airway obstruction, cardiac arrest	Failed intubation by resident	Successful tracheostomy	ICU, death
Blome,[79] 1985	Awake direct laryngoscopy	Stage 4	Rapid deterioration, respiratory arrest on arrival to OT	Failed intubation by experienced anaesthetist (massively swollen epiglottis)	Successful emergency tracheostomy	Recovery
Heslet,[80] 1985	General anaesthesia apnoea (i.v. induction without NMB)	Stage 4	Rapid deterioration with complete airway obstruction in ED	Failed intubation with direct laryngoscopy (unable to recognise anatomic landmarks because of severe oedema)	Retrograde nasal intubation using transtracheal wire required 2 attempts: (i) first attempt failed because of tracheal tube hold up at glottis, (ii) second attempt successful using direct laryngoscopy and McGills forceps to advance tube through glottis	Recovery
Chaisson,[81] 1986	Awake direct laryngoscopy	Stage 4	Respiratory arrest after indirect laryngoscopy performed in OT	Failed intubation (large epiglottis)	Successful emergency tracheostomy	Recovery
Yardley,[82] 1986	Awake direct laryngoscopy	Stage 4	Rapid deterioration and complete airway obstruction on ward during transfer to OT for tracheostomy	Failed intubation (gross supraglottic oedema made intubation impossible)	Successful emergency tracheostomy	Hypoxia, severe hypoxic encephalopathy, death
Gerrish,[83] 1987	Awake direct laryngoscopy	Stage 4	Rapid deterioration on ward, complete airway obstruction, cardiac arrest	Intubation impossible because of unrecognisable laryngeal anatomy	Successful cricothyroidotomy	Cerebral hypoxia, death
Gerrish,[83] 1987	Inhalation induction	Stage 3	OT	Failed intubation with direct laryngoscopy because of severe	Successful intubation using FOB and bougie	Not reported

Continued

Table 3 Continued

First author, year of publication	Primary technique	Friedman stage	Scenario and location	Reason for failure	Secondary technique	Outcome
				oedema and deformity of laryngeal anatomy		
Crosby,[42] 1991	Inhalation induction	Stage 3	OT	Failed intubation	Successful emergency tracheostomy by ENT surgeon	NPPO, recovery
Mayo-Smith,[84] 1993	Awake direct laryngoscopy	Stage 4	Rapid deterioration in ICU	Failed intubation by anaesthetist, then cardiac arrest	Tracheostomy successful but prolonged insertion (15 min)	Failed resuscitation, death
Stuart,[85] 1994	Awake direct laryngoscopy	Stage 4	Prehospital OOHA	Failed intubation by paramedics	Successful direct laryngoscopy in ED	Failed resuscitation, death
Ames,[86] 2000	Awake tracheostomy	Stage 4	Rapid deterioration on ward	Primary technique abandoned because of hypoxia, loss of consciousness and seizure	(i) Successful direct laryngoscopy and intubation by anaesthetist (ii) formal tracheostomy after transfer to operating room	Recovery
Ames,[86] 2000	Inhalation induction	Stage 2	OT	Complete airway obstruction	NMB, failed intubation attempt, successful emergency needle cricothyroidotomy and jet ventilation, formal tracheostomy	Recovery
Ames,[86] 2000	General anaesthesia apnoea (NMB)	Stage 4	Rapid deterioration with complete airway obstruction and respiratory arrest in ED	Failed intubation after intralingual suxamethonium (trismus, no i.v. access), unable to visualise glottis	(i) Successful needle cricothyroidotomy performed, (ii) successful nasal fibreoptic intubation	Surgical tracheostomy, HDU, recovery
Wick,[56] 2002	Awake direct laryngoscopy	Stage 4	Misdiagnosis, arrest on ward	Failed intubation	No rescue attempt described	Death
Madhotra,[57] 2004	Inhalation induction	Stage 3	OT	Failed intubation with direct laryngoscopy	Successful emergency tracheostomy	Not reported
Madhotra,[57] 2004	Inhalation induction	Stage 3	OT	Failed intubation with direct laryngoscopy	Successful emergency tracheostomy	Not reported
Rucklidge,[87] 2004	Inhalation induction	Stage 2	OT	Difficult prolonged induction, early complete airway obstruction resolved with Guedel, first intubation attempt with direct laryngoscopy failed (unable to visualise glottis because of oedema)	(i) NMB facilitated FMV, (ii) second intubation attempt unsuccessful using McCoy blade and bougie, (iii) third intubation attempt successful with direct laryngoscopy and MLT size 4	Recovery
Shepherd,[88] 2004	Inhalation induction	Stage 3	OT	Failed intubation	Successful emergency tracheostomy	Recovery

Continued

Table 3 Continued

First author, year of publication	Primary technique	Friedman stage	Scenario and location	Reason for failure	Secondary technique	Outcome
Chandradeva,[89] 2005	General anaesthesia apnoea (RSI)	Stage 4	Presents to ED in severe respiratory distress, peri-arrest, seizure	Failed intubation with direct laryngoscopy (3 unsuccessful attempts by anaesthetists), unable to visualise glottis because of severe oedema	(i) Successful needle cricothyroidotomy and jet ventilation, (ii) successful repeat direct laryngoscopy and intubation using bougie (glottis identified by gas egress)	ICU, recovery
Mathoera,[90] 2008	Awake direct laryngoscopy	Stage 4	Rapid deterioration in ED, complete airway obstruction	Failed intubation, failed FMV	Tracheostomy	Cardiac arrest, hypoxic encephalopathy, death
Diaz,[91] 2012	Awake direct laryngoscopy	Stage 4	Rapid deterioration and respiratory arrest in ED after FNE	Failed intubation (diffusely oedematous supraglottis)	(i) Multiple unsuccessful attempts to intubate by different specialists using VL and FOB. (ii) Successful emergency cricothyroidotomy	ICU, elective surgical tracheostomy, recovery
Harvey,[92] 2012	Awake direct laryngoscopy	Stage 4	Prehospital OOHA	Unable to ventilate using SGA inserted by paramedics	No secondary attempt or intubation attempt	Unsuccessful CPR, death
Shafiq,[93] 2012	Inhalation induction	Stage 2	Pre-emptive intubation in OT before transfer to higher centre	Multiple attempts to intubate failed with direct laryngoscopy, FOB, or both, unable to visualise glottis because of oedema	Successful emergency tracheostomy (spontaneous ventilation maintained)	Recovery
Barrett,[94] 2013	General anaesthesia apnoea (RSI)	Stage 3	Progressive deterioration in ED	Failed intubation with direct laryngoscopy (no view of glottis because of severe oedema and secretions)	Two further attempts at intubation: (i) unsuccessful attempt with videolaryngoscopy (unable to view glottis, or insert tracheal tube or bougie), (ii) successful attempt with direct laryngoscopy and blind insertion of bougie). FMV was difficult but possible between attempts	Recovery
Choi,[95] 2016	Awake direct laryngoscopy	Stage 4	Rapid deterioration, peri-arrest in ED	Failed intubation (supraglottic oedema occluded airway) then cardiac arrest	Successful emergency cricothyroidotomy	NPPO, ARDS, hypoxic encephalopathy
Lindquist,[96] 2017	Inhalation induction	Stage 3	Rapid deterioration during transfer to OT from ED (planned AFOI changed to inhalation induction)	Failed intubation with videolaryngoscopy (glottis not seen because of very inflamed epiglottis), unable to FMV	Successful emergency tracheostomy	Recovery

Continued

Table 3 Continued

First author, year of publication	Primary technique	Friedman stage	Scenario and location	Reason for failure	Secondary technique	Outcome
Collins,[97] 2018	Awake direct laryngoscopy	Stage 4	Presented to ED in extremis with worsening hypoxaemia, peri-arrest	Failed intubation by anaesthetist (grossly swollen epiglottis/ supraglottis), then cardiac arrest	Successful emergency cricothyroidotomy	Successful resuscitation, recovery
Zimmermann,[98] 2018	Awake videolaryngoscopy	Stage 4	Very rapid deterioration after CT scan in ED, respiratory failure, hypoxaemia, peri-arrest	Failed intubation (extremely difficult because of oedema) followed by hypoxic cardiac arrest with hypoxaemia and cardiac arrest	Two attempts to intubate with direct laryngoscopy (initially unsuccessful then successful during CPR)	ICU, elective tracheostomy, prolonged ventilation, recovery with temporary neurological impairment
Ma,[99] 2018	General anaesthesia apnoea (i.v. induction without NMB)	Stage 4	Rapid deterioration, peri-arrest in ED	Two failed intubation attempts with videolaryngoscopy (unable to visualise glottis because of severe oedema)	Difficult FMV with hypoxia, successful emergency tracheostomy by surgeon	Cardiac arrest during tracheostomy, hypoxic brain injury (GCS 6)
Epskamp,[100] 2019	Awake cricothyroidotomy	Stage 4	Rapid deterioration in ICU, complete airway obstruction, arrest	Failed cricothyroidotomy with worsening severe hypoxaemia	Emergency percutaneous tracheostomy	NPPO, recovery

management of epiglottitis has undergone iterative changes coinciding with improvements in knowledge and capabilities.[10] Sideris and colleagues[16] suggested that improvements in ICU airway monitoring and a preference for early airway intervention in the prevaccine era were likely factors. Airway management has also evolved over this time frame.[17,102] It is plausible that the advancement in technology, techniques, and training has reduced the need for routine intubation or tracheostomy in many cases.

The main limitations of our analysis include the high heterogeneity of reported outcomes and the incomplete data reported by many studies. Our results should be interpreted with caution. There is increased uncertainty in the pooled estimates because of the high heterogeneity. The wider confidence intervals of the subgroup pooled estimates also reduced the power to detect subgroup differences, which may have impacted the time trend analysis. Non-registration with PROSPERO increased the potential for bias. Measures to mitigate this risk included engagement of an independent biostatistician (SL), who was not affiliated with our research institution, and a senior researcher (DS) to provide oversight of the review. Furthermore, we otherwise adhered to the PRISMA guidelines and have reported deviation from our original protocol (non-reporting of mortality as a secondary outcome).

The high heterogeneity was not surprising. Effect size variation between studies may reflect the wide range of sample sizes, different geographical populations, and different approaches to airway management over a long-time frame. Our subgroup analysis for airway intervention suggested that time is a factor. Sideris and colleagues[16] suggested that small study size was contributory in their review. However, heterogeneity in our small sample size sensitivity analysis remained similar to our main analysis, which indicated sample size was not a major factor. Geographical location may have influenced heterogeneity because of variations in regional practice and the approach to airway management. For example, we noted a higher relative proportion of patients receiving tracheostomy in many Asian studies.[15,24,58,67] Shimizu and colleagues[15] reported that tracheostomy is the preferred method of airway intervention for adult epiglottitis in Japan, compared with tracheal intubation in Western countries. This difference is also highlighted by two large database studies from Japan and the USA.[10,73]

Our review was unable to determine whether tracheostomy or tracheal intubation is preferred for adult epiglottitis.[3,45,58] The data to support either method were scant. A clinically important finding was the high intubation failure rate, although individual techniques were rarely described. The pooled data from our meta-analysis found that one in 25 intubations failed, which is notably greater than the published failure rates across all critical care settings.[103,104] Of note, six studies that contained almost half of the intubations (294 patients) did not report intubation failure rates and were excluded from this outcome analysis.[6,47,68,69,73,75] Tracheostomy outcomes were poorly reported, often because the relevant studies focussed on airway predictors.[15,58,73] Many studies in our meta-analysis reported overall tracheostomy rates, which did not distinguish between a primary or secondary (rescue) intervention. We excluded this outcome from analysis because of the potential for bias towards a higher tracheostomy rate. Our meta-analysis suggests that the overall prevalence of tracheostomy was half that of tracheal intubation, which is consistent with the Sideris review.[16]

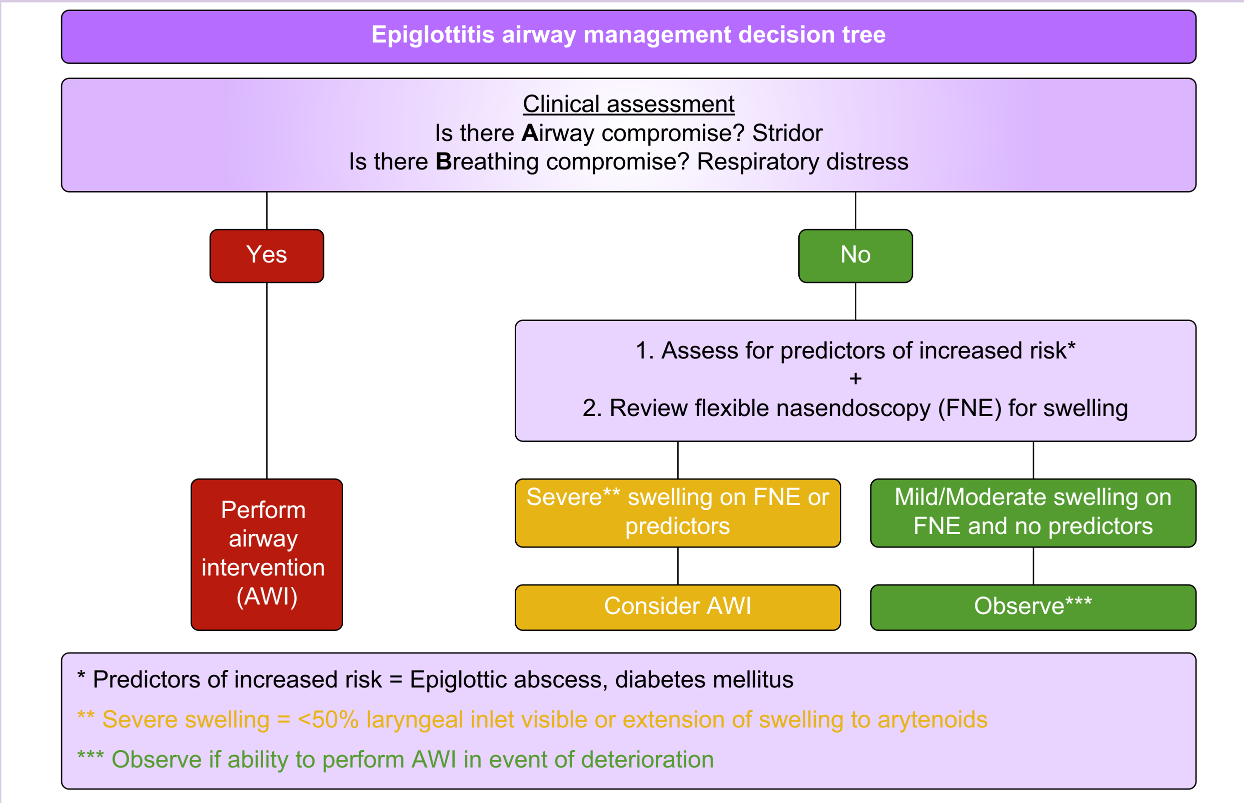

Fig 4. Clinical algorithm to guide airway management for adult epiglottitis.

Less than 10% of the airway interventions in our review were included in our airway technique summary because of insufficient detail. Baxter and Dunn[3] identified a similar lack of detail in their 1988 review, which highlights a lack of reporting progress over time. We recommend that all future epiglottitis studies report the specific techniques used for airway management, coupled with outcomes and details of the clinical scenario. A data registry may benefit the collection of high-quality data to guide optimal management.[105]

Despite the limited numbers and potential for reporting bias, our technique summary did provide several clinical observations that our meta-analysis and previous large database studies were unable to examine.[10] Awake fibreoptic intubation reported the best success rate (100%) and appears to be a logical first-line technique. However, awake fibreoptic intubation was only performed in the less severe cases. In contrast, awake laryngoscopy had the worst success rate (52%) but was mainly performed in the severely obstructed patients in the emergency department or in unfavourable environments. In this regard, classifying the techniques by severity was a strength of our review. It provided a context to the airway management in terms of the urgency, location, difficulty, and outcomes. The most severe cases (stage 4) appeared to have a shorter onset, a more rapid clinical progression, and were primarily managed in the emergency department. In contrast, the less severe cases (stage 2 and 3) had a slower clinical progression and were primarily managed in the operating theatre. The temporal aspect of airway obstruction is a key determinant of airway technique selection, including the environment and personnel involved.[106,107] Although awake fibreoptic intubation is commonly recommended for adult epiglottitis, it requires a cooperative patient, a specific skillset, and takes time to perform.[8,12,108] For a patient in extremis, the airway options were generally limited to a laryngoscopy attempt followed by emergency front of neck access if unsuccessful.[3]

Inhalation induction of general anaesthesia was the most common technique in our summary, comprising one-third of the cases. Preservation of spontaneous ventilation has been a longstanding principle for the airway management of epiglottitis and airway obstruction.[3,108,109] Inhalation induction in childhood epiglottitis is the norm, however its current role in adults is unclear.[11,110] Although we reported a primary failure rate of 25%, all cases were successfully rescued and the patients survived. This highlights the importance of a back-up plan and immediate surgical availability for inhalation induction success.[109,110]

The use of neuromuscular blocking agents in adult epiglottitis is contentious. Traditional dogma states they should be avoided because of the risk of complete airway obstruction from reduced airway tone.[3,86] Therefore, the induction of general anaesthesia to cause apnoea is a critical and stressful decision point. Most cases in our summary were reported in the 2010 decade, which may indicate a shift away from traditional practice. Intubation success also appeared to vary with the severity of epiglottitis (100% in stage 2 or 3 *vs* 25% in stage

4). Although recent guidelines advocate neuromuscular blocking agents to manage the difficult airway,[111] it remains unclear if this should extend to adult epiglottitis.

We identified several mechanisms that contributed to failed airway management. These were consistent with the pathophysiology of supraglottic inflammation and progressive obstruction.[3,11] Firstly, the mechanics of intubation (including visualisation or tracheal tube passage) were impaired by extensive oedema, distortion of airway anatomy, glottic/supraglottic obstruction, secretions, or all. Videolaryngoscopy did not appear to improve intubation success, compared with direct laryngoscopy. Several videolaryngoscopy failures reported that no glottic view was possible. Airway oedema is a predictor of failed intubation using videolaryngoscopy in the ICU, which may limit its utility in adult epiglottitis.[112,113] Its role remains undefined. Secondly, disease progression or airway manipulation often resulted in complete airway obstruction with hypoxaemia or cardiac arrest. Thirdly, airway management was often performed in extremely stressful scenarios associated with urgency, hypoxaemia, cardiopulmonary arrest, a suboptimal environment, or all. Human factors are known contributors to the failed airway and are likely to have reduced performance in the high-pressure management of adult epiglottitis, irrespective of the technique or device used.[106,107,111,114] Furthermore, two-thirds of the failed primary intubation attempts resulted in rescue cricothyroidotomy or tracheostomy. This suggests that preparedness for emergency front of neck access is essential.[11]

It is possible that an optimal method of airway management cannot be generalised for adult epiglottitis. Our data have shown that airway intervention occurs in a wide range of healthcare settings by practitioners with variable skillsets for patients with diverse clinical presentations. There appeared to be different patterns of technique selection and outcomes associated with the location of airway intervention. A context-sensitive approach may be more suitable.[115] Baxter and Dunn[3] suggested that the skillset and available facilities are more important than a specific technique. Lee and colleagues[13] outlined several contextual factors that determine technique selection: (i) severity of obstruction, (ii) patient characteristics (e.g. ability to cooperate), (iii) equipment availability, and (iv) familiarity with a particular technique. Our data suggest that severity and location are important. Context-sensitive airway management has been recommended for other types of airway obstruction and a broader focus on process rather than specific technique is recognised to maximise intubation success in the emergency department.[107,116]

Our meta-analysis confirms that airway intervention is currently required in ~10% of adults with epiglottitis, with the majority suitable for conservative management.[16] This supports a selective approach to airway management, in contrast to paediatric cases.[7,11,14,45,58] Determining who should receive airway intervention remains an ongoing management dilemma.[13] The optimal timing of airway intervention also remains unclear because of the unpredictable nature of adult epiglottitis.[13,14,45] Although predictors of airway intervention and objective measures of epiglottic swelling exist, there is no unifying guidance.[16,58] Success of a selective approach relies on several crucial components: (i) correctly identifying which patients require early or immediate airway intervention, (ii) understanding the signs of deterioration and pending airway obstruction in those who are managed conservatively, and (iii) having the ability to rapidly provide airway intervention in a deteriorating patient.[16,70] A possible evidence-based clinical algorithm to guide a selective approach to airway management is presented in Fig 4.[16,58,70]

In conclusion, the rate of airway intervention for adult epiglottitis has decreased over four decades to a current level of ~10%. Tracheal intubation appears to be performed more frequently than tracheostomy but is a high-risk scenario with a relatively high failure rate. Evidence to support an optimal method of airway management was limited. Specific technique selection is most likely influenced by contextual factors, especially the severity of epiglottitis and location of airway intervention.

Author's contributions

Study design: KP, AB, SL, KV.
Data acquisition: KP, AWGB.
Data analysis and interpretation: all authors.
Writing paper: all authors.

Declarations of interest

AWGB is a director of Specialist Airway Solutions Pty Ltd and inventor of the D-FLECT® deflectable-tip bougie. AGWB has received a single travel and accommodation grant from Fisher and Paykel Healthcare to attend a clinical forum in 2016. Total funding: approximately $1000.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bjao.2023.100250.

References

1. Meyer A. Pediatric infectious disease. In: Flint PW, Haughey BH, Lund VJ, et al., editors. *Cummings Otolaryngology - Head & neck Surgery*. Philadelphia: Saunders Elsevier; 2015. p. 3045–54
2. Friedman M, Toriumi DM, Grybauskas V, Applebaum EL. A plea for uniformity in the staging and management of adult epiglottitis. *Ear Nose Throat J* 1988; **67**: 873–80
3. Baxter FJ, Dunn GL. Acute epiglottitis in adults. *Can J Anaesth* 1988; **35**: 428–35
4. Guldfred L-A, Lyhne D, Becker B. Acute epiglottitis: epidemiology, clinical presentation, management and outcome. *J Laryngol Otol* 2008; **122**: 818–23
5. Hanna J, Brauer P, Berson E, Mehra S. Adult epiglottitis: trends and predictors of mortality in over 30 thousand cases from 2007 to 2014. *Laryngoscope* 2019; **129**: 1107–12
6. Frantz TD, Rasgon BM, Quesenberry Jr CP. Acute epiglottitis in adults. Analysis of 129 cases. *JAMA* 1994; **272**: 1358–60
7. Berger G, Landau T, Berger S, Finkelstein Y, Bernheim J, Ophir D. The rising incidence of adult acute epiglottitis and epiglottic abscess. *Am J Otolaryngol* 2003; **24**: 374–83
8. Chroboczek T, Cour M, Hernu R, et al. Long-term outcome of critically ill adult patients with acute epiglottitis. *PLoS One* 2015; **10**, e0125736
9. Shapira Galitz Y, Shoffel-Havakuk H, Cohen O, Halperin D, Lahav Y. Adult acute supraglottitis: analysis of 358 patients for predictors of airway intervention. *Laryngoscope* 2017; **127**: 2106–12
10. Shah R, Stocks C. Epiglottitis in the United States: national trends, variances, prognosis, and management. *Laryngoscope* 2010; **120**: 1256–62

11. Lichtor J, Rodriguez M, Aaronson N, Spock T, Goodman T, Baum E. Epiglottitis - it hasn't gone away. *Anesthesiology* 2016; **124**: 1404–7
12. Guardiani E, Bliss M, Harley E. Supraglottitis in the era following widespread immunization against Haemophilus influenzae type B: evolving principles in diagnosis and management. *Laryngoscope* 2010; **120**: 2183–8
13. Lee PK, Booth AWG, Vidhani K. Spontaneous respiration using intravenous anesthesia and high-flow nasal oxygen (STRIVE Hi) management of acute adult epiglottitis: a case report. *A A Pract* 2018; **10**: 73–5
14. Kass EG, McFadden EA, Jacobson S, Toohill RJ. Acute epiglottitis in the adult: experience with a seasonal presentation. *Laryngoscope* 1993; **103**: 841–4
15. Shimizu Y, Mori E, Wada K, Otori N, Kojima H. Airway intervention in cases of acute epiglottitis. *B-ENT* 2016; **12**: 279–84
16. Sideris A, Holmes TR, Cumming B, Havas T. A systematic review and meta-analysis of predictors of airway intervention in adult epiglottitis. *Laryngoscope* 2020; **130**: 465–73
17. Doyle DJ. A brief history of clinical airway management. *Anesthesiology News* 2015; **9–14**
18. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *Br Med J* 2009; **339**: b2700
19. Tveteras K, Kristensen S. Acute epiglottitis in adults: bacteriology and therapeutic principles. *Clin Otolaryngol Allied Sci* 1987; **12**: 337–43
20. Arndal H, Andreassen UK. Acute epiglottis in children and adults. Nasotracheal intubation, tracheostomy or careful observation? Current status in Scandinavia. *J Laryngol Otol* 1988; **102**: 1012–6
21. Wolf M, Strauss B, Kronenberg J, Leventon G. Conservative management of adult epiglottitis. *Laryngoscope* 1990; **100**: 183–5
22. Chang Y-L, Lo S-H, Wang P-C, Shu Y-H. Acute adult epiglottitis: experiences in a Taiwanese setting. *Otolaryngol Head Neck Surg* 2005; **132**: 689–93
23. Barrow HN, Vastola AP, Wang RC. Adult supraglottitis. *Otolaryngol Head Neck Surg* 1993; **109**: 474–7
24. Nakamura H, Tanaka H, Matsuda A, Fukushima E, Hasegawa M. Acute epiglottitis: a review of 80 patients. *J Laryngol Otol* 2001; **115**: 31–4
25. Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C. Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and incidence data. *Int J Evid Based Healthc* 2015; **13**: 147–53
26. Nyaga VN, Arbyn M, Aerts M. Metaprop: a Stata command to perform meta-analysis of binomial data. *Arch Public Health* 2014; **72**: 39
27. Apfelbaum JL, Hagberg CA, Caplan RA, et al. Practice guidelines for management of the difficult airway: an updated report by the American society of Anesthesiologists task force on management of the difficult airway. *Anesthesiology* 2013; **118**: 251–70
28. Ossoff RH, Wolff AP, Ballenger JJ. Acute epiglottitis in adults: experience with fifteen cases. *Laryngoscope* 1980; **90**: 1155–61
29. Black MJ, Harbour J, Remsen KA, Baxter JD. Acute epiglottitis in adults. *J Otolaryngol* 1981; **10**: 23–7
30. Chung C. Case and literature review: adult acute epiglottitis – rising incidence or increasing awareness? *Hong Kong J Emerg Med* 2001; **8**: 227–31
31. Cruz MGY, Almazan NA. Adult acute epiglottitis: an eight - year experience in a Philippine tertiary government hospital. *Philipp J Otolaryngol Head Neck Surg* 2016; **31**: 20–3
32. Mustoe T, Strome M. Adult epiglottitis. *Am J Otolaryngol* 1983; **4**: 393–9
33. Deeb Z, Yenson A, DeFries H. Acute epiglottitis in the adult. *Laryngoscope* 1985; **95**: 289–91
34. Stair TO, Hirsch BE. Adult supraglottitis. *Am J Emerg Med* 1985; **3**: 512–8
35. Mayo-Smith MF, Hirsch PJ, Wodzinski SF, Schiffman FJ. Acute epiglottitis in adults. An eight-year experience in the state of Rhode Island. *N Engl J Med* 1986; **314**: 1133–9
36. Murrage KJ, Janzen VD, Ruby RR. Epiglottis: adult and pediatric comparisons. *J Otolaryngol* 1988; **17**: 194–8
37. Shih L, Hawkins D, Stanley R. Acute epiglottitis in adults - a review of 48 cases. *Ann Otol Rhinol Laryngol* 1988; **97**: 527–9
38. Stanley RE, Liang TS. Acute epiglottitis in adults (the Singapore experience). *J Laryngol Otol* 1988; **102**: 1017–21
39. Fontanarosa PB, Polsky SS, Goldman GE. Adult epiglottitis. *J Emerg Med* 1989; **7**: 223–31
40. Sheikh KH, Mostow SR. Epiglottitis–an increasing problem for adults. *West J Med* 1989; **151**: 520–4
41. Carenfelt C, Sobin A. Acute infectious epiglottitis in children and adults: annual incidence and mortality. *Clin Otolaryngol Allied Sci* 1989; **14**: 489–93
42. Crosby E, Reid D. Acute epiglottitis in the adult: is intubation mandatory? *Can J Anaesth* 1991; **38**: 914–8
43. Andreassen UK, Baer S, Nielsen TG, Dahm SL, Arndal H. Acute epiglottitis–25 years experience with nasotracheal intubation, current management policy and future trends. *J Laryngol Otol* 1992; **106**: 1072–5
44. Ryan M, Hunt M, Snowberger T. A changing pattern of epiglottitis. *Clin Pediatr (Phila)* 1992; **31**: 532–5
45. Dort JC, Frohlich AM, Tate RB. Acute epiglottitis in adults: diagnosis and treatment in 43 patients. *J Otolaryngol* 1994; **23**: 281–5
46. Torkkeli T, Ruoppi P, Nuutinen J, Kari A. Changed clinical course and current treatment of acute epiglottitis in adults a 12-year experience. *Laryngoscope* 1994; **104**: 1503–6
47. Berg S, Trollfors B, Nylén O, Hugosson S, Prellner K, Carenfelt C. Incidence, aetiology, and prognosis of acute epiglottitis in children and adults in Sweden. *Scand J Infect Dis* 1996; **28**: 261–4
48. Kucera C, Silverstein M, Jacobson R, Wollan P, Jacobsen S. Epiglottitis in adults and children in olmsted County, Minnesota, 1976 through 1990. *Mayo Clin Proc* 1996; **71**: 1155–61
49. Hébert PC, Ducic Y, Boisvert D, Lamothe A. Adult epiglottitis in a Canadian setting. *Laryngoscope* 1998; **108**: 64–9
50. Park KW, Darvish A, Lowenstein E. Airway management for adult patients with acute epiglottitis: a 12-year experience at an academic medical center (1984-1995). *Anesthesiology* 1998; **88**: 254–61
51. Solomon P, Weisbrod M, Irish JC, Gullane PJ. Adult epiglottitis: the Toronto Hospital experience. *J Otolaryngol* 1998; **27**: 332–6
52. Alho OP, Jokinen K, Pirila T, Ilo A, Koivunen P. Acute epiglottitis in northern Finland today–still a potential

emergency situation. *Int J Circumpolar Health* 1999; **58**: 226–33
53. Rizk SS, Kacker A, Komisar A. Need for tracheotomy is rare in patients with acute supraglottitis: findings of a retrospective study. *Ear Nose Throat J* 2000; **79**: 952–7
54. Chan KO, Pang YT, Tan KK. Acute epiglottitis in the tropics: is it an adult disease? *J Laryngol Otol* 2001; **115**: 715–8
55. Wong EY, Berkowitz RG. Acute epiglottitis in adults: the Royal Melbourne Hospital experience. *ANZ J Surg* 2001; **71**: 740–3
56. Wick F, Ballmer PE, Haller A. Acute epiglottis in adults. *Swiss Med Wkly* 2002; **132**: 541–7
57. Madhotra D, Fenton JE, Makura ZG, Charters P, Roland NJ. Airway intervention in adult supraglottitis. *Ir J Med Sci* 2004; **173**: 197–9
58. Katori H, Tsukuda M. Acute epiglottitis: analysis of factors associated with airway intervention. *J Laryngol Otol* 2005; **119**: 967–72
59. Price IM, Preyra I, Fernandes CM, Woolfrey K, Worster A. Adult epiglottitis: a five-year retrospective chart review in a major urban centre. *CJEM* 2005; **7**: 387–90
60. Hafidh MA, Sheahan P, Keogh I, Walsh RM. Acute epiglottitis in adults: a recent experience with 10 cases. *J Laryngol Otol* 2006; **120**: 310–3
61. Ng HL, Sin LM, Li MF, Que TL, Anandaciva S. Acute epiglottitis in adults: a retrospective review of 106 patients in Hong Kong. *Emerg Med J* 2008; **25**: 253–5
62. Berger G, Averbuch E, Zilka K, Berger R, Ophir D. Adult vallecular cyst: thirteen-year experience. *Otolaryngol Head Neck Surg* 2008; **138**: 321–7
63. Briem B, Thorvardsson O, Petersen H. Acute epiglottitis in Iceland 1983-2005. *Auris Nasus Larynx* 2009; **36**: 46–52
64. Cheung CS, Man SY, Graham CA, et al. Adult epiglottitis: 6 years experience in a university teaching hospital in Hong Kong. *Eur J Emerg Med* 2009; **16**: 221–6
65. Qazi IM, Jafar AM, Hadi KA, Hussain Z. Acute epiglottitis: a retrospective review of 47 patients in Kuwait. *Indian J Otolaryngol Head Neck Surg* 2009; **61**: 301–5
66. Sarkar S, Roychoudhury A, Roychaudhuri BK. Acute epiglottitis in adults - a recent review in an Indian hospital. *Indian J Otolaryngol Head Neck Surg* 2009; **61**: 197–9
67. Yoon TM, Choi JO, Lim SC, Lee JK. The incidence of epiglottic cysts in a cohort of adults with acute epiglottitis. *Clin Otolaryngol* 2010; **35**: 18–24
68. Bizaki AJ, Numminen J, Vasama JP, Laranne J, Rautiainen M. Acute supraglottitis in adults in Finland: review and analysis of 308 cases. *Laryngoscope* 2011; **121**: 2107–13
69. Riffat F, Jefferson N, Bari N, McGuinness J. Acute supraglottitis in adults. *Ann Otol Rhinol Laryngol* 2011; **120**: 296–9
70. Park HH, Lee JC, Lee TH, Kwon JK, Nam JK. Acute supraglottitis in adults: what's the optimal airway intervention? *Auris Nasus Larynx* 2012; **39**: 204–7
71. Lee YC, Kim TH, Eun YG. Routine computerised tomography in patients with acute supraglottitis for the diagnosis of epiglottic abscess: is it necessary? A prospective, multicentre study. *Clin Otolaryngol* 2013; **38**: 142–7
72. Ovnat Tamir S, Marom T, Barbalat I, Spevak S, Goldfarb A, Roth Y. Adult supraglottitis: changing trends. *Eur Arch Otorhinolaryngol* 2015; **272**: 929–35
73. Suzuki S, Yasunaga H, Matsui H, Fushimi K, Yamasoba T. Factors associated with severe epiglottitis in adults: analysis of a Japanese inpatient database. *Laryngoscope* 2015; **125**: 2072–8
74. Baird SM, Marsh PA, Padiglione A, et al. Review of epiglottitis in the post Haemophilus influenzae type-b vaccine era. *ANZ J Surg* 2018; **88**: 1135–40
75. Wu I-Y, Lin P-C, Hsu C-C, Chen K-T. Clinical features of patients with acute epiglottitis in the emergency department. *Hong Kong J Emerg Med* 2019; **26**: 268–74
76. Warden JC, Fisher MM. Acute epiglottitis in adults. *Med J Aust* 1984; **140**: 746–7
77. Love JB, Phelan DM, Runciman WB, Skowronski GA, Turnidge JD. Acute epiglottitis in adults. *Anaesth Intens Care* 1984; **12**: 264–9
78. McNelis FL. Medical and legal management of adult acute epiglottitis. *Laryngoscope* 1985; **95**: 125–7
79. Blome M, Small H. Recurrent acute adult epiglottitis treated by epiglottectomy. *Ear Nose Throat J* 1985; **64**: 71–5
80. Heslet L, Christensen KS, Sanchez R, Schlichting J. Facilitated blind intubation using a transtracheal guide wire. *Dan Med Bull* 1985; **32**: 275–7
81. Chaisson RE, Ross J, Gerberding JL, Sande MA. Clinical aspects of adult epiglottitis. *West J Med* 1986; **144**: 700–3
82. Yardley MH. Supraglottitis in adults. *Practitioner* 1986; **230**: 583–7
83. Gerrish SP, Jones AS, Watson DM, Wight RG. Adult epiglottitis. *Br Med J (Clin Res Ed* 1987; **295**: 1183–4
84. Mayo-Smith M. Fatal respiratory arrest in adult epiglottitis in the intensive care unit. Implications for airway management. *Chest* 1993; **104**: 964–5
85. Stuart M, Hodgetts T. Adult epiglottitis: prompt diagnosis saves lives. *Br Med J* 1994; **308**: 329–30
86. Ames WA, Ward VM, Tranter RM, Street M. Adult epiglottitis: an under-recognized, life-threatening condition. *Br J Anaesth* 2000; **85**: 795–7
87. Rucklidge MW, Patel A. Failure of the single-use bougie in acute epiglottitis. *Anaesthesia* 2004; **59**: 925–6
88. Shepherd M, Kidney E. Adult epiglottitis. *Accid Emerg Nurs* 2004; **12**: 28–30
89. Chandradeva K, Palin C, Ghosh SM, Pinches SC. Percutaneous transtracheal jet ventilation as a guide to tracheal intubation in severe upper airway obstruction from supraglottic oedema. *Br J Anaesth* 2005; **94**: 683–6
90. Mathoera RB, Wever PC, van Dorsten FR, Balter SG, de Jager CP. Epiglottitis in the adult patient. *Neth J Med* 2008; **66**: 373–7
91. Diaz K, Malave A. "Cherry red emergency": acute epiglottitis requiring surgical airway. *Chest* 2012; **142**(Supplement): 12A
92. Harvey M, Quagliotto G, Milne N. Fatal epiglottic abscess after radiotherapy for laryngeal carcinoma. *Am J Forensic Med Pathol* 2012; **33**: 297–9
93. Shafiq F, Sladkowski A. Do the clinical parameters provide the reliable indication of airway findings in adult patients with acute supraglottitis? *J Anaesthesiol Clin Pharmacol* 2012; **28**: 378–80
94. Barrett O, De'Francesco Brace R, Mukherjee A. A *case report: the tight orifice. 19th Annual Conference of ISCCM*. Criticare 2013: P070. Available from: https://www.ijccm.org/doi/IJCCM/pdf/10.5005/ijccm-17-S2-1 (accessed 21 August 2021).
95. Choi HL, Min JH, Kang JH, Kim H, Park JS. Postobstructive pulmonary edema that developed immediately after emergency surgical cricothyroidotomy. *Am J Emerg Med* 2016; **34**: 936. e1–936.e2

96. Lindquist B, Zachariah S, Kulkarni A. Adult epiglottitis: a case series. *Perm J* 2017; **21**: 16–89
97. Collins J, Bailey K. Scalpel, bougie, tube: successful front-of-neck access in the emergency department. *Anaesthesia* 2018; **73**(Suppl. 4): 12–116
98. Zimmermann T, Chmiel C. *Neisseria meningitidis* sepsis in a patient with acute epiglottitis and respiratory failure. *BMJ Case Rep* 2018; **2018**, bcr2017223388
99. Ma J-G, An J-X. Acute epiglottitis in a diabetic adult patient. *Chin Med J (Engl)* 2018; **131**: 109–10
100. Epskamp J, Winters SM, Spronk PE. Pulmonary oedema after acute upper airway obstruction. *Neth J Crit Care* 2019; **27**: 24–5
101. Wenger D, Donovan L, Adamson R. A difficult airway: a case of Strep milleri group epiglottitis. *Chest* 2016; **150**(Supplement): 420A
102. McNarry AF, Patel A. The evolution of airway management - new concepts and conflicts with traditional practice. *Br J Anaesth* 2017; **119**(suppl_1): i154–66
103. Cook TM, MacDougall-Davis SR. Complications and failure of airway management. *Br J Anaesth* 2012; **109**(Suppl 1). i68–i85
104. Brown III CA, Bair AE, Pallin DJ, Walls RM. Techniques, success and adverse events of emergency department adult intubations. *Ann Emerg Med* 2015; **65**: 363–70
105. Cook TM. Strategies for the prevention of airway complications – a narrative review. *Anaesthesia* 2018; **73**: 93–111
106. Flavell E, Stacey M, Hall J. The clinical management of airway obstruction. *Curr Anaesth Crit Care* 2009; **20**: 102–12
107. Lynch J, Crawley S. Management of airway obstruction. *BJA Educ* 2018; **18**: 46–51
108. Bridwell RE, Koyfman A, Long B. High risk and low prevalence diseases: adult epiglottitis. *Am J Emerg Med* 2022; **57**: 14–20
109. Mason RA, Fielder CP. The obstructed airway in head and neck surgery. *Anaesthesia* 1999; **54**: 625–8
110. Patel A, Pearce A, Pracy P. Head and neck pathology. In: *Royal College of Anaesthetists. 4th National Audit Project: major Complications of airway management in the UK*. London: RCoA; 2011 [Chapter 18]
111. Frerk C, Mitchell V, McNarry A, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth* 2015; **115**: 827–48
112. Joshi R, Hypes C, Greenberg J, et al. Difficult airway characteristics associated with first-attempt failure at intubation using video laryngoscopy in the intensive care unit. *Ann Am Thorac Soc* 2017; **14**: 368–75
113. Semler M, Mikkelsen M. If at first you don't succeed: patient characteristics associated with first-attempt failure of video laryngoscopy in the intensive care unit. *Ann Am Thorac Soc* 2017; **14**: 305–6
114. Kelly FE, Frerk C, Bailey CR, et al. Human factors in anaesthesia: a narrative review. *Anaesthesia* 2023; **78**: 479–90
115. Hung O, Murphy M. Context-sensitive airway management. *Anesth Analg* 2010; **110**: 982–3
116. Driver BE, Mosier JM, Brown 3rd CA. The importance of the intubation process for the safety of emergency airway management. *Acad Emerg Med* 2020; **27**: 1362–5

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