A META-ANALYSIS OF PREHOSPITAL AIRWAY CONTROL TECHNIQUES PART I: OROTRACHEAL AND NASOTRACHEAL INTUBATION SUCCESS RATES

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ABSTRACT

Background. Airway management is a key component of prehospital care for seriously ill and injured patients. Although endotracheal intubation has been a commonly performed prehospital procedure for nearly three decades, the safety and efficacy profile of prehospital intubation has been challenged in the last decade. Reported intubation success rates vary widely, and established benchmarks are lacking. **Objective.** We sought to determine pooled estimates for oral endotracheal intubation (OETI) and nasotracheal intubation (NTI) placement success rates through a meta-analysis of the literature. **Methods.** We performed a systematic literature search for all English-language articles reporting placement success rates for prehospital intubation. Studies of field procedures performed by prehospital personnel from any nation were included. All titles were reviewed independently by two authors using prespecified inclusion criteria. Pooled estimates of success rates for each airway technique, including drug-facilitated intubation (DFI) and rapid-sequence intubation (RSI), were calculated using a random-effects model. Historical trends were evaluated using meta-regression. **Results.** Of 2,005 identified titles reviewed, 117 studies addressed OETI and 23 addressed NTI, encompassing a total of 57,132 prehospital patients. There was substantial interrater reliability in the review process (kappa = 0.81). The pooled estimates (and 95% confidence intervals [CIs]) for intervention success for nonphysician clinicians were as follows: overall non-RSI/non-DFI OETI success rate: 86.3% (82.6%–89.4%); OETI for non–cardiac arrest patients: 69.8% (50.9%–83.8%); DFI 86.8% (80.2%–91.4%); and RSI 96.7% (94.7%–98.0%). For pediatric patients, the paramedic OETI success rate was 83.2% (55.2%–95.2%). The overall NTI success rate for nonphysician clinicians was 75.9% (65.9%–83.7%). The historical trend of OETI reflects a 0.49% decline in success rates per year. **Conclusions.** We provide pooled estimates of placement success rates for prehospital airway interventions. For some patient and clinician characteristics, OETI has relatively low success rates. For nonarrest patients, DFI and RSI appear to increase success rates. Across all clinicians, NTI has a low rate of success, raising questions about the safety and efficacy of this procedure.
Key words: EMS; paramedic; prehospital; intubation; airway management; RSI; orotracheal intubation; nasotracheal intubation

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INTRODUCTION

Airway management is fundamental in the out-of-hospital resuscitation of critically ill and injured patients, and failure to establish a patent airway in the field is associated with negative outcomes in some patients.[1,2] Early advanced prehospital airways included the esophageal obturator airway (EOA) and the esophageal gastric tube airway (EGTA), but these were quickly supplanted by endotracheal intubation (ETI), which has now been commonly employed in the prehospital arena for nearly three decades.[3–5] However, the safety and efficacy of prehospital ETI have been challenged in the last decade,[6–8] and reported failure rates vary widely, ranging between 0% and 50%.[9–13]

The wide variation in reported ETI failure rates may partially be explained by the route (oral vs. nasal), setting, training and experience of the clinician, access to neuromuscular-blocking agents, patient age, and other patient characteristics such as trauma vs. nontrauma and cardiac arrest vs. nonarrest. Unfortunately, most investigations of prehospital airway management include heterogeneous patient populations, settings, and clinicians, obscuring the true procedural success rates for these subgroups. Furthermore, many of the studies evaluating prehospital airway management are small and underpowered, which is especially problematic when these relatively small differences in success rates may be clinically relevant. To address these

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limitations of the current body of literature and provide some clarity regarding the procedural success rates of prehospital airway interventions, we sought to determine pooled estimates for oral endotracheal intubation (OETI) and nasotracheal intubation (NTI) placement success rates across varied yet homogeneous groupings of patient characteristics, clinician credentials, and practice settings, using meta-analytic techniques.

METHODS

This systematic review and meta-analysis received exemption from institutional review board (IRB) monitoring from Western Carolina University and, to the extent possible, was designed to conform to the recommendations of the Quality of Reporting of Meta-Analysis (QUOROM) statement.[14]

Search Strategy

The search strategy was designed to identify all reports concerning out-of-hospital airway management, from which we could then isolate papers regarding success rates of OETI and NTI performed by prehospital personnel in the field. Studies were identified through a comprehensive search of the PubMed database using Medical Subject Headings (MeSH) and text word searches, as well as Boolean search strings (Table 1). The search was limited to English-language articles, but international papers were not otherwise excluded. The search was originally conducted on November 20, 2008, and updated on July 6, 2009. The bibliographies of selected studies were also reviewed to identify any additional relevant studies. Study authors were not contacted in an attempt to identify additional unpublished studies.

Screening Process

All titles identified by the search were distributed among the study team for independent review by two authors; only those titles for which both reviewers indicated a lack of relevance were excluded. The abstracts of the retained papers were then subjected to an identical independent review process, and again papers were excluded only if both reviewers indicated a lack of relevance. Finally, the full manuscripts of papers retained after the abstract review underwent independent review by two authors, with discrepancies in decisions about relevance resolved by consensus. Interrater reliability at each of these steps—including prior to consensus discussions in the final step—was measured using the kappa statistic.

Selection

All published reports of airway procedures performed by emergency medical technicians (EMTs), paramedics, nurses, or physicians practicing in the prehospital environment were included. Studies conducted on cadavers or manikins, studies not conducted in a field setting (e.g., procedures performed in an emergency department or surgical suite), and any studies that did not include sufficient data to calculate a procedural success rate were excluded. We did not restrict our search to randomized controlled trials (RCTs); cohort studies as well as retrospective reviews were eligible for inclusion. Case studies and case series with small sample sizes ($N < 5$), reviews, editorials, and abstracts were excluded. Where studies reported duplicate data, preference was given to the earliest publication providing the most detailed data; similarly, where studies reported overlapping data (e.g., multiple queries of the same data registry), preference was given to the broadest study with the most detailed data.

Quality Assessment

Most quality assessment tools commonly employed in meta-analysis are designed for evaluating RCTs.[14] To better accommodate non-RCT study designs, the quality of each study was evaluated using an assessment tool devised by the authors (Table 2). The tool is a 10-item scale that measures the methodologic quality of the included studies relative to the purpose of our meta-analysis. The primary foci of the scale are study design, setting, patient population, personnel, and verification of successful placement of the airway device. Potential scores on the scale range from 0 to 10. Quality scores were independently assigned by two authors, with discrepancies resolved by consensus.

Data Extraction

The following variables were extracted from each study: route of intubation (OETI vs. NTI), patient age, clinical characteristics of the patient population (e.g., cardiac arrest vs. nonarrest, trauma vs. nontrauma), use of sedatives or other drugs for drug-facilitated intubation (DFI) or neuromuscular-blocking agents for rapid-sequence intubation (RSI), credentials of the intubating personnel, setting in which the procedure was performed, mechanism for verifying successful placement, whether the airway interventions were used for primary airway control or as a salvage airway, and the numbers of successful and unsuccessful attempts. Consistent with previous investigations, we used an a priori definition of age less than or equal to 12 years to identify pediatric patients.[6] Data were independently abstracted by at least two authors.

TABLE 1. Search Terms

Airway search terms	
intubation [mh]	*King airway* [tw]
intubation, intratracheal [mh]	*King* [tw]
endotracheal intubation [tw]	*pharyngeotracheal airway* [tw]
orotracheal intubation [tw]	*pharyngeal-tracheal airway* [tw]
oral intubation [tw]	*PTLA* [tw]
nasotracheal intubation [tw]	*laryngeal mask airway* [tw]
nasal intubation [tw]	
EMS search terms	
emergency medical technicians [mh]	*prehospital* [tw]
emergency medical services [mh]	*pre-hospital* [tw]
ambulances [mh]	*out-of-hospital* [tw]
air ambulances [mh]	*out of hospital* [tw]
paramedic [tw]	
Boolean search strings	
prehospital and *endotracheal intubation*	*field* and *endotracheal intubation*
prehospital and *orotracheal intubation*	*field* and *orotracheal intubation*
prehospital and *oral intubation*	*field* and *oral intubation*
prehospital and *nasotracheal intubation*	*field* and *nasotracheal intubation*
prehospital and *nasal intubation*	*field* and *nasal intubation*
prehospital and *King tube*	*field* and *King tube*
prehospital and *King airway*	*field* and *King airway*
prehospital and *pharyngeal tracheal airway*	*field* and *pharyngeal tracheal airway*
prehospital and *pharyngeal-tracheal airway*	*field* and *pharyngeal-tracheal airway*
prehospital and *pharyngeotracheal airway*	*field* and *pharyngeotracheal airway*
prehospital and *PTLA*	*field* and *PTLA*
prehospital and *LMA*	*field* and *LMA*
prehospital and *laryngeal mask airway*	*field* and *laryngeal mask airway*
prehospital and *esophageal-tracheal airway*	*field* and *esophageal-tracheal airway*
prehospital and *Combitube*	*field* and *Combitube*
paramedic and *endotracheal intubation*	*paramedic* and *pharyngeal-tracheal airway*
paramedic and *orotracheal intubation*	*paramedic* and *pharyngeotracheal airway*
paramedic and *oral intubation*	*paramedic* and *PTLA*
paramedic and *nasotracheal intubation*	*paramedic* and *LMA*
paramedic and *nasal intubation*	*paramedic* and *laryngeal mask airway*
paramedic and *King tube*	*paramedic* and *esophageal-tracheal airway*
paramedic and *King airway*	*paramedic* and *Combitube*
paramedic and *pharyngeal tracheal airway*	

EMS = emergency medical services; LMA = laryngeal mask airway; [mh] = Medical Subject Heading (MeSH); PTLA = pharyngeal tracheal lumen airway; [tw] = text word.

Disconcordant opinions regarding abstracted data were resolved by discussion until consensus was attained. In cases in which consensus could not be achieved regarding data abstraction, differences were adjudicated by a third author.

Data Analysis

The primary outcome variable was the pooled proportion (and 95% confidence interval [CI]) for successful OETI and NTI. The proportion of successful placements was defined as the number of patients in whom a patent airway was established divided by the number of patients in whom an airway procedure was attempted, regardless of the number of placement attempts. Nonplacement and esophageal, hypopharyngeal, and mainstem bronchial positioning were all considered to be unsuccessful placement.

All data were analyzed using the Comprehensive Meta-Analysis software package, version 2.0 (Biostat, Inc., Englewood, NJ). Because of variations in the design, setting, and patient populations of the selected studies, a random-effects model was used for pooling study results. Subgroup analysis was performed when it was possible to isolate certain patient groups (e.g., evaluating trauma patients and nontrauma patients independently), clinician credentials (e.g., paramedic vs. physician), and ancillary procedures (e.g., RSI vs. non-RSI).

Heterogeneity was explored through the use of the Cochrane Q test for heterogeneity and the I^2 statistic. Publication bias was evaluated with funnel plots and the Egger regression test. Meta-regression was used to analyze the historical trend of OETI success rate.

RESULTS

Trial Flow

Figure 1 shows the screening process and the results at each step in the format recommended by the QUOROM statement.[14] There was moderate to substantial interrater reliability for the reviews, with increasing kappa values at each step of the process.

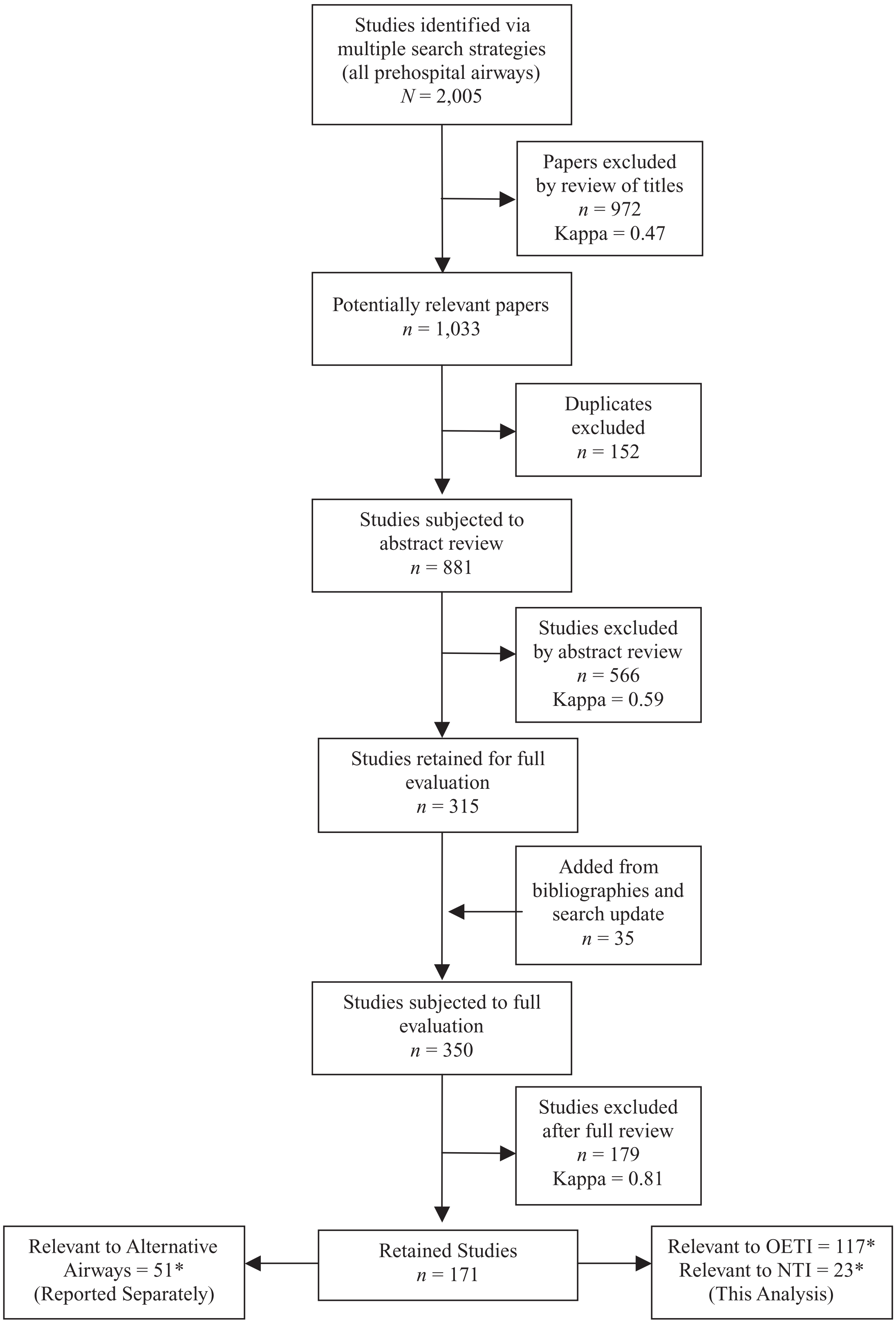

FIGURE 1. Search strategies and results for each airway procedure. *Some studies reported multiple techniques. NTI = nasotracheal intubation; OETI = oral endotracheal intubation.

TABLE 2. Study Quality Assessment Tool Used to Assess the Quality of Included Studies

Criteria	Points
Study design	
Retrospective or before–after design	0
Prospective design	1
Clinician	
Credentials of clinicians not clearly stated or mixed	0
Clearly defined homogeneous group	1
Patient mix	
Patient population undefined or mixture of trauma and medical patients	0
Clearly defined homogeneous group	1
Setting	
Mixture of hospital, air, and field settings	0
Homogeneous field or air setting	1
Verification of successful placement	
Undefined or clinical verification only (breath sounds, chest rise, etc.)	0
Verified by a single objective criterion (colorimetric $ETCO_2$ detector, continuous capnography, oxygen saturation)	1
Verified by two or more objective criteria or ED physician	2
Age	
Patient population undefined or mixture of adult and pediatric patients	0
Clearly defined homogeneous group	1
Cardiac arrest	
Patient population undefined or mixture of arrest/nonarrest patients	0
Clearly defined homogeneous group	1
Drug-assisted intubation	
Undefined or mixture of drug-assisted, non–drug-assisted, and rapid-sequence intubations	0
Clearly defined homogeneous group	1
Salvage airway	
Undefined or device used as both primary and salvage airway technique	0
Clearly defined homogeneous group	1
Total score	__/10

ED = emergency department; $ETCO_2$ = end-tidal carbon dioxide.

The initial PubMed search strategy identified 2,005 citations relevant to prehospital airway techniques. Of these, 881 abstracts were evaluated with 315 studies selected for full review. Hand searching of the bibliographies of the studies and the updated search identified an additional 35 titles, for a total of 350 papers subjected to full review. Of these, 171 met our criteria for reporting any type of advanced prehospital airway intervention—117 studies specifically addressed OETI and 23 addressed NTI, encompassing a combined total of 57,132 prehospital patients—and were retained for inclusion in this meta-analysis.

Study Characteristics

An overall summary of the characteristics for OETI and NTI studies retained in the analysis is shown in Table 3. Of the 117 studies reporting prehospital OETI,[3,6–7,9–13,15–123] 56 were prospective, eight had a before–after design, and those remaining were retrospective. Combined, the studies included 54,933 patients. The quality scores for the studies ranged from 1 to 10, with a mean (±standard deviation) score of 5.1 (±2.1). Detailed characteristics of the OETI studies are provided in Appendix 1.

Of the 23 studies reporting NTI,[13,21,27,28,31,37,62,69,74,87,88,92,107,108,113,116,117,121,122,124–127] nine had a prospective design and 14 had retrospective designs. The total sample size was 2,199 patients. The quality scores ranged from 1 to 7, with a mean of 4.6 (±1.5). Detailed characteristics of the NTI studies are provided in Appendix 2.

Rapid-sequence intubations were included in 27 studies, encompassing 6,532 patients.[7,9,18,23,26,35,54,65,68,71,77,78,80,87,94,96–99,105,106,109,112,113,117,118,120] These studies had a mean quality score of 5.6 (±2.1), with scores ranging from 2 to 10. DFI, utilizing sedatives or other drugs but not neuromuscular-blocking agents, was reported in 12 studies with a total of 1,285 patients.[20,26,30,42,45,58,66,68,85,90,102,118] The quality scores for these studies ranged from 2 to 9, with a mean of 5.8 (±1.9). Details of the RSI and DFI studies are provided in Appendix 3 and Appendix 4, respectively.

Quantitative Data Synthesis

Orotracheal Intubation

Across all clinicians and all 54,933 patients for whom OETI was attempted (including RSI and DFI), the pooled success rate was 89.2% (CI = 87.7%–90.5%). Substantial heterogeneity existed in the group of studies as evidenced by the Cochrane Q statistic (χ^2 = 3,151; $p < 0.001$), and the I^2 statistic was 95.1%, suggesting that a substantial amount of across-study variance was caused by heterogeneity. The funnel plot exhibited only mild asymmetry and the result of the Egger test for publication bias was nonsignificant ($t = 1.91$, $p = 0.058$) (Fig. 2).

Several subgroup analyses were performed on the non-RSI/non-DFI subset of OETI studies to evaluate the influence of patient characteristics and clinician credentials on the procedural success rate (Table 4). Nonphysician clinicians attempted OETI in 18,404 patients, with a pooled success rate of 86.3% (CI = 82.6%–89.4%) (Fig. 3). There was little difference in OETI success rates between air medical crews and ground paramedics (88.1% vs. 87.5%). Overall intubation success rates were substantially higher in nontrauma patients (88.6%, CI = 83.6%–92.2%) than in trauma patients (73.7%, CI = 62.6%–82.5%), as well as in cardiac arrest patients (91.2% CI = 88.8%–93.1%) compared with nonarrest patients (70.4%, CI = 58.7%–80.0%). This remained true when limiting the analysis to OETI performed only by ground paramedics.

Representing less than 1% of the total pooled data, physicians attempted 127 intubations, with a pooled

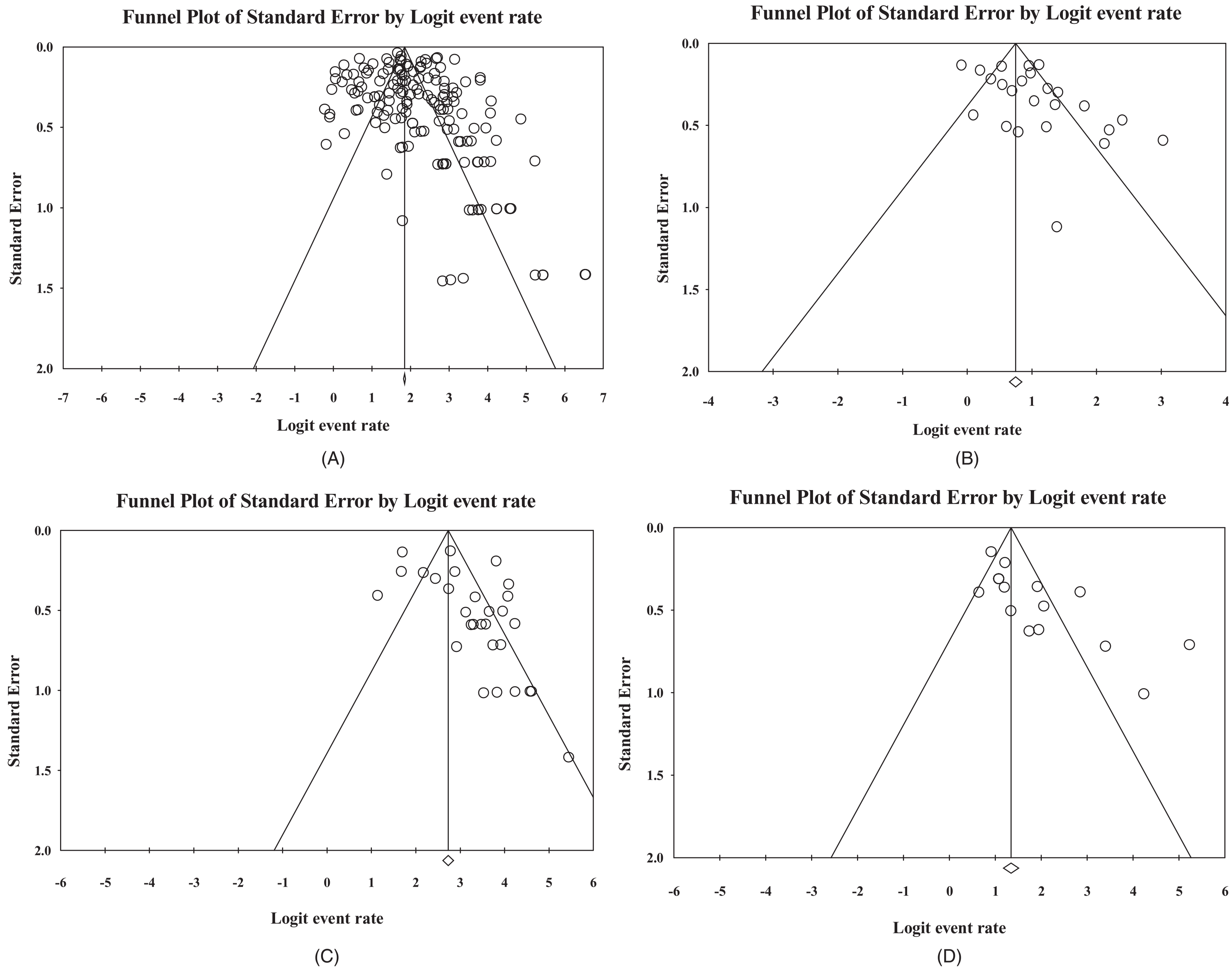

FIGURE 2. Funnel plot assessment of publication bias: **A**) oral endotracheal intubation; **B**) nasotracheal intubation; **C**) rapid-sequence intubation; and **D**) drug-facilitated intubation.

TABLE 3. Study Design and Population Characteristics*

Study Characteristics	OETI ($n = 117$)	NTI ($n = 23$)
Design		
Prospective	56 (47.9%)	9 (39.1%)
Before–after	8 (6.8%)	0 (0.0%)
Retrospective	53 (45.3%)	14 (60.9%)
Subjects (n)		
Minimum–maximum	7–5,371	5–315
Median (IQR)	5 (4–7)	63 (37–105)
Mean ± SD	349 ± 727	92 ± 86
Quality score		
Minimum–maximum	1–10	1–7
Median (IQR)	5 (4–7)	5 (4–6)
Mean ± SD	5.1 ± 2.1	4.6 ± 1.5
Clinician		
Physician	11 (9.4%)	1 (4.3%)
Paramedic	56 (47.9%)	11 (47.8%)
Nurse	4 (3.4%)	1 (4.3%)
EMT/EMT-I	3 (2.6%)	0 (0.0%)
Other†	7 (6.0%)	0 (0.0%)
Mixed/not specified	38 (32.5%)	11 (47.8%)
Patient mix		
Nontrauma	15 (12.8%)	1 (4.3%)
Trauma	27 (23.1%)	6 (26.1%)
Mixed/not specified	78 (66.7%)	16 (69.6%)
Setting		
Ground	69 (59.0%)	11 (47.8%)
Air	26 (22.2%)	6 (26.1%)
Mixed/not specified	24 (20.5%)	6 (26.1%)
Verifier		
Intubator	53 (45.3%)	11 (47.8%)
ED physician	32 (27.4%)	8 (34.8%)
Mixed/not specified	32 (27.4%)	4 (17.4%)
Verification method		
Clinical assessment	8 (6.8%)	1 (4.3%)
Objective methods	10 (8.5%)	3 (13.0%)
Multiple methods	37 (31.6%)	6 (26.1%)
Not specified	62 (53.0%)	13 (56.5%)
Patient ages		
Adult (>12 years old)	35 (29.9%)	4 (17.4%)
Pediatric (≤12 years old)	16 (13.7%)	1 (4.3%)
Mixed/not specified	73 (62.4%)	18 (78.3%)
Perfusion		
Cardiac arrest	22 (18.8%)	0 (0.0%)
Nonarrest	36 (30.8%)	11 (47.8%)
Mixed/not specified	69 (59.0%)	12 (52.2%)
RSI/DFI		
None	37 (31.6%)	11 (47.8%)
RSI	26 (22.2%)	1 (4.3%)
DFI	13 (11.1%)	0 (0.0%)
Mixed/not specified	57 (48.7%)	11 (47.8%)
Intervention		
Primary intubation	50 (42.7%)	9 (39.1%)
Salvage airway	7 (6.0%)	0 (0.0%)
Mixed/not specified	62 (53.0%)	14 (60.9%)

*Totals may exceed 100% because some studies reported multiple subanalyses.

†Respiratory therapists, nurse practitioners, nonparamedic international EMS providers, etc.

Capnography, capnometry, etc.

DFI = drug-facilitated intubation; ED = emergency department; EMS = emergency medical services; EMT = emergency medical technician; IQR = interquartile range; NTI = nasotracheal intubation; OETI = oral endotracheal intubation; RSI = rapid-sequence intubation; SD = standard deviation.

success rate of 91.8% (CI = 85.0%–95.6%). Only one small study explicitly identified intubations of nontrauma patients performed by physicians, for which the success rate was 94.0% (CI = 86.3%–97.5%). No studies specifically evaluated physician prehospital intubation of trauma patients or nonarrest patients.

Only three studies reported non-RSI/non-DFI intubation success rates among pediatric patients.[16,44,70] For this group, all intubations were performed by ground paramedics, with a pooled success rate of 83.2% (CI = 55.2%–95.2%).

Nasotracheal Intubation

Across all clinicians and patient groups, NTI was attempted in 2,199 patients (including RSI and DFI), with a pooled success rate of 73.1% (CI = 67.8%–77.7%). Substantial heterogeneity existed in the group of studies as evidenced by the Cochrane Q statistic ($\chi^2 = 131.47$; $p < 0.001$), and the I^2 statistic was 82.5%. The funnel plot exhibited moderate asymmetry and the result of the Egger test for publication bias was significant ($t = 2.662$, $p = 0.014$) (Fig. 2).

In the subgroup of NTI without RSI or DFI (Table 4), there were 585 reported patients in whom NTI was attempted by nonphysician clinicians, with a pooled success rate of 75.9% (CI = 65.9%–83.7%) (Fig. 4). Only one study reported NTI performed specifically in trauma patients by nonphysician clinicians, with a success rate of 90.0% (CI = 76.2%–96.2%). A total of 87 patients had NTI attempted by nonphysician air medical personnel, yielding a pooled success rate of 77.9% (CI = 67.9%–85.5%), compared with a pooled success rate of 76.2% (CI = 63.9%–85.2%) for NTI performed by ground personnel. There were no reports of non-RSI/non-DFI NTI performed exclusively by physicians.

Rapid-Sequence Intubation and Drug-Facilitated Intubation

A total of 6,532 patients received RSI across all levels of clinician credentials and settings. The pooled success rate for this group was 96.1% (CI = 94.5%–97.3%). Substantial heterogeneity existed in the group of studies as evidenced by the Cochrane Q statistic ($\chi^2 = 199.0$; $p < 0.001$), and the I^2 statistic was 85.9%. The funnel plot exhibited moderate asymmetry and the result of the Egger test for publication bias was significant ($t = 2.89$, $p = 0.007$) (Fig. 2).

When performed by all nonphysician clinicians, the RSI success rate was 96.7% (CI = 94.7%–98.0%) (Fig. 5). In the air medical setting, the RSI success rate was 97.7% (CI = 96.7%–98.5%), compared with a success rate of 94.8% (CI = 90.2%–97.3%) for RSI performed by ground paramedics. Similar to OETI success, RSI success was greater in nontrauma patients, and this remained true when limiting the analysis to RSI performed only by ground paramedics. A single study reported a prehospital RSI success rate of 93.9% (CI = 88.3%–96.9%) for physicians. Across all patients and clinicians, RSI success rates were greater than those for OETI in nonarrest patients without RSI or DFI.

OETI Success Rates (all patients, non-physicians only)

Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Total
Aijian, 1989 (Ages 0-19 mix)[16]	0.643	0.454	0.796	1.490	0.136	18 / 28
Bradley, 1998[11]	0.491	0.365	0.619	-0.132	0.895	28 / 57
Bulger, 2002 (non-RSI only)[23]	0.907	0.891	0.921	25.119	0.000	1308 / 1442
Cady, 2005 (OETI post-Combitube)[25]	0.916	0.904	0.927	30.687	0.000	1964 / 2144
Cady, 2005 (OETI pre-Combitube)[25]	0.935	0.926	0.943	36.840	0.000	2938 / 3142
Colwell, 2005[27]	0.928	0.871	0.961	7.764	0.000	128 / 138
Davis, 2006[29]	0.809	0.779	0.837	15.060	0.000	569 / 703
DeLeo,1977 (paramedics only)[3]	0.906	0.883	0.924	18.524	0.000	711 / 785
Doran, 1995[31]	0.888	0.833	0.927	8.738	0.000	159 / 179
Eckstein, 2000[33]	0.628	0.548	0.702	3.088	0.002	93 / 148
Frankel, 1997[36]	0.810	0.689	0.892	4.336	0.000	47 / 58
Garza, 2003[38]	0.853	0.830	0.873	20.319	0.000	909 / 1066
Gerritse, 2008 (paramedics only)[44]	0.854	0.710	0.933	3.991	0.000	35 / 41
Goldenberg, 1986[46]	0.902	0.838	0.942	7.580	0.000	119 / 132
Gray, 1992[47]	0.977	0.913	0.994	5.241	0.000	85 / 87
Hedges, 1988 (non-RSI)[54]	0.958	0.922	0.978	9.193	0.000	206 / 215
Jones, 2004[62]	0.950	0.907	0.974	8.610	0.000	171 / 180
Kenny, 1996 (no drug assist)[66]	0.617	0.489	0.730	1.790	0.073	37 / 60
Losek, 1989 (arrests of all ages)[70]	0.907	0.777	0.965	4.338	0.000	39 / 43
Losek,1989 (non arrests of all ages)[70]	0.476	0.279	0.682	-0.218	0.827	10 / 21
McCall, 2008[73]	0.913	0.790	0.967	4.494	0.000	42 / 46
Mishark, 1992[74]	0.810	0.709	0.882	5.058	0.000	64 / 79
Murray, 2000[75]	0.587	0.503	0.666	2.033	0.042	81 / 138
Pratt, 2005[83]	0.938	0.782	0.984	3.708	0.000	30 / 32
Reed, 2002 (non-drug assist only)[85]	0.842	0.802	0.875	11.964	0.000	324 / 385
Rocca, 2000[88]	0.961	0.934	0.977	11.299	0.000	318 / 331
Sayre, 1998 (EMT all attempts)[91]	0.515	0.419	0.609	0.296	0.768	53 / 103
Sayre, 1998 (paramedic after EMT fail)[91]	0.977	0.856	0.997	3.718	0.000	43 / 44
Shea, 1985[93]	0.867	0.811	0.908	8.885	0.000	169 / 195
Slater, 1998 (non RSI)[96]	0.946	0.808	0.986	3.937	0.000	35 / 37
Stewart, 1984 (cardiac arrest, medical)[100]	0.906	0.882	0.925	17.602	0.000	642 / 709
Stewart, 1984 (mixed cardiac arrest, trauma)[100]	0.788	0.617	0.895	3.082	0.002	26 / 33
Stewart, 1984 (non-cardiac arrest, medical)[100]	0.892	0.745	0.959	3.986	0.000	33 / 37
Stiell, 2004 (cardiac arrest)[101]	0.937	0.929	0.944	40.693	0.000	3605 / 3848
Tam, 2009[107]	0.662	0.631	0.693	9.444	0.000	581 / 877
Wang, 2001 (cardiac arrest, no drug assist)[116]	0.932	0.909	0.950	16.017	0.000	551 / 591
Weitze,l 2004[121]	0.750	0.544	0.883	2.331	0.020	18 / 24
Weston, 1992[123]	0.947	0.909	0.970	9.712	0.000	214 / 226
Summary Effect	**0.863**	**0.826**	**0.894**	**12.564**	**0.000**	**16403/18404**

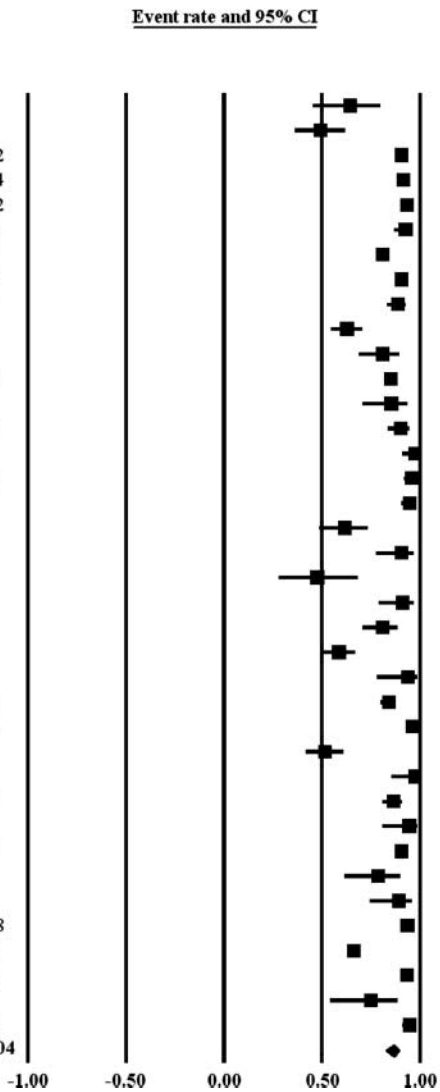

FIGURE 3. Forest plot of oral endotracheal intubation (OETI) (nonphysician only). CI = confidence interval; EMT = emergency medical technician; RSI = rapid-sequence intubation.

Drug-facilitated intubation was attempted in 1,355 patients, with a pooled success rate of 86.2% (CI = 79.9%–90.8%) across all patients and clinicians. Substantial heterogeneity existed in the group of studies as evidenced by the Cochrane Q statistic ($\chi^2 = 81.7$; $p < 0.001$), and the I^2 statistic was 82.87%. The funnel plot exhibited moderate asymmetry and the result of the Egger test for publication bias was significant ($t = 3.84$, $p = 0.002$) (Fig. 2). The success rate for DFI performed by nonphysician clinicians was 86.8% (CI = 80.2%–91.4%) (Fig. 6). The success rate for DFI performed by nonphysician clinicians in the air medical setting was 94.6% (CI = 89.3%–97.4%), which was substantially greater than the 79.1% (CI = 73.6%–83.7%) success rate for DFI by ground paramedics. Only one small study ($n = 29$) reported DFI performed by physicians. In this study of trauma patients with a mixture of trismus, restlessness, and/or anatomic airway disruption, physicians were able to perform DFI with a success rate of 65.5% (46.9%–80.3%). The complete RSI and DFI subanalysis results are shown in Table 4.

Verification Techniques

For most analyses, success rates were based on self-reported success by the intubating clinician. A subanalysis was performed to compare self-reported success rates with those from studies in which placement was independently verified in the receiving

TABLE 4. Subanalysis Results: Success Rate (%) and 95% Confidence Interval

Patient Group	All Clinicians	All Nonphysicians*	Ground Paramedics	Nonphysician Flight Crews*	Physicians
OETI†					
All	86.5 (83.3–89.2)	86.3 (82.6–89.4)	87.5 (83.7–90.5)	88.1 (65.7–96.6)	91.8 (85.0–95.6)
Trauma only	73.7 (62.6–82.5)	69.8 (60.1–78.0)	73.7 (62.1–82.7)	—	—
Nontrauma only	88.6 (83.6–92.2)	—	87.9 (82.2–91.9)	—	94.0 (86.3–97.5)
Cardiac arrest only	91.2 (88.8–93.1)	—	91.1 (88.0–93.4)	—	91.8 (85.0–95.6)
Nonarrest only	70.4 (58.7–80.0)	—	69.8 (50.9–83.8)	—	—
Pediatric only	—	—	83.2 (55.2–95.2)	—	—
NTI†					
All	75.4 (68.6–81.2)	75.9 (65.9–83.7)	76.2 (63.9–85.2)	77.9 (67.9–85.5)	—
Trauma only	79.9 (70.1–87.0)	—	90.0 (76.2–96.2)	—	—
RSI					
All	96.1 (94.5–97.3)	96.7 (94.7–98.0)	94.8 (90.2–97.3)	97.7 (96.7–98.5)	93.9 (88.3–96.9)
Trauma only	93.8 (89.8–96.3)	94.0 (89.2–96.7)	88.7 (77.9–94.6)	97.0 (94.9–98.3)	—
Nontrauma only	98.4 (96.9–99.1)	—	—	—	—
DFI					
All	86.2 (79.9–90.8)	86.8 (80.2–91.4)	79.1 (73.6–83.7)	94.6 (89.3–97.4)	—
Trauma only	94.8 (16.8–99.9)	—	—	—	65.5 (46.9–80.3)
Nontrauma Only	87.1 (77.1–93.2)	—	—	—	—

Note: Many articles included aggregated data that encompassed subcategories but that could not be explicitly extracted.
*Includes paramedics, nurses, other EMS personnel, and other allied health professionals.
†Excludes RSI and DFI.
DFI = drug-facilitated intubation; EMS = emergency medical services; NTI = nasotracheal intubation; OETI = oral endotracheal intubation; RSI = rapid-sequence intubation.

emergency department (Table 5). Across all patients, the pooled success rate for studies with independently verified placement was 82.9% (CI = 79.3%–85.9%), which was lower than that from studies using clinician self-reported verification based on clinical assessment alone (auscultation of breath sounds and/or chest rise) (91.5%, CI = 89.0%–93.4%). Notably, the highest self-reported success rate was among patients in whom multiple objective techniques, such as capnometry and capnography, were employed (93.8%, CI = 90.9%–95.8%).

Historical Trend

A post hoc meta-regression analysis was performed on all OETIs performed by nonphysician ground personnel that were verified in the emergency department, with the year in which the data were collected serving as the independent variable. When data were collected over more than one year, the last year of data collection was used as the independent variable. A total of 34 study subgroups from 27 unique studies met the inclusion criteria, encompassing 9,206 patients. The pooled success rate was 82.3% (CI = 78.6%–85.5%) and

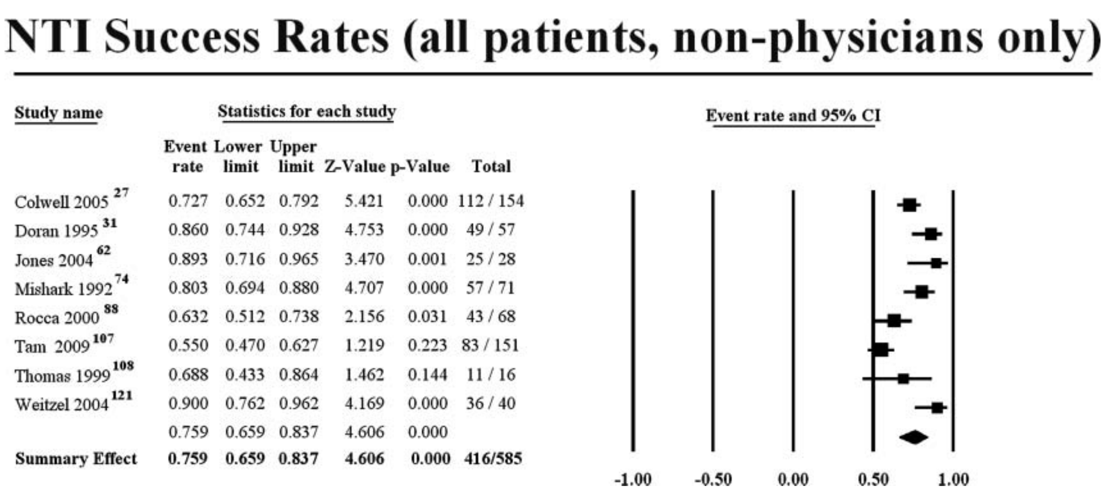

FIGURE 4. Forest plot of nasotracheal intubation (NTI) (nonphysician only). CI = confidence interval.

TABLE 5. Success Rate by Method of Verification

Verification Techniques*				
	Successful Insertion Rate			
Verification	Number of Unique Studies	Pooled *N*	Point Estimate (%) and 95% CI	Quality Score (±SD)
ED verification only	35	10,781	82.9 (79.3–85.9)	6.51 (±2.03)
Clinician verification only (all methods)	45	22,475	89.5 (86.4–92.0)	4.72 (±1.93)
Clinician verification only (clinical assessment only)†	3	5,522	91.5 (89.0–93.4)	3.50 (±0.58)
Clinician verification only (multiple objective techniques only)	16	8,846	93.8 (90.9–95.8)	5.87 (±1.71)

*Nonphysicians only. Includes OETI, RSI, DFI, NTI, and all patient groups.
†Auscultation of breath sounds and/or chest rise.
CI = confidence interval; DFI = drug-facilitated intubation; ED = emergency department; NTI = nasotracheal intubation; OETI = oral endotracheal intubation; RSI = rapid-sequence intubation; SD = standard deviation.

the mean quality score was 7.24 (±1.64). Regressing the year in which the data were collected on the logit event rate, the intercept term was 2.5777 ($p < 0.001$) and the slope coefficient for year was −0.0393 ($p = 0.031$). After converting the logits back to probabilities, the intercept term represents a success rate of 92.9% and the slope represents a decline in success rate of 0.49% per year (Fig. 7).

DISCUSSION

Prehospital intubation is being viewed with increasing skepticism. The literature cites many problems with prehospital intubation, but the most common metric for evaluating intubation is the rate of successful placement.[64,128,129] In our study, we sought to determine pooled estimates for OETI and NTI procedural success rates using meta-analytic techniques, both generally and within homogeneous subgroupings of patient and clinician characteristics.

Overall, the pooled non-RSI/non-DFI OETI success rate was 86.5%, with a success rate of 86.3% for nonphysician clinicians. Stated differently, nonphysician clinicians can be expected to fail at approximately one out of every seven non-RSI/non-DFI intubation attempts. Success rates for nonphysician clinicians were very low for trauma patients (69.8%) compared with nontrauma patients (87.9%), and nonarrest patients (69.8%) compared with cardiac arrest patients (91.1%). In pediatrics, the OETI success rate for nonphysician clinicians was 83.2%; that is, approximately one out of every six prehospital pediatric intubation attempts

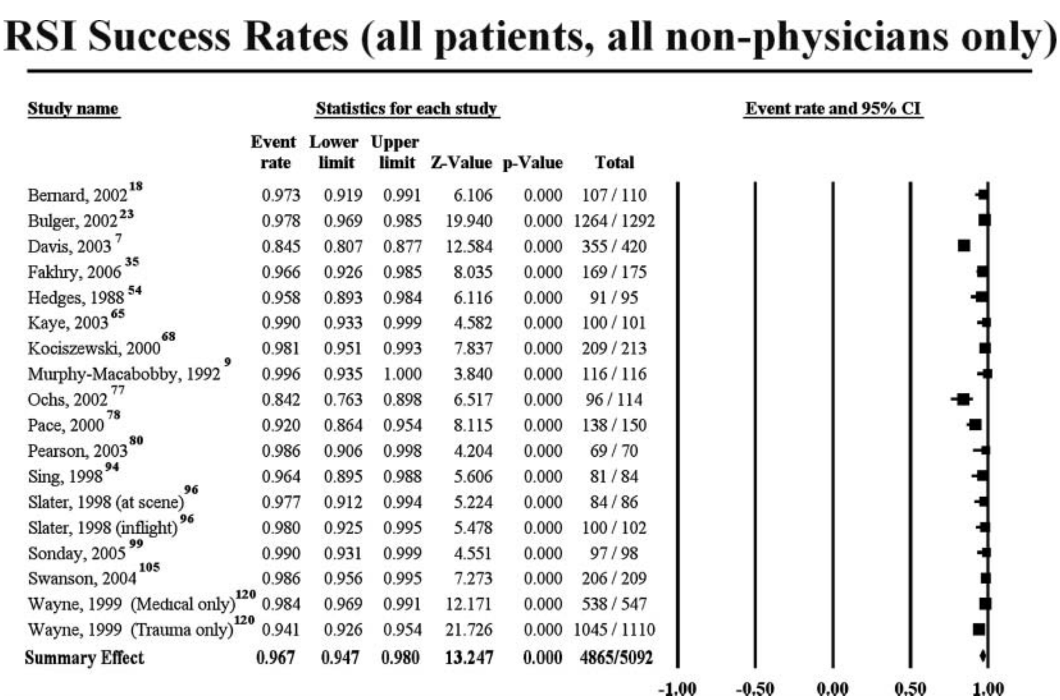

FIGURE 5. Forest plot of rapid-sequence intubation (RSI) (nonphysicians only). CI = confidence interval.

DFI Success Rates (all patients, all non-physicians only)

Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Total
Bozeman, 2002 [20]	0.886	0.755	0.952	4.324	0.000	39 / 44
Dickinson, 1999 [30]	0.850	0.624	0.951	2.770	0.006	17 / 20
Jacoby, 2006 (etomidate only) [58]	0.745	0.615	0.843	3.471	0.001	41 / 55
Jacoby, 2006 (midazolam only) [58]	0.745	0.615	0.843	3.471	0.001	41 / 55
Kenny, 1996 [66]	0.875	0.676	0.959	3.153	0.002	21 / 24
Kociszewski, 2000 (drug assist) [68]	0.968	0.880	0.992	4.732	0.000	60 / 62
Pearson, 2003 (DFI) [80]	0.986	0.906	0.998	4.204	0.000	69 / 70
Reed, 2002 (etomidate only) [85]	0.792	0.587	0.911	2.656	0.008	19 / 24
Reed, 2002 (diazepam only) [85]	0.767	0.619	0.870	3.307	0.001	33 / 43
Sams, 1999 [90]	0.945	0.890	0.974	7.331	0.000	121 / 128
Stiell, 2007 (non-cardiac arrest) [102]	0.871	0.771	0.932	5.359	0.000	61 / 70
Summary Effect	**0.868**	**0.802**	**0.914**	**7.604**	**0.000**	**522/595**

FIGURE 6. Forest plot of drug-facilitated intubation (DFI) (nonphysicians only). CI = confidence interval.

made by a nonphysician can be expected to fail. These data suggest that certain patient populations represent greater challenges to field intubation.

Orotracheal intubation success rates among physicians working in the emergency department and typically employing RSI have been reported in the range of 97.0%–99.3%,[130–132] which is higher than our findings for physicians working in the prehospital setting, although our sample size for physicians was small. Arguably, success rates of physicians working in the prehospital environment can be considered the upper limit of attainable competency for nonphysicians working under similar conditions. In Europe, where prehospital intubations are usually performed by physicians using sedatives and neuromuscular-blocking agents, success rates are high. This suggests that the intubation difficulties encountered by paramedics are related to the training and experience of the paramedics and the availability of sedatives and neuromuscular-blocking agents, rather than being related to the complicating factors of the field setting itself.

The high success rate for nonphysician prehospital RSI found in our meta-analysis contrasts sharply with the non-RSI/non-DFI success rates and highlights the difficulty of intubating nonarrest patients

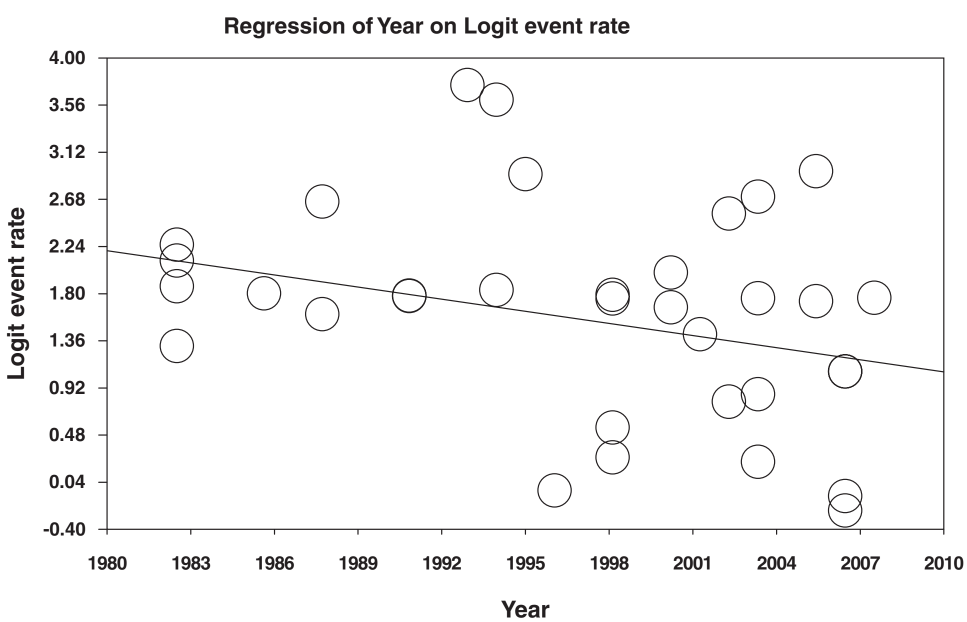

FIGURE 7. Historical trend of oral endotracheal intubation success rate for nonphysician, non–air medical crews with emergency department verification of successful placement.

without pharmaceutical support. In the absence of neuromuscular-blocking drugs, intubation success rates are comparatively poor for nonarrest patients: 69.8% in nonarrest patients intubated without any pharmacologic intervention, 86.8% in nonarrest patients receiving DFI, and 96.7% for nonarrest patients receiving RSI. Although the DFI success rates were higher than those for non-RSI/non-DFI patients, they were still lower than the success rates for RSI. In a series of 49 patients with failed prehospital intubations, Wang et al. reported that 49% were the result of inadequate relaxation, including patients who had prehospital DFI attempts with midazolam.[133] In our subanalysis of DFI, there were insufficient data to differentiate success rates using different medications. Notably, one study used nebulized lidocaine rather than a sedative, but the results for that study did not differ significantly from the pooled results. Regardless of the medication used, DFI is likely to improve success rates over non-DFI in nonarrest patients, but it is unlikely to be as successful as RSI. However, Wang et al. estimated that only about 4% of prehospital intubations potentially require RSI.[133]

Although low intubation success rates may partially be explained by patient characteristics and the lack of access to DFI and RSI, the initial skill attainment of prehospital personnel has also been implicated. The national standard paramedic curriculum requires students to perform only five successful intubations to meet graduation requirements, which is less than what is believed to be necessary to attain competency,[134] and far fewer than the number suggested for other clinicians.[135,136] In addition to the initial acquisition of intubation skills, routine use of those skills is necessary to maintain proficiency. Unfortunately, the opportunity to intubate may be too infrequent for some prehospital providers to maintain proficiency.[24,137] Given the challenges posed by the field setting, it may be unreasonable to expect paramedics to achieve a very high intubation success rate with such minimal intubation experiences during initial training and so few opportunities to maintain the skill after graduation.

In fact, based on our analysis using meta-regression techniques, a long-term decline in OETI success rates is evident in the historical trend for patients in whom successful placement was verified in the emergency department. We can only hypothesize as to the cause of this decline. It may be the result of fewer opportunities to perform live intubation during initial training, or a decreased emphasis on the initial teaching of the skill of intubation, as it is no longer novel. It may be the result of increased numbers of practicing paramedics, expansion of the basic EMT curriculum to permit OETI, or the recurring introduction of new blind insertion airway devices and their increasing acceptance as the primary airway in cardiac arrest, all of which further reduce opportunities for skill maintenance. It may be the result of an expansion in the patient population in which intubation is used, particularly its increasing use in nonarrest patients. It is likely a combination of these and many other issues, but it is a trend that must be noted and addressed.

In our study, intubations performed by air medical crews consistently had success rates that were slightly higher than those of their ground-based counterparts. This may be due to the experience level of the crews, additional training, more frequent opportunities to intubate and maintain skills, or greater access to operating rooms for skill reinforcement. It may also be an artifact of data classification. In our study, intubations by air medical crews may include those performed at outlying referring facilities rather than in the field; we eliminated data for such intubations when it was possible to explicitly identify them, but some studies did not provide sufficient detail to make that possible.

Aside from the issues of initial and continuing competency, protocols for determining successful placement may also influence intubation success rates. Silvestri et al. reviewed the impact of waveform capnography in an effort to address an unacceptably high rate of unrecognized esophageal intubations in patients arriving at a level I trauma center.[10] They found that the rate of tube misplacement was 23.3% without capnography and 0% with capnography. Consequently, some level of airway misadventure might potentially be avoided by incorporating capnography into airway management protocols. Our data echo these findings, with self-reported intubation success rates generally being greater than emergency department–verified success rates, but with the greatest success rates coming from studies where multiple objective methods for verification, including capnometry and/or capnography, were used by the intubating clinicians. Unrecognized misplacement may partially explain the higher self-reported success rates in comparison with emergency department–verified rates. We posit that unrecognized placement is avoided when multiple objective verification techniques are employed, resulting in removal of misplaced airways and the reintubation of the patient.

Importantly, a "failed" intubation is not synonymous with failed airway management; it is possible (indeed likely) that patients with failed intubation attempts are supported through other airway management and ventilation techniques, including bag–valve–mask ventilation or placement of a salvage airway such as a laryngeal mask airway. As such, the clinical implications of our expected procedural failure rate ($\approx$14%; CI $\approx$ 11%–17%) for prehospital OETI remain to be determined. Unrecognized esophageal intubation, however, is a more insidious issue. Quality improvement initiatives must reinforce and measure adequate ventilation and oxygenation as the key indicators of airway management success rather than focusing purely on an enumeration of endotracheal tubes in place after an attempt.

Compared with OETI, where low success rates were associated with specific patient populations, a distinctly different pattern emerges in our pooled NTI data, with success rates being ubiquitously low. The overall NTI success rate was 75.4%; for nonphysician clinicians, the pooled success rate was 75.9%, and for air medical crews, it was 77.9%. Around one in four NTI attempts can be expected to fail regardless of patient circumstances or clinician characteristics. These data raise serious questions about the safety and efficacy of NTI as a prehospital intervention.

Limitations

This study has several noteworthy limitations. Primarily, we evaluated only placement success rates; we did not explore the relationship between intubation and patient outcome, nor did we evaluate procedural complications reported in the literature such as hypoxia, inadvertent hyperventilation, tube dislodgment, barotrauma, or iatrogenic injuries from traumatic insertions. In essence, the overarching goal of our study was limited to providing a pooled estimate of successful placement for each airway procedure across a variety of patient characteristics, clinical settings, and clinicians.

The strength of our results is tempered by the quality of the body of published works with respect to prehospital airway control. Based on our criteria, quality scores showed considerable variation, and the overall quality of the studies was poor. Nearly half of the studies were retrospective and descriptive, some were not designed specifically for evaluating airway success rates, and oftentimes successful placement was self-reported by the clinician using only clinical criteria such as breath sounds and chest rise. Few studies used objective verification measures such as capnography, or had placement confirmed by the emergency department physician. Such self-reported verification of placement likely overestimates the true proportion of procedural success. Through subgroup analysis, we compared studies with self-reported success rates with those verified in the emergency department, finding that the pooled success rate for placements verified by emergency department physicians (82.9%) was substantially lower than the 91.5% success rate among studies with self-reported verification using clinical assessment alone. This variance, coupled with reports of unrecognized esophageal intubations in up to 25% of prehospital intubations,[64] may suggest an upward bias of intubation success rates reported in the literature. Moreover, there was no universal definition among the studies of what constitutes a procedural attempt, which ultimately affects success rates.

Although we were able to adequately address differences in the credentials of the clinicians (i.e., ground paramedics vs. air medical personnel), we were not able to control for their experience in airway management, which has been demonstrated to have a substantial impact on the rate of successful placement of endotracheal tubes by prehospital providers.[138] In addition, we did not control for any differences in training between international nonphysician prehospital clinicians and their U.S. counterparts. Further, for our subgroup analyses, it was not possible to extract the necessary data from all studies, as some studies reported aggregated data encompassing the subgroups but did not report data explicitly for each subgroup.

The use of meta-analysis as a research method is not devoid of criticism. An advantage of the meta-analysis methodology is to combine underpowered studies to increase the sample size and confidence in the resulting pooled effect.[139,140] However, some of our subgroups were based on only a few studies; some studies represented a disproportionately large segment of the pooled data; and, in some cases, the total number of patients was small even after pooling. For these reasons we were unable to conduct any sensitivity analyses limited to only the highest-quality studies.

Aggregation of individual studies necessarily incorporates the biases of those studies and injects new sources of bias as a result of study selection. Study selection bias is further compounded by the inherent bias against publication of studies with negative results. Such bias is evaluated using funnel plots. In the absence of publication bias, the funnel plot should provide a symmetrical distribution of studies within the funnel. As demonstrated by asymmetrical funnel plots, our meta-analysis suffered from publication bias in the NTI, RSI, and DFI groups.

Another limitation of meta-analysis is statistical heterogeneity. In a homogeneous distribution, the dispersion of success rates around the pooled estimate differs only by sampling error. A significant Q statistic rejects this assumption, indicating that the dispersion of success rates is associated with differences in study characteristics as well as sampling error. We discovered significant heterogeneity among the prehospital airway literature when evaluating airway procedures across all-inclusive clinician and patient groups. Even when isolating studies into homogeneous patient and clinician groups, statistical heterogeneity was present in 23 of 40 (58%) of our subanalyses. In addition, the I^2 statistic, which ranges from 0% to 100% and measures the amount of inconsistency across studies, was high in several analyses, indicating considerable between-study variation. Consequently, our results must be interpreted accordingly.

Lastly, the computational methods employed in this study represent another limitation. When observed proportions are less than 0.2 or greater than 0.8, the proportion effect size equation provides an appropriate estimate of the mean proportion across studies, but underestimates the CI around the mean effect size (proportion) and overestimates the degree of heterogeneity across effect sizes.[139] This is due to the compression of the standard error as the proportion estimate approaches 0 or 1 and may explain some of the heterogeneity experienced in our pooled results; it may also suggest that some of the CIs reported in our subanalyses are artificially narrow.

CONCLUSIONS

Through a meta-analysis of published prehospital airway data, we generated pooled estimates for prehospital intubation placement success rates. For some patient and clinician characteristics, OETI has relatively low success rates. The global non-RSI/non-DFI OETI success rate is 86.5%, with generally lower success rates for trauma, nonarrest, and pediatric patients. For nonarrest patients, DFI and RSI appear to increase success rates, with an overall pooled estimate of RSI success of 96.1%. Across all clinicians and patient groups, NTI has a low rate of success, raising questions about the safety and efficacy of this procedure in the prehospital setting.

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APPENDIX 1. Characteristics of the Studies of Oral Endotracheal Intubation, Including Rapid-Sequence Intubation and Drug-Facilitated Intubation

First Author, Year*	Type of Design	Clinician	Air Medical Team	Patient Mix	Setting	Verification	Verification Type	Pediatric	Cardiac Arrest	Drug Assist	Salvage Airway	Sample Size	Quality Score
Adams, 2008[15]	P	P/MD/PA/RN	M	M	M	ED	M	NS	M	NS	M	253	3
Aijian, 1989[16] (ages 0–19 years, mix)	R	P	N	NT	G	NS	NS	M	Y	N	NS	28	6
Aijian, 1989[16] (ages 0–10 years, pediatrics only)	R	P	N	NT	G	NS	NS	Y	Y	N	NS	25	5
Aprahamian, 1985[17]	R	P	N	T	G	NS	NS	M	Y	NS	NS	95	4
Bernard, 2002[18]	R	I/P	Y	T	A	P	M	M	N	R	N	110	8
Boswell, 1995[19] (adults)	R	NS	M	T	M	NS	NS	N	NS	NS	N	296	3
Boswell, 1995[19] (pediatrics)	R	NS	M	T	M	NS	NS	Y	NS	NS	N	58	
Bozeman, 2002[20]	R	P/N	Y	M	A	P	M	M	N	D	NS	44	5
Bradley, 1998[11]	B	E	N	M	G	ED	M	N	M	N	N	57	7
Brown, 2001[21]	R	P/N	Y	M	A	P	NS	M	N	M	Y	10	3
Brownstein, 1996[22]	R	P	N	M	G	ED	M	M	M	M	NS	270	4
Bulger, 2002[23] (non-RSI only)	R	P	N	M	G	P	NS	M	M	N	NS	1,442	3
Bulger, 2002[23] (RSI only)	R	P	N	M	G	P	NS	M	M	R	NS	1,292	
Burton, 2003[24] (adults only)	R	MD/P/E/N	N	M	G	P	NS	N	M	M	NS	5,371	2
Burton, 2003[24] (pediatrics only)	R	MD/P/E/N	N	M	G	P	NS	Y	M	NS	NS	127	
Cady, 2005[25] (post-Combitube)	B	P/E	N	M	G	P	A	N	M	N	NS	2,144	3
Cady, 2005[25] (pre-Combitube)	B	P/E	N	M	G	P	A	N	M	N	NS	3,142	
Cole, 2006[26] (RSI)	P	MD/P/N	M	NS	M	NS	NS	NS	NS	R	NS	158	2
Cole, 2006[26] (sedation)	P	MD/P/N	M	NS	M	NS	NS	NS	NS	D	NS	230	
Colwell, 2005[27]	R	P	N	NS	G	ED	M	M	NS	N	Y	138	6
Denver Metro Airway Study Group, 2009[12]	P	P/E/N	N	M	M	ED	M	NS	NS	NS	NS	27	4
Denver Metro Airway Study Group, 2009[12] (pediatrics)	P	P/E/N	N	M	M	ED	M	Y	NS	NS	NS	23	
Cwinn, 1987[28]	R	P	N	T	G	NS	NS	NS	NS	NS	NS	14	3
Davis, 2003[7]	P	P	N	T	G	P	M	N	N	R	N	420	10
Davis, 2006[29]	P	P	N	M	G	P	C	NS	M	N	N	703	6
DeLeo, 1977[3] (physicians only)	R	MD	N	NS	G	P	NS	NS	Y	N	NS	44	4
DeLeo, 1977[3] (paramedics only)	R	P	N	NS	G	P	NS	NS	Y	N	NS	785	
Dickinson, 1999[30]	R	P	M	M	M	P	M	NS	N	D	M	20	5
Doran, 1995[31]	P	P	N	M	G	P	A	NS	M	N	M	179	4
Duchynski,1998[32]	R	MD/P/N	Y	NS	A	P	NS	NS	NS	NS	N	429	2
Eckstein, 2000[33]	R	P	N	T	G	NS	NS	M	M	N	NS	148	4
Ehrlich, 2004[34] (nurses only)	R	N	Y	T	M	P	NS	M	NS	NS	NS	48	2
Ehrlich, 2004[34] (paramedics only)	R	P	N	T	M	P	NS	M	NS	NS	NS	11	

Fakhry, 2006[35]	R	P	Y	T	A	NS	NS	M	N	R	NS	175	5
Frankel, 1997[36]	R	P	N	T	G	P	M	N	NS	N	NS	58	7
Gabram, 1989[37]	P	MD/N/RT	Y	T	A	NS	NS	M	NS	M	M	77	3
Garza, 2003[38]	R	P	N	NT	G	ED	NS	N	Y	N	N	1,066	9
Garza, 2005[39] (adult medical arrest only)	R	P	N	NT	G	ED	M	N	Y	NS	N	2,401	8
Garza, 2005[39] (adult trauma arrest only)	R	P	N	T	G	ED	M	N	Y	NS	N	182	
Garza, 2005[39] (pediatric medical arrest only)	R	P	N	NT	G	ED	M	Y	Y	NS	N	86	
Garza, 2008[40]	P	P	N	NT	G	ED	NS	N	Y	NS	N	1,235	9
Gausche, 2000[6]	P	P	N	M	G	ED	NS	Y	M	NS	N	324	7
Geehr, 1985[41]	P	P	N	NT	G	ED	NS	NS	Y	NS	N	106	8
Gerich, 1998[42]	P	I/MD/P	Y	T	A	ED	M	NS	M	D	N	375	7
Germann, 2009[43]	R	P/N	Y	M	A	P	M	M	NS	M	N	369	4
Gerritse, 2008[44] (paramedics only)	P	I/P	N	M	G	ED	M	Y	NS	N	N	41	8
Gerritse, 2008[44] (physicians only)	P	I/MD	Y	M	G	ED	M	Y	NS	NS	NS	114	6
Gofrit, 1997[45]	P	I/MD	Y	T	A	NS	NS	NS	N	D	Y	29	7
Goldenberg, 1986[46]	P	P	N	NT	G	P	NS	N	Y	N	M	132	7
Gray, 1992[47]	P	I/P	N	NS	G	ED	NS	NS	Y	N	N	87	8
Grmec, 2002[48]	P	I/MD	N	M	G	P	M	N	M	NS	N	345	7
Gunning, 2009[49] (physicians only)	P	I/MD	Y	M	A	NS	NS	NS	NS	M	NS	10	3
Gunning, 2009[49] (paramedics only)	P	I/P	Y	M	A	NS	NS	NS	NS	M	NS	7	
Guss, 1985[50]	P	P	NS	NS	NS	NS	NS	NS	NS	NS	NS	768	2
Hankins, 1993[51]	P	P	N	NT	G	M	A	N	Y	NS	NS	269	6
Harrison, 1997[52] (ground)	R	P/N	Y	M	A	ED	M	M	NS	M	NS	120	3
Harrison, 1997[52] (in flight)	R	P/N	Y	M	A	ED	M	M	NS	M	NS	120	
Harrison, 2004[53] (in flight)	R	P/N	Y	M	A	M	M	Y	NS	NS	NS	36	4
Harrison, 2004[53] (at scene)	R	P/N	Y	M	A	M	M	Y	NS	NS	NS	44	
Hedges, 1988[54] (non-RSI)	R	P	N	M	G	NS	NS	M	M	N	NS	215	3
Hedges, 1988[54] (RSI)	R	P	N	M	G	NS	NS	M	M	R	NS	95	3
Helm, 2006[55]	P	I/MD	Y	M	A	P	NS	NS	M	M	N	342	4
Jabre, 2005[56]	P	I/MD/N	N	M	G	NS	NS	N	M	M	Y	41	4
Jabre, 2007[57]	B	I/MD/N	N	M	G	NS	NS	N	M	M	N	1,177	3
Jacoby, 2006[58] (etomidate only)	P	P	N	M	G	ED	NS	N	N	D	N	55	9

(*Continued on next page*)

APPENDIX 1. Characteristics of the Studies of Oral Endotracheal Intubation, Including Rapid-Sequence Intubation and Drug-Facilitated Intubation (*Continued*)

First Author, Year*	Type of Design	Clinician	Air Medical Team	Patient Mix	Setting	Verification	Verification Type	Pediatric	Cardiac Arrest	Drug Assist	Salvage Airway	Sample Size	Quality Score
Jacoby, 2006[58] (midazolam only)	P	P	N	M	G	ED	NS	N	N	D	M	55	
Jemmett, 2003[59]	P	P/E	N	M	M	ED	M	NS	NS	NS	NS	109	
Jenkins, 1994[60]	P	P	N	M	G	ED	M	M	M	NS	NS	39	5
Johannigman, 1995[61]	P	P	N	NS	G	NS	NS	NS	M	NS	N	132	4
Jones, 2004[62]	P	P	N	M	G	ED	M	NS	NS	N	N	180	7
Karch, 1996[63]	R	P	N	T	G	NS	NS	NS	M	NS	N	94	4
Katz, 2001[64] (medical)	P	P	N	NT	G	ED	M	NS	NS	NS	N	56	7
Katz, 2001[64] (trauma)	P	P	N	T	G	ED	M	NS	NS	NS	N	52	
Kaye, 2003[65]	P	P	N	M	G	P	M	M	N	R	N	101	8
Kenny, 1996[66] (nebulized lidocaine)	B	P	N	NS	G	NS	NS	NS	N	D	N	24	5
Kenny, 1996[66] (no drug assist)	B	P	N	NS	G	NS	NS	NS	N	N	N	60	
King, 2001[67]	P	N	N	NS	G	NS	NS	Y	NS	NS	N	8	5
Kociszewski, 2000[68] (drug assist)	R	P/N	Y	M	A	P	M	N	N	D	N	62	7
Kociszewski, 2000[68] (RSI)	R	P/N	Y	M	A	P	M	N	N	R	N	213	
Krisanda, 1992[13]	R	P/N	N	M	NS	P	NS	NS	N	NS	NS	168	1
Leicht, 1991[69]	R	MD/N	Y	M	A	ED	NS	M	M	M	NS	53	3
Losek, 1989[70] (arrests of all ages)	R	P	N	M	G	NS	NS	M	Y	N	N	43	6
Losek,1989[70] (nonarrests of all ages)	R	P	N	M	G	NS	NS	M	N	N	N	21	
Losek, 1989[70] (pediatric arrests only)	R	P	N	M	G	NS	NS	Y	Y	N	N	29	
Mackay, 2001[71]	R	I/MD/P	Y	T	A	P	M	NS	N	R	N	359	7
MacLeod, 1991[72] (cardiac arrest)	P	MD/P/N	M	M	M	P	C	N	Y	NS	N	106	5
MacLeod, 1991 [72] (nonarrest)	P	MD/P/N	M	M	M	P	C	N	N	NS	N	144	
McCall, 2008[73]	P	P	N	NS	G	P	NS	N	M	N	M	46	5
Mishark, 1992[74]	R	N	Y	M	A	NS	NS	M	NS	N	M	79	3
Murphy-Macabobby, 1992[9]	R	P	Y	M	A	P	NS	M	NS	R	NS	115	3
Murray, 2000[75]	R	NS	NS	T	M	NS	NS	NS	NS	N	NS	138	2
Nakayama, 1990[76]	R	NS	NS	T	NS	NS	NS	Y	NS	NS	NS	14	2
Ochs, 2002[77]	P	P	N	T	G	ED	M	NS	N	R	Y	114	9
Pace, 2000[78]	R	P	N	M	G	P	NS	M	N	R	NS	150	4
Pattinson, 2004[79]	P	I/P	N	M	G	NS	NS	NS	M	NS	M	382	3
Pearson, 2003[80] (DFI)	R	P/N	Y	M	M	P	M	M	N	D	N	70	4
Pearson, 2003[80] (RSI)	R	P/N	Y	M	M	P	M	M	N	R	N	70	
Pointer, 1988[81]	P	P	N	M	G	ED	A	NS	M	NS	N	383	6
Pointer, 1989[82]	P	P	N	M	G	ED	NS	Y	M	NS	N	36	7
Pratt, 2005[83]	P	E	N	M	G	ED	M	N	M	N	N	32	8
Rabitsch, 2003[84]	P	I/MD	N	NT	G	NS	NS	N	Y	N	N	83	8
Reed, 2002[85] (non–drug assist)	B	P	N	M	G	P	C	N	M	N	N	385	6

Reed, 2002[85] (etomidate only)	B	P	N	M	G	P	C	N	N	D	NS	24	
Reed, 2002[85] (diazepam only)	B	P	N	M	G	P	C	N	N	D	NS	43	
Reines, 1988[86]	R	P/E	N	T	G	P	NS	NS	NS	NS	NS	74	2
Rhee, 1994[87]	P	MD/N	Y	T	M	P	C	N	N	R	NS	33	6
Rocca, 2000[88]	R	I/P	N	M	G	P	NS	NS	Y	N	NS	331	4
Rumball, 2004[89]	P	I/E	N	M	G	ED	NS	N	M	NS	NS	273	6
Sams, 1999[90]	R	I/P	Y	M	M	P	NS	M	N	D	NS	128	3
Sayre, 1998[91] (EMTs, all attempts)	P	E	N	NS	G	P	C	N	M	N	N	103	7
Sayre, 1998[91] (paramedics, after EMT failure)	P	P	N	NS	G	P	C	N	M	N	Y	44	
Schaller, 1997[92]	P	P/E	N	M	G	ED	C	N	M	NS	NS	38	5
Shea, 1985[93]	P	P	N	NT	G	ED	A	N	Y	N	N	195	10
Silvestri, 2005[10] (with $ETCO_2$ monitor)	P	P	M	M	M	ED	M	M	M	NS	NS	93	4
Silvestri, 2005[10] (without $ETCO_2$ monitor)	P	P	M	M	M	ED	M	M	M	NS	NS	60	
Sing, 1998[94]	R	P/N	Y	T	A	P	NS	M	N	R	NS	84	4
Slagt, 2004[95]	R	I/MD	Y	M	A	P	NS	M	M	M	NS	653	2
Slater, 1998[96] (at scene)	R	N	Y	M	G	P	M	M	NS	R	M	86	5
Slater, 1998[96] (in flight)	R	N	Y	M	A	P	M	M	NS	R	M	102	
Slater, 1998[96] (non-RSI)	R	N	Y	M	M	P	M	M	M	N	M	37	
Sloane, 2000[97]	R	MD/N	Y	T	A	ED	M	N	N	R	N	47	8
Smith, 2002[98]	P	MD/N	Y	M	A	P	M	N	N	R	N	100	8
Sonday, 2005[99]	B	NS	Y	T	A	P	M	N	N	R	NS	98	7
Stewart, 1984[100] (cardiac arrest, medical)	P	P	N	NT	G	ED	A	NS	Y	N	N	709	9
Stewart, 1984[100] (mixed cardiac arrest, trauma)	P	P	N	T	G	ED	A	NS	M	N	N	33	
Stewart, 1984[100] (non–cardiac arrest, medical)	P	P	N	NT	G	ED	A	NS	N	N	N	37	
Stiell, 2004[101] (cardiac arrest)	B	I/P	N	NT	G	NS	NS	N	Y	N	N	3,848	7
Stiell, 2007[102] (non–cardiac arrest)	B	I/P	N	NT	G	NS	NS	N	N	D	N	70	7
Stratton, 1991[103]	P	P	N	M	G	ED	A	N	M	NS	N	174	7
Swanson, 2002[104]	R	P/N	Y	M	NS	P	NS	M	NS	M	N	372	1
Swanson, 2004[105]	R	P/N	Y	M	A	P	C	M	N	R	NS	209	4
Syverud, 1988[106]	P	MD/N	Y	M	A	P	A	M	N	R	NS	39	4
Tam, 2009[107]	R	P	N	M	G	P	NS	M	NS	N	N	877	4
Thomas, 1999[108]	R	N/P	Y	M	M	ED	NS	M	M	M	M	704	2
Thompson, 1995[109] (RSI)	P	MD/P/N/RT	Y	M	M	P	M	M	M	R	M	301	4
Thompson, 1995[109] (non-RSI)	P	MD/P/N/RT	Y	M	M	P	M	M	M	N	M	422	
Tiamfook-Morgan, 2006[110]	P	P/N	Y	M	M	P	M	M	NS	M	N	200	4

(*Continued on next page*)

APPENDIX 1. Characteristics of the Studies of Oral Endotracheal Intubation, Including Rapid-Sequence Intubation and Drug-Facilitated Intubation (*Continued*)

First Author, Year*	Type of Design	Clinician	Air Medical Team	Patient Mix	Setting	Verification	Verification Type	Pediatric	Cardiac Arrest	Drug Assist	Salvage Airway	Sample Size	Quality Score
Timmermann, 2006[111]	P	I/MD	N	M	M	P	C	NS	M	M	N	1,108	4
Timmermann, 2007[112]	P	I/MD	N	M	G	P	C	Y	M	R	NS	132	6
Vilke, 1994[113] (non-RSI)	R	MD/P/N	Y	T	A	ED	NS	NS	NS	N	NS	170	5
Vilke, 1994[113] (RSI)	R	MD/P/N	Y	T	A	ED	NS	NS	NS	R	NS	156	5
Vilke, 2002[114]	R	P	N	M	G	ED	M	Y	Y	NS	NS	324	6
Vollmer, 1985[115]	P	MD	N	NS	G	NS	NS	NS	NS	NS	N	21	4
Wang, 2001[116] (cardiac arrest, no drug assist)	R	P	N	M	G	P	M	M	Y	N	NS	591	6
Wang, 2001[116] (nonarrest, drug assist and no drug assist)	R	P	N	M	G	P	M	M	N	M	NS	214	
Wang, 2001[116] (nonarrest, no drug assist)	R	P	N	M	G	P	M	M	N	N	NS	126	
Wang, 2003[117] (nonarrest RSI)	P	MD/P/N	M	M	M	P	M	N	N	R	N	35	6
Wang, 2003[117] (mixed arrest, no drug assist)	P	MD/P/N	M	M	M	P	M	N	M	N	N	618	6
Wang, 2006[118] (cardiac arrest)	P	MD/P/N	M	NS	M	P	NS	M	Y	N	NS	1,272	3
Wang, 2006[118] (nonarrest, drug assist)	P	MD/P/N	M	NS	M	P	NS	M	N	D	NS	126	
Wang, 2006[118] (nonarrest RSI)	P	MD/P/N	Y	NS	M	P	NS	M	N	R	NS	80	
Wang, 2006[118] (nonarrest, no drug assist)	P	MD/P/N	M	NS	M	P	NS	M	N	N	NS	463	
Warner, 2009[119]	P	P	N	M	G	P	M	M	M	M	N	4,193	6
Wayne, 1999[120] (medical only)	R	P	N	NT	G	P	M	N	N	R	NS	547	8
Wayne, 1999[120] (trauma only)	R	P	N	T	G	P	M	N	N	R	NS	1,110	
Weitzel, 2004[121]	R	P	N	T	G	P	NS	M	N	N	NS	24	5
Werman, 2004[122]	P	P/N	Y	M	M	P	M	M	N	M	NS	81	4
Weston, 1992[123]	R	I/P	N	M	G	NS	NS	NS	Y	N	NS	226	4

*For complete reference citations, see the reference list.

Key: Type of Design: B = before–after; P = prospective; R = retrospective. Clinician: E = emergency medical technician; I = international; MD = physician; N = nurse; NS = not stated; P = paramedic; PA = physician assistant; RN = registered nurse. Air Medical Team: M = mixed; N = clinician not a member of air medical team; NS = not stated; Y = clinician member of air medical team. Patient Mix: M = mixed; NS = not stated; NT = nontrauma; T = trauma. Setting: A = air ambulance; G = ground ambulance; M = mixed; NS = not stated. Verification: ED = emergency department; NS = not stated; P = practitioner. Verification Type: A = clinical assessment such as breath sounds and chest rise; C = single objective criterion such as colorimetric carbon dioxide (CO_2) detector, end-tidal carbon dioxide ($ETCO_2$), saturation of peripheral oxygen (SpO_2), or esophageal detector device (EDD); M = multiple objective criteria such as CO_2 detector, $ETCO_2$, EDD, SpO_2, etc.; NS = not stated. Pediatric: M = mixed pediatric and adult; N = non-drug facilitated, non-RSI; NS = not stated; Y = yes. Cardiac Arrest: M = mixture of arrest and nonarrest patients; N = no; NS = not stated; Y = yes. Drug Assist: D = drug facilitated; M = mixture of rapid-sequence intubation (RSI), non-RSI, drug-facilitated, non–drug-facilitated; NS = not stated; R = RSI. Salvage Airway: M = mixture of salvage and primary airway; N = no; NS = not stated; Y = yes.

APPENDIX 2. Characteristics of the Studies of Nasotracheal Intubation, Including Rapid-Sequence Intubation and Drug-Facilitated Intubation

First Author, Year*	Type of Design	Clinician	Air Medical Team	Patient Mix	Setting	Verification	Verification Type	Pediatric	Cardiac Arrest	Drug Assist	Salvage Airway	Sample Size	Quality Score
Brown, 2001[21]	R	P/N	Y	M	A	P	NS	M	N	M	N	21	3
Colwell, 2005[27]	R	P	N	NS	G	ED	M	M	NS	N	N	154	6
Cwinn, 1987[28]	R	P	N	T	G	NS	NS	NS	NS	NS	NS	22	3
Doran, 1995[31]	P	P	N	M	G	P	A	NS	M	N	M	57	4
Gabram, 1989[37]	P	MD/N	Y	T	A	NS	NS	M	NS	M	N	76	4
Jones, 2004[62]	P	P	N	M	G	ED	M	NS	NS	N	N	28	7
Krisanda, 1992[13]	R	P/N	N	M	NS	P	NS	NS	N	NS	NS	226	1
Leicht, 1991[69]	R	MD/N	Y	M	A	ED	NS	M	M	M	NS	90	3
Mishark, 1992[74]	R	N	Y	M	A	NS	NS	M	NS	N	N	71	4
O'Brien, 1988[124]	R	MD/P	Y	M	A	NS	NS	NS	NS	NS	N	65	2
O'Brien, 1989[125] (nontrauma)	R	P	N	NT	G	ED	NS	NS	N	NS	NS	270	6
O'Brien, 1989[125] (trauma)	R	P	N	T	G	ED	NS	NS	N	NS	NS	54	6
O'Connor, 2000[126]	P	P	N	NS	G	ED	M	N	N	NS	NS	219	7
Rhee, 1994[87]	P	MD/N	Y	T	M	P	C	N	N	N	NS	44	6
Rocca, 2000[88]	R	I/P	N	M	G	P	NS	NS	N	N	NS	68	4
Schaller, 1997[92]	P	P/E	N	M	G	ED	C	N	M	NS	NS	5	5
Tam, 2009[107]	R	P	N	M	G	P	NS	M	N	N	N	151	5
Thomas, 1999[108]	R	P/N	Y	M	M	ED	NS	NS	N	N	N	16	5
Timmermann, 2007[127]	P	I/MD	N	M	M	P	C	Y	M	R	NS	17	5
Vilke, 1994[113]	R	MD/P/N	Y	T	A	ED	NS	NS	NS	N	NS	315	5
Wang, 2001[116]	R	P	N	M	G	P	M	M	N	NS	NS	88	5
Wang, 2003[117]	P	MD/P/N	M	M	M	P	M	N	M	N	N	42	6
Weitzel, 2004[121]	R	P	N	T	G	P	NS	M	N	N	NS	40	5
Werman, 2004[122]	P	P/N	Y	M	M	P	M	M	N	M	NS	60	4

*For complete reference citations, see the reference list.

Key: Type of Design: B = before–after; P = prospective; R = retrospective. Clinician: E = emergency medical technician; I = international; MD = physician; N = nurse; NS = not stated; P = paramedic; PA = physician assistant; RN = registered nurse. Air Medical Team: M = mixed; N = clinician not a member of air medical team; NS = not stated; Y = clinician member of air medical team. Patient Mix: M = mixed; NS = not stated; NT = nontrauma; T = trauma. Setting: A = air ambulance; G = ground ambulance; M = mixed; NS = not stated. Verification: ED = emergency department; NS = not stated; P = practitioner. Verification Type: A = clinical assessment such as breath sounds and chest rise; C = single objective criterion such as colorimetric carbon dioxide (CO_2) detector, end-tidal carbon dioxide ($ETCO_2$), saturation of peripheral oxygen (SpO_2), or esophageal detector device (EDD); M = multiple objective criteria such as CO_2 detector, $ETCO_2$, EDD, SpO_2, etc.; NS = not stated. Pediatric: M = mixed pediatric and adult; N = no; NS = not stated; Y = yes. Cardiac Arrest: M = mixture of arrest and nonarrest patients; N = no; NS = not stated; Y = yes. Drug Assist: D = drug facilitated; M = mixture of rapid-sequence intubation (RSI), non-RSI, drug-facilitated, non–drug-facilitated; NS = not stated; R = RSI. Salvage Airway: M = mixture of salvage and primary airway; N = no; NS = not stated; Y = yes.

APPENDIX 3. Characteristics of the Studies of Rapid-Sequence Intubation

First Author, Year*	Type of Design	Clinician	Air Medical Team	Patient Mix	Setting	Verification	Verification Type	Pediatric	Cardiac Arrest	Drug Assist	Salvage Airway	Sample Size	Quality Score
Bernard, 2002[18]	R	I/P	Y	T	A	P	M	M	N	R	N	110	8
Bulger, 2002[23] (RSI only)	R	P	N	M	G	P	NS	M	M	R	NS	1,292	5
Cole, 2006[26] (RSI)	P	MD/P/N	M	NS	M	NS	NS	NS	NS	R	NS	158	2
Davis, 2003[7]	P	P	N	T	G	P	M	N	N	R	N	420	10
Fakhry, 2006[35]	R	P	Y	T	A	NS	NS	M	N	R	NS	175	5
Hedges, 1988[54] (RSI)	R	P	N	M	G	NS	NS	M	M	R	NS	95	3
Kaye, 2003[65]	P	P	N	M	G	P	M	M	N	R	N	101	8
Kociszewski, 2000[68] (RSI)	R	P/N	Y	M	A	P	M	N	N	R	N	213	7
Mackay, 2001[71]	R	I/MD/P	Y	T	A	P	M	NS	N	R	N	359	7
Murphy-Macabobby, 1992[9]	R	P	Y	M	A	P	NS	M	NS	R	NS	115	3
Ochs, 2002[77]	P	P	N	T	G	ED	M	NS	N	R	Y	114	9
Pace, 2000[78]	R	P	N	M	G	P	NS	M	N	R	NS	150	4
Pearson, 2003 (RSI)[80]	R	P/N	Y	M	M	P	M	M	N	R	N	70	4
Rhee, 1994[87]	P	MD/N	M	T	M	P	C	N	N	R	NS	33	6
Sing, 1998[94]	R	P/N	Y	T	A	P	NS	M	N	R	NS	84	4
Slater, 1998[96] (at scene)	R	N	Y	M	G	P	M	M	NS	R	M	86	5
Slater, 1998[96] (in flight)	R	N	Y	M	A	P	M	M	NS	R	M	102	
Sloane, 2000[97]	R	MD/N	Y	T	A	ED	M	N	N	R	N	47	8
Smith, 2002[98]	P	MD/N	Y	M	A	P	M	N	N	R	N	100	8
Sonday, 2005[99]	B	NS	Y	T	A	P	M	N	N	R	NS	98	7
Swanson, 2004[105]	R	P/N	Y	M	A	P	C	M	N	R	NS	209	4
Syverud, 1988[106]	P	MD/N	Y	M	A	P	A	M	N	R	NS	39	4
Thompson, 1995[109] (RSI)	P	MD/P/N/RT	Y	M	M	P	M	M	M	R	M	301	4
Timmermann, 2007[112]	P	I/MD	N	M	G	P	C	Y	M	R	NS	132	6
Vilke, 1994[113] (RSI)	R	MD/P/N	Y	T	A	ED	NS	NS	NS	R	NS	156	5
Wang, 2003[117] (nonarrest RSI)	P	MD/P/N	M	M	M	P	M	N	M	R	N	35	6
Wang, 2006[118] (nonarrest RSI)	P	MD/P/N	Y	NS	M	P	NS	M	N	R	NS	80	3
Wayne, 1999[120] (medical only)	R	P	N	NT	G	P	M	N	N	R	NS	547	8
Wayne, 1999[120] (trauma only)	R	P	N	T	G	P	M	N	N	R	NS	1,110	

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Key: Type of Design: B = before–after; P = prospective; R = retrospective. Clinician: E = emergency medical technician; I = international; MD = physician; N = nurse; NS = not stated; P = paramedic; PA = physician assistant; RN = registered nurse. Air Medical Team: M = mixed; N = clinician not a member of air medical team; NS = not stated; Y = clinician member of air medical team. Patient Mix: M = mixed; NS = not stated; NT = nontrauma; T = trauma. Setting: A = air ambulance; G = ground ambulance; M = mixed; NS = not stated. Verification: ED = emergency department; NS = not stated; P = practitioner. Verification Type: A = clinical assessment such as breath sounds and chest rise; C = single objective criterion such as colorimetric carbon dioxide (CO_2) detector, end-tidal carbon dioxide ($ETCO_2$), saturation of peripheral oxygen (SpO_2), or esophageal detector device (EDD); M = multiple objective criteria such as CO_2 detector, $ETCO_2$, EDD, SpO_2, etc.; NS = not stated. Pediatric: M = mixed pediatric and adult; N = no; NS = not stated; Y = yes. Cardiac Arrest: M = mixture of arrest and nonarrest patients; N = no; NS = not stated; Y = yes. Drug Assist: D = drug facilitated; M = mixture of rapid-sequence intubation (RSI), non-RSI, drug-facilitated, non–drug-facilitated; NS = not stated; R = RSI. Salvage Airway: M = mixture of salvage and primary airway; N = no; NS = not stated; Y = yes.

APPENDIX 4. Characteristics of the Studies of Drug-Facilitated Intubation

First Author, Year*	Type of Design	Clinician	Air Medical Team	Patient Mix	Setting	Verification	Verification Type	Pediatric	Cardiac Arrest	Drug Assist	Salvage Airway	Sample Size	Quality Score
Bozeman, 2002[20]	R	P/N	Y	M	A	P	M	M	N	D	NS	44	5
Cole, 2006[26] (sedation)	P	MD/P/N	M	NS	M	NS	NS	NS	NS	D	NS	230	2
Dickinson, 1999[30]	R	P	M	M	M	P	M	NS	N	D	M	20	5
Gerich, 1998[42]	P	I/MD/P	Y	T	A	ED	M	NS	M	D	N	375	7
Gofrit, 1997[45]	P	I/MD	Y	T	A	NS	NS	NS	N	D	Y	29	7
Jacoby, 2006[58] (etomidate only)	P	P	N	M	G	ED	NS	N	N	D	N	55	9
Jacoby, 2006[58] (midazolam only)	P	P	N	M	G	ED	NS	N	N	D	M	55	8
Kenny, 1996[66] (nebulized lidocaine)	B	P	N	NS	G	NS	NS	NS	N	D	N	24	5
Kociszewski, 2000[68] (drug assist)	R	P/N	Y	M	A	P	M	N	N	D	N	62	7
Reed, 2002[85] (etomidate only)	B	P	N	M	G	P	C	N	N	D	NS	24	6
Reed, 2002[85] (diazepam only)	B	P	N	M	G	P	C	N	N	D	NS	43	6
Sams, 1999[90]	R	I/P	Y	M	M	P	NS	M	N	D	NS	128	3
Stiell, 2007[102] (non–cardiac arrest)	B	I/P	N	NT	G	NS	NS	N	N	D	N	70	7
Wang, 2006[118] (nonarrest drug assist)	P	MD/P/N	M	NS	M	P	NS	M	N	D	NS	126	4

*For complete reference citations, see the reference list.

Key: Type of Design: B = before–after; P = prospective; R = retrospective. Clinician: E = emergency medical technician; I = international; MD = physician; N = nurse; NS = not stated; P = paramedic; PA = physician assistant; RN = registered nurse. Air Medical Team: M = mixed; N = clinician not a member of air medical team; NS = not stated; Y = clinician member of air medical team. Patient Mix: M = mixed; NS = not stated; NT = nontrauma; T = trauma. Setting: A = air ambulance; G = ground ambulance; M = mixed; NS = not stated. Verification: ED = emergency department; NS = not stated; P = practitioner. Verification Type: A = clinical assessment such as breath sounds and chest rise; C = single objective criterion such as colorimetric carbon dioxide (CO_2) detector, end-tidal carbon dioxide ($ETCO_2$), saturation of peripheral oxygen (SpO_2), or esophageal detector device (EDD); M = multiple objective criteria such as CO_2 detector, $ETCO_2$, EDD, SpO_2, etc.; NS = not stated. Pediatric: M = mixed pediatric and adult; N = no; NS = not stated; Y = yes. Cardiac Arrest: M = mixture of arrest and nonarrest patients; N = no; NS = not stated; Y = yes. Drug Assist: D = drug facilitated; M = mixture of rapid-sequence intubation (RSI), non-RSI, drug-facilitated, non–drug-facilitated; NS = not stated; R = RSI. Salvage Airway: M = mixture of salvage and primary airway; N = no; NS = not stated; Y = yes.