SYSTEMATIC REVIEW

Paramedics' Success and Complications in Prehospital Pediatric Intubation: A Meta-Analysis

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Abbreviations:
ETI: endotracheal intubation
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

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Abstract

Background: Prehospital pediatric intubation is a potentially life-saving procedure in which paramedics are relied upon. However, due to the anatomical nature of pediatrics and associated adverse events, it is more challenging compared to adult intubation. In this study, the knowledge and attitude of paramedics was assessed by measuring their overall success rate and associated complications.

Methods: An online search using PubMed, Scopus, Web of Science, and Cochrane CENTRAL was conducted using relevant keywords to include studies that assess success rates and associated complications. Studies for eligibility were screened. Data were extracted from eligible studies and pooled as risk ratio (RR) with a 95% confidence interval (CI).

Results: Thirty-eight studies involving 14,207 pediatrics undergoing intubation by paramedics were included in this study. The prevalence of success rate was 82.5% (95% CI, 0.745-0.832) for overall trials and 77.2% (95% CI, 0.713-0.832) success rate after the first attempt. By subgrouping the patients according to using muscle relaxants during intubation, the group that used muscle relaxants showed a high overall successful rate of 92.5% (95% CI, 0.877-0.973) and 79.9% (95% CI, 0.715-0.994) success rate after the first attempt, more than the group without muscle relaxant which represent 78.9% (95% CI, 0.745-0.832) overall success rate and 73.3% (95% CI, 0.616-0.950) success rate after first attempt.

Conclusion: Paramedics have a good overall successful rate of pediatric intubation with a lower complication rate, especially when using muscle relaxants.

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Introduction

Prehospital medical care is a critical component of health care services.[1] Delivering early care at the site of emergency has an important resuscitation role in reducing mortality, morbidity, and disabilities.[2] In the case of pediatric emergencies, effective airway management is important, as cardiac arrest in children is frequently linked to hypoxia.[3] Pediatric out-of-hospital cardiac arrest results in a 12% mortality rate and leads to unfavorable neurological outcomes.[4] Severe traumatic injuries are a common source of mortality; often, endotracheal intubation (ETI) is important to enhance oxygen levels and prevent the risk of aspiration.[5] The expeditious intubation out of the hospital by paramedics significantly enhances the survival rate by maintaining a patent airway, ensuring effective ventilation, and preventing aspiration.[6]

Paramedics equipped with advanced training and intubation experience have shown high success rates (ranging from 84%-95%) in adults.[7–9] The anatomical and physiological characteristics of pediatric patients, combined with the specific challenges in emergencies, increase the complexity of ETI and raise the risk of failure and complications.[10] However, pediatric cases represent only approximately 8.9%-13.0% of emergencies,[11] and only 0.1%-5.0% required ETI.[12] Pediatric patients who present at the hospital with no detectable pulse and apnea exhibit a lower survival rate, in addition to neurological impairment in survival cases.[13] Pediatric tolerance to apnea is less efficient than adult, due to high oxygen demand and low oxygen reserves.[14]

While many Emergency Medical Services consider pediatric intubation as an essential paramedic skill, there is notable divergence in the utilization of this skill across the United States.[15] The specialized training in procedural and decision-making competencies establish and elevate quality standards in the paramedics outside of a hospital setting.[16] Pediatric intubation has been conducted without the use of muscle relaxants, but there is a current trend among several protocols to use muscle relaxants during intubation, which may enhance overall success rates.[17]

This meta-analysis aims to systematically review and synthesize the available literature to assess the knowledge, confidence, and attitude of paramedics through overall success rate and associated complications.

Methods

The study followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[18] and Cochrane guidelines.[19]

Literature Search Strategy

Databases searched were PubMed (National Center for Biotechnology Information, National Institutes of Health; Bethesda, Maryland USA); SCOPUS (Elsevier; Amsterdam, Netherlands); Cochrane (Wiley; Hoboken, New Jersey USA); and Web of Science (Clarivate Analytics; London, United Kingdom) for relevant articles reporting the paramedic's pediatric intubation, success rate, and complications using the following keywords: ("Airway Management" OR Intubation OR Prehospital OR Airway OR "out-of-hospital") AND (Pediatrics OR Child) AND (Paramedics OR EMS); Figure 1.

Eligibility Criteria and Study Selection

In the study, all study designs were included reporting the paramedic's pediatric intubation and assessing the success rate or complications. Non-English studies, conference abstracts, reviews, and studies without eligible data were excluded. The selection procedure involved two separate sets of authors, and in case of disagreements, a third author was consulted for resolution.

Assessing the Risk of Bias

The Newcastle-Ottawa Scale (NOS) was employed to evaluate the quality of cohort studies, considering domains related to selection, comparability, and exposure, with each domain receiving a star rating, up to a maximum of nine stars.[20] Additionally, for the assessment of potential bias in the included clinical trials, the Cochrane risk of bias was used and studies were assigned a judgment of low, high, or unclear risk of bias.[21] Two independent authors conducted the quality assessment of the studies, and with any disagreements, a third author was consulted for resolution.

Data Extraction

Data were extracted in an Excel (Microsoft Corp.; Redmond, Washington USA) sheet on the following: (1) study characteristics including study ID, study setting, study design, total pediatric population, inclusion criteria, and gender; and (2) outcomes including overall intubation success rate, first attempt success rate, overall complication, esophageal intubation, aspiration, and three or more intubation attempts.

Statistical Analysis

A meta-analysis was conducted to report point estimates and the confidence interval (CI) using open meta-analyst software. Data were pooled as risk ratio (RR) and 95% confidence interval. The meta-analysis was performed using a random effects model because of heterogeneity in the eligible studies that were synthesized. The heterogeneity of individual studies was evaluated using the I-square (I^2); data were considered heterogeneous with chi-square $P < .1$.

Results

Literature Search

Based on the systemic search, 1,525 records were retrieved, and 416 duplicates were removed. A total of 1,109 records were screened by title and abstract screening and 1,053 were excluded. Fifty-six studies were suitable for full-text screening, and 38 were finally included according to the eligibility criteria[12,22–58] (PRISMA Flow Diagram; Figure 1).

Characteristics of the Included Studies

This systematic review included 38 studies; 33 were retrospective cohorts, three were prospective cohorts, one was a clinical trial, and one was a case-control. The summary of characteristics is summarized in Table 1.

Quality Assessment

Included cohort studies had methodological quality scores ranging from six to nine, which indicated moderate to high quality. The included case-control study reached a score of nine and the trial had a moderate risk of bias. Quality assessment of the included studies can be found in Supplementary Tables 1-3 (available online only).

Outcomes

Overall Intubation Success Rate—Pooling data from 38 studies that involved 14,207 pediatrics undergoing intubation by paramedics showed an 82.5% overall success rate (95% CI, 0.745-0.832). The group of paramedics who used the muscle relaxant during intubation had a higher success rate of 92.5% (95% CI, 0.877-0.973) in comparison to the group intubated without muscle relaxant with 78.9% (95% CI, 0.745-0.832). In the overall analysis, the group with muscle relaxant and the group without muscle relaxant showed a heterogeneity between groups: (I^2 = 98.3%; P <.001), (I^2 = 94.72%; P <.001), and (I^2 = 98.59%; P <.001), respectively (Figure 2).

First Attempt Success Rate—Data syntheses of 4,600 pediatrics undergoing intubation by paramedics showed a 77.2% success rate after the first attempt (95% CI, 0.713-0.832). The group of paramedics who used the muscle relaxant during intubation showed a higher success rate after the first attempt of 79.9% (95% CI, 0.715-0.994) than the group intubated without muscle relaxant with 73.3% (95% CI, 0.616-0.950). The overall analysis of the group with muscle relaxant and the group without muscle relaxant showed a heterogeneity between groups: (I^2 = 94.7%; P <.001), (I^2 = 92.8%; P <.001), and (I^2 = 96.4%; P <.001), respectively (Figure 3).

Three or More Intubation Attempts Rate—By analysis of data from 993 pediatrics undergoing intubation by paramedics, only 106 pediatrics needed three or more trials to insert tubes successfully. The prevalence of three or more intubation attempts was 9.0% (95% CI, 0.040-0.140). The pooled data were heterogeneous (I^2 = 86.65%; P <.001); Figure 4.

Overall Complication Rate—Of ten studies involving a total of 1,566 pediatric patients reporting the overall complication rate, 384 patients experience complications during intubation by paramedics at 23.4% (95% CI, 0.122-0.346). Pooled data were heterogenous (I^2 = 97.01%; P <.001); Figure 5.

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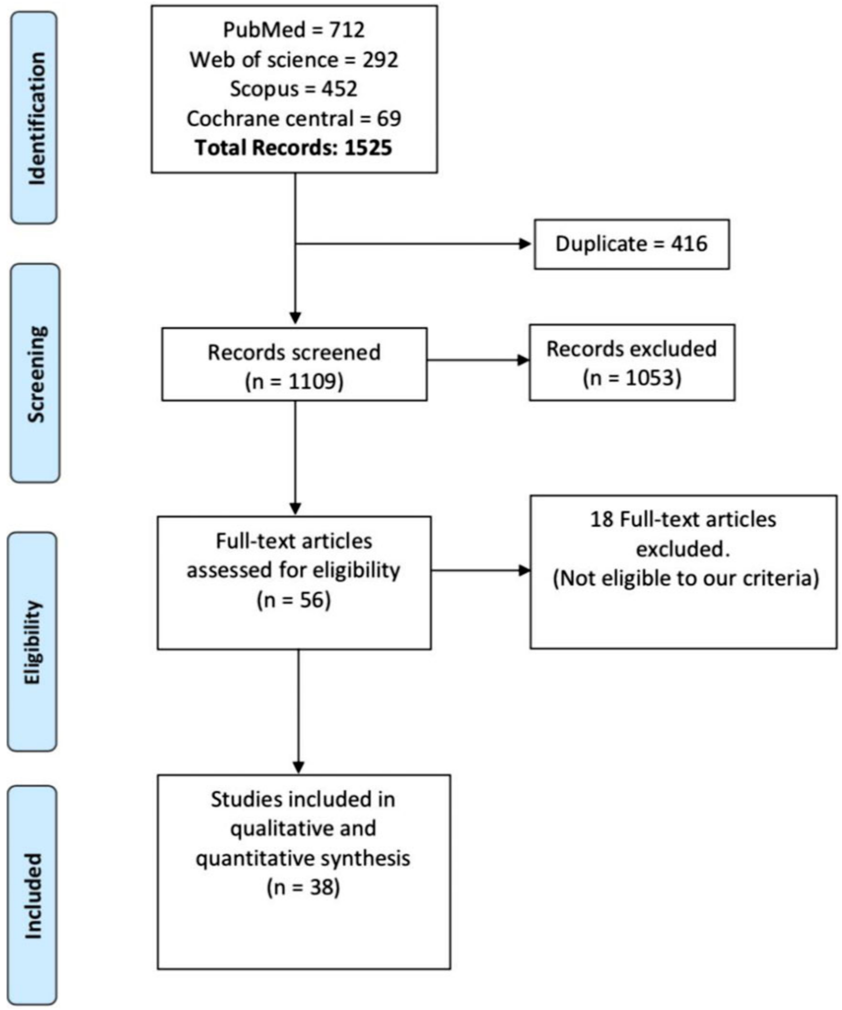

Figure 1. PRISMA Illustrating the Study Selection Process.
Abbreviation: PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Esophageal Intubation Rate—Pooling data from 12 studies involving 2,905 pediatrics reporting the esophageal intubation rate revealed that esophageal intubation occurred in 93 with a rate of 3.0% (95% CI, 0.017-0.043); pooled data were heterogenous ($I^2 = 81.27\%$; P <.001); Figure 6.

Aspiration Rate—A total of 957 pediatrics pooled from four studies that reported the aspiration rate demonstrated that aspiration occurred in 120 with a rate of 12.9% (95% CI, 0.041-0.216). Pooled data were heterogenous ($I^2 = 94.1\%$; P <.001); Figure 7.

Discussion

In this systematic review, the overall success rate and associated complications of prehospital intubations of pediatrics done by paramedics were assessed. The prevalence of the overall success rate was 82.5% for all trials, 77.2% success rate after the first attempt, and 9.0% of pediatrics needed three or more attempts. By subgrouping the patients according to utilization of muscle relaxants during intubation, the group that took muscle relaxants showed a high overall success rate of 92.5% and a 79.9% success rate after the first attempt. In contrast, the group without muscle relaxants had a 78.9% overall success rate and a 73.3% success rate after first attempt. In terms of complications, there was an overall rate of 23.4%, 3.0% esophageal intubation, and a 12.9% aspiration rate. Due to its infrequency and difficult nature due to anatomical differences, pediatric prehospital intubation requires expertise and skill.[59] A major issue with multiple intubation attempts or failures, along with complications that frequently occur during advanced airway procedures, plays a significant role in reducing survival chances.[60]

The analysis demonstrated an 82% success for all trials and a 77.2% success rate on the first attempt. Similarly, a previous meta-analysis conducted by Garner, et al[17] reported an 88% overall success rate and a 77% successful rate of first attempt. However, the meta-analysis included both physicians and paramedics; nonetheless, paramedics were superior in success rate with 99% while paramedics had a 95% success rate. Additionally, a retrospective study on in-flight intubations on pediatric patients reported a 95% overall success rate and 82% success after first attempt.[24] A prospective study on Australian helicopter emergency providers reported a 91% ETI success rate.[61] In contrast, some studies reported a lower rate of success. A retrospective analysis conducted in nine centers in the United States reported a 64% success rate.[62] Furthermore, Boswell, et al reported a 65.5% successful ETI rate, which is less than what was found in this study.[53]

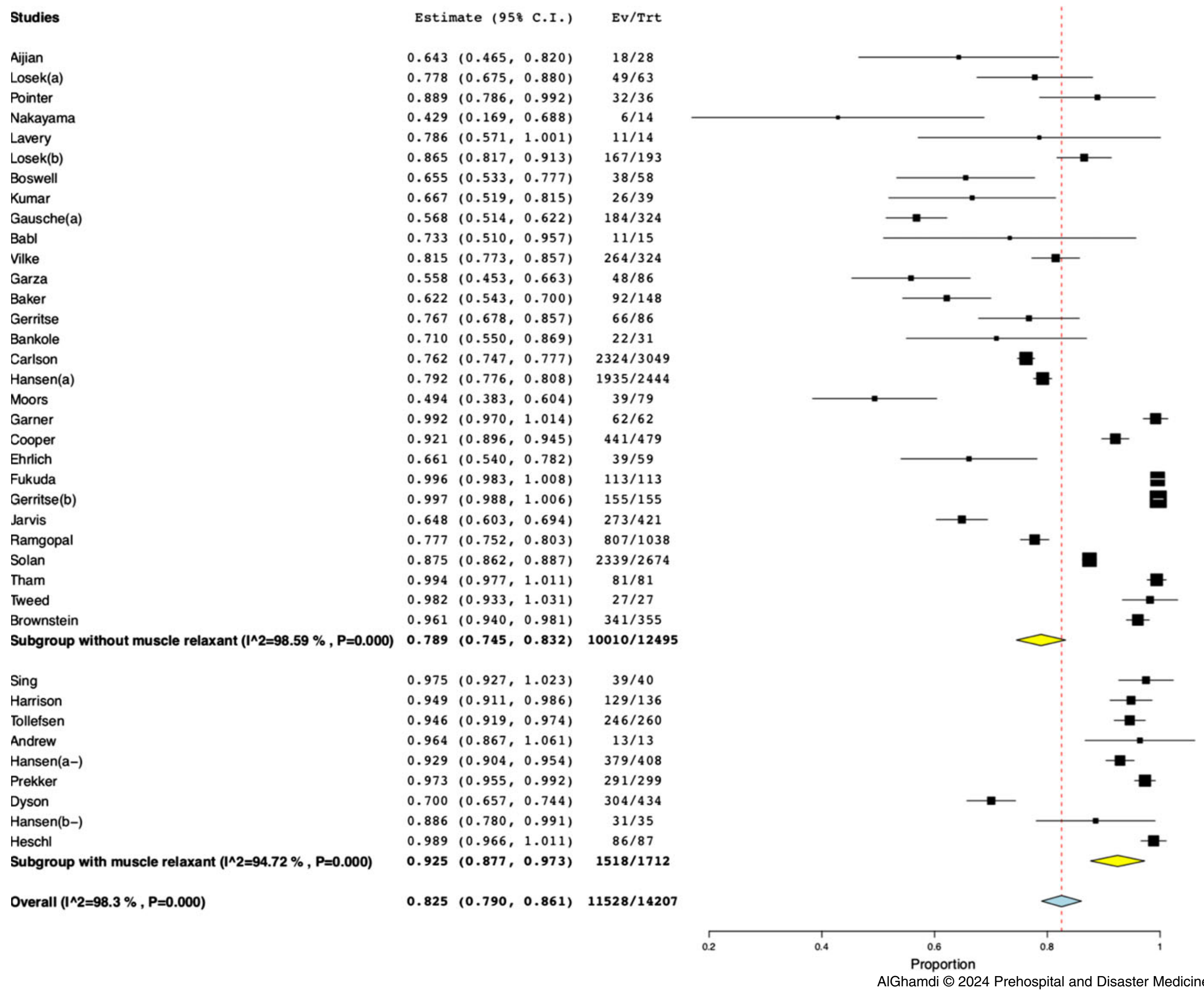

Figure 2. Forest Plot for Overall Success Rate of Intubation With and Without Muscle Relaxant.

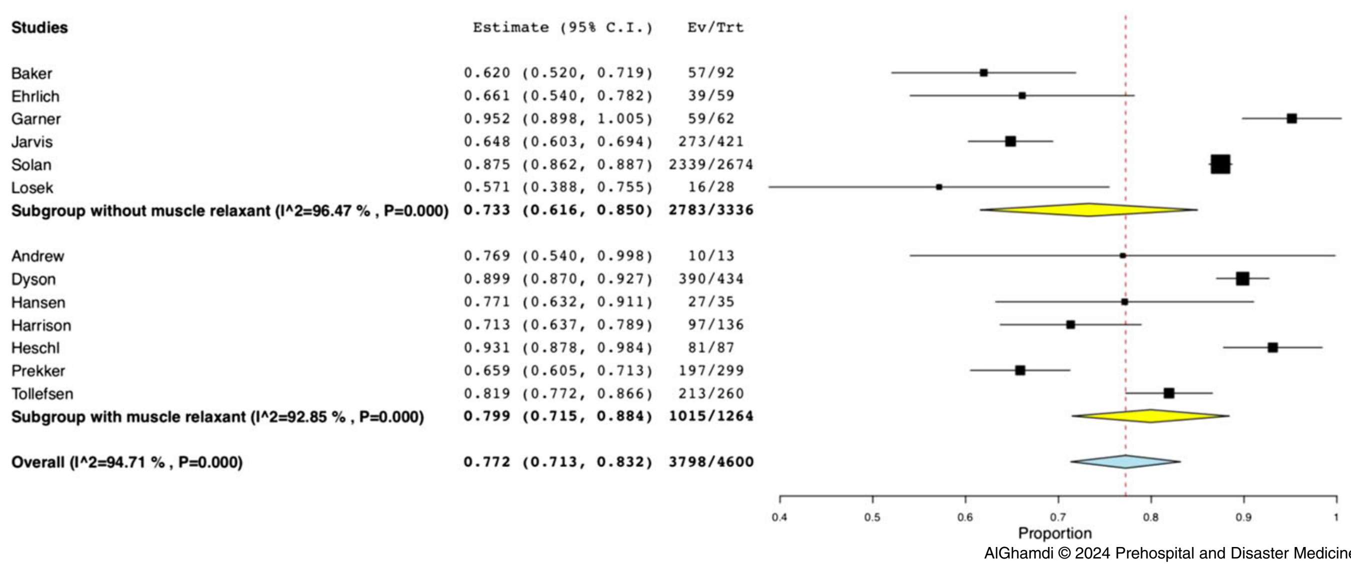

Figure 3. Forest Plot for First Time Success Rate of Intubation With and Without Muscle Relaxant.

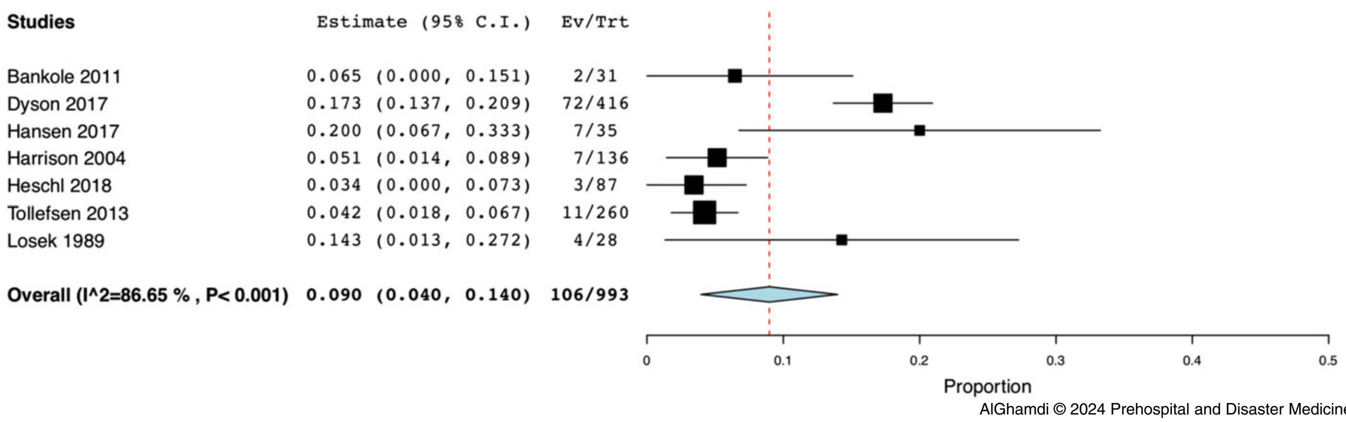

Figure 4. Forest Plot Showing Intubation More than Three Attempts.

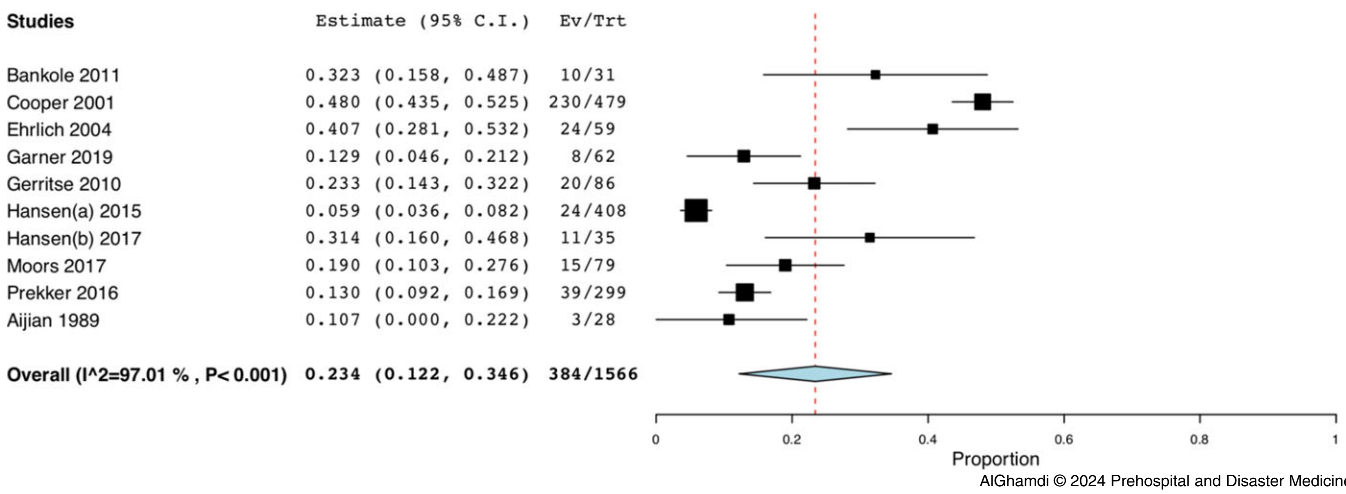

Figure 5. Forest Plot Showing Overall Complications of Intubation.

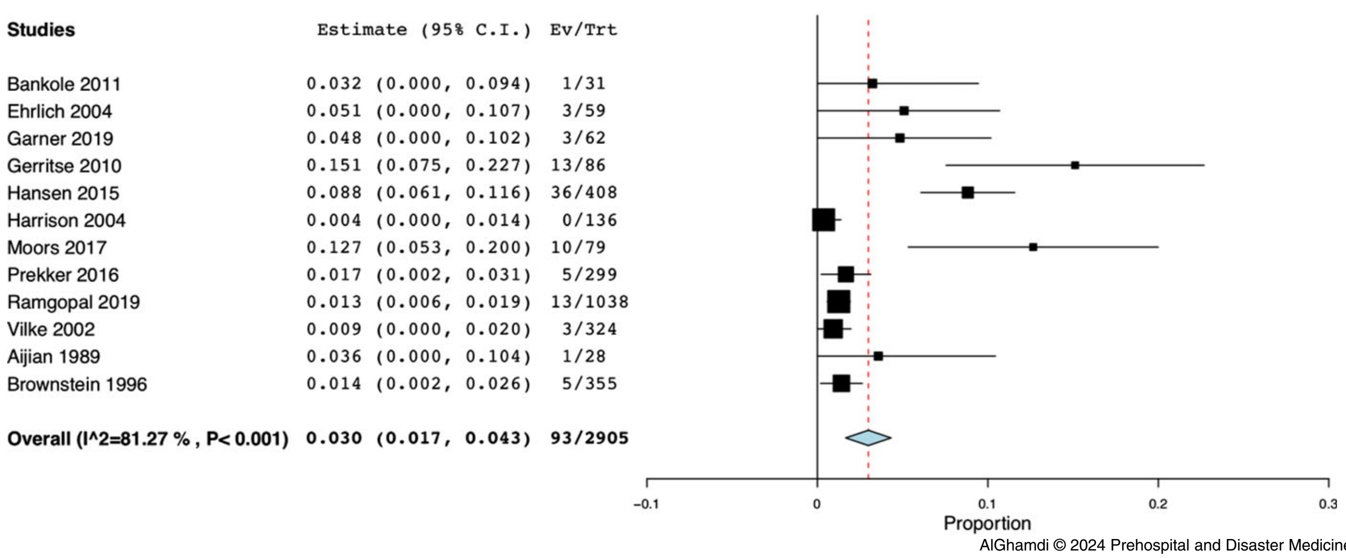

Figure 6. Forest Plot Showing Esophageal Intubation.

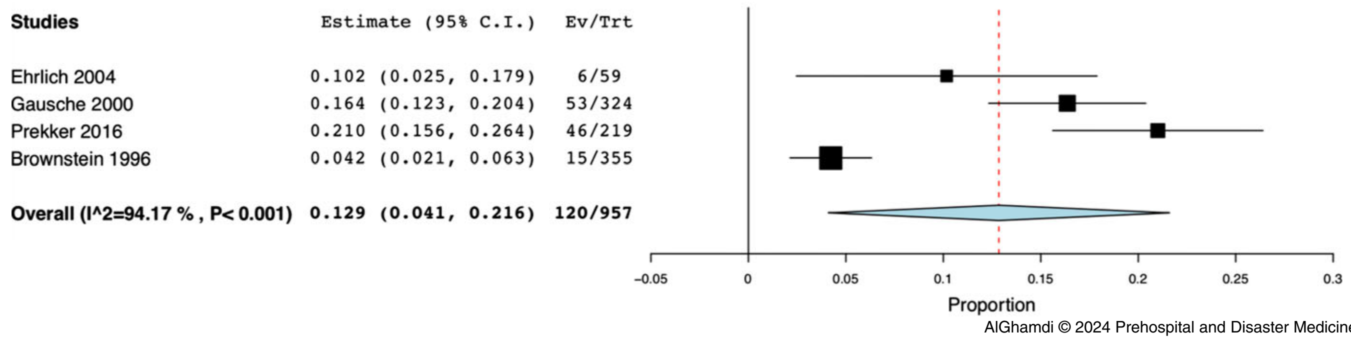

Figure 7. Forest Plot Showing Number of Aspirations.

Previous studies have established that the failure rate rises in younger individuals, likely attributed to variances in laryngeal and craniofacial anatomy, along with age-related equipment needs, rendering ETI more technically challenging in pediatric patients compared to adults.[63,64] A multi-center study conducted on 85,704 patients including neonates, children, and adults intubated by a trained critical care transport team reported that the first attempt was higher in adults at 87.0%, followed by pediatrics at 81.7%, and a low success rate in neonates of 59.3%.[65] A systematic review conducted by Rodriguez, et al revealed that failure in pediatrics was 3.5-times more than in adults.[66] This evidence in research comparing adult and pediatric ETI rates underscores the importance of specialized prehospital provider training in pediatric airway management.[67] This has gone to the extent that the 2020 International Consensus on Cardiopulmonary Resuscitation for Pediatric Life Support recommends bag-mask ventilation due to complications associated with ETI.[68] Further support was received by the 2020 American Heart Association (AHA; Dallas, Texas USA) guidelines that showed the same survival rate comparable between bag-mask ventilation and ETI.[69]

The most common complications associated with ETI include tube misplacement, broncho aspiration, esophageal perforation, hypoxia, atelectasis, or even irreversible brain injury or death from hypoxia.[70] The complications reported in the study include overall complications (23.4%), esophageal intubation (3.0%), and aspiration rate (12.9%). Consistent with this study's findings, Garner, et al[17] reported that the prevalence of complications with paramedics was 30%-39% and was only 10% in physicians. Also, the most frequent complication was aspiration (12%), the esophageal intubation rate was four percent, and unexpectedly, there was no hypoxia that occurred with paramedics; however, there was seven percent hypoxia with the physician group. A previous meta-analysis conducted by Rodriguez, et al[66] reported that esophageal intubation was the most frequent complication. While pediatrics encountered potential complications, most of these complications were promptly recognized and resolved; some may not be directly linked to intubation, but are possibly associated with an underlying acute medical condition, such as aspiration.[71]

Limitations

The limitations of this study include the absence of a direct control or comparison group, uncertainties, and limited evidence in that combining observational studies and randomized controlled trials leads to significant heterogeneity found in some outcomes. Finally, the different studies included have a variation in defining their pediatrics age group, with some studies including those patients under the age of 12 and others younger than 18 years of age. This variability could affect the validity of the outcomes, as adolescents tend to have airway structures similar to those as adults. All of this affects the generalizability of this study to the general population.

Conclusion

Paramedics have a good successful rate of pediatric intubation with a lower complication rate, especially when using muscle relaxants. Regarding the clinical implications, this study, in alignment with prior research, highlighted the importance of early pediatric intubation. While the performance of paramedics shows promise, there remains a need for continuous training programs to further enhance their proficiency in this critical skill.

Supplementary Materials

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X24000244

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	Study ID	Study Setting	Study Design	Total Pediatric Population	Inclusion Criteria	Gender, Male n (%)	Clinical Condition	Definition of Successful Intubation
1	Andrew[57] 2015	Australia	Retrospective	119	<16 years	NR	Major trauma, minor trauma, and no trauma	Successful first or second attempt
2	Babl[56] 2001	USA	Retrospective	555	<18 years	342 (61.6)	Respiratory emergencies, non-respiratory emergencies traffic-related blunt trauma, penetrating trauma	Successful outcome regardless of the number of attempts
3	Baker[55] 2009	USA	Retrospective	183	<18 years	103 (56.3)	Arrest, and trauma	NR
4	Bankole[54] 2011	USA	Retrospective	102	<13 years	57 (55.9)	Head injuries	Any attempt that did not involve any problem such as failed attempts, dislodgement, esophageal intubation, wrong size, more than three attempts
5	Carlson[51] 2015	USA	Retrospective	8,216	<18 years	NR	Critical cases and trauma	NR
6	Cooper[50] 2001	USA	Retrospective	578	<15 years	359 (62.1)	Head injuries	NR
7	Dyson[49] 2017	Australia	Case Control	82	<16 years	NR	Trauma	Documented confirmation by end-tidal capnography waveform or disposable $^{ETCO}{}_{2}$ detector
8	Ehrlich[48] 2004	USA	Retrospective	59	<18 years	NR	Trauma	NR
9	Fukuda[47] 2020	Japan	Retrospective Cohort	967	<18 years	644 (66.6)	Trauma, asphyxia, or drowning	NR
10	Garner[12] 2019	Australia	Retrospective	61	<18 years	47 (73)	Trauma, cardiac arrest, hanging, or asphyxia	NR
11	Garza[46] 2005	USA	Retrospective	120	<16 years	NR	Cardiac arrest	Correct placement of the endotracheal tube was verified by the receiving ED physician using standard verification techniques including physical assessment and qualitative or quantitative end-tidal carbon dioxide detection
12	Gausche[45] 2000	USA	Controlled Clinical Trial	830	<12 years	483 (58.2)	Critical cases and trauma	Placement of an endotracheal tube into a child's trachea or main stem bronchus as determined by the emergency physician or by the study investigator after review of all available data pertaining to the intubation attempt and subsequent treatment in the ED
13	Gerritse[44] 2008	Netherlands	Prospective Cohort	300	<18 years	NR	Trauma	Confirmed in the field by continuous end-tidal carbon dioxide monitoring and auscultation, and a chest X-ray on arrival in the emergency ward

Table 1. Study Characteristics *(continued)*

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14	Gerritse[43] 2010	Netherlands	Prospective Cohort	558	<16 years	NR	Trauma or other medical condition	Symmetrical breath sounds by auscultation, and a positive mainstream capnography, followed by mechanical ventilation with normal airway pressures
15	Hansen[42] 2015	USA	Prospective Cohort	1,881	<18 years	8,172 (58.1)	Trauma and cardiac arrest	NR
16	Hansen[41] 2018	USA	Retrospective	490	<17 years	295 (60)	Cardiac arrest	NR
17	Harrison[40] 2004	USA	Retrospective	143	<12 years	NR	Trauma	Intratracheal placement of the tube as judged by standard clinical criteria (eg, auscultation, pulse oximetry, detection of exhaled CO_2) and by follow-up with receiving hospitals
18	Heschl[39] 2018	Australia	Retrospective	106	<14 years	69 (65)	Trauma or other medical condition	Satisfactory end-tidal wave-form capnography
19	Jarvis[38] 2019	USA	Retrospective Cohort	522	< 14 years	305 (58.4)	Trauma	NR
20	Moors[33] 2018	Netherlands	Retrospective	201	<17 years	NR	Trauma, drowning, or other medical condition	Intubation in the absence of intraesophageal or intrabronchial tube placement if the patient experiences return of spontaneous circulation after intubation
21	Nehme[31] 2018	Australia	Retrospective	948	<16 years	570 (60.4)	Cardiac arrest	NR
22	Prekker[29] 2016	USA	Retrospective	299	<12 years	179 (60)	Trauma	Tracheal tube position was confirmed by capnography and subsequently verified in the hospital or at autopsy
23	Ramgopal[28] 2020	USA	Retrospective	1,038	<18 years	993 (96)	Critical cases and trauma	NR
24	Solan[26] 2023	Australia	Retrospective	2,674	<18 years	1,604 (60)	Trauma or other medical condition	Passage of endotracheal tube into the trachea
25	Tham[25] 2022	Multicenter Worldwide	Retrospective	3,583	<17 years	2278 (63.6)	Trauma and cardiac arrest	NR
26	Tollefsen[24] 2013	USA	Retrospective	260	<14 years	NR	Trauma	Defined by tube passage, resulting in chest rise and color change on a qualitative end-tidal CO2 detector
27	Tweed[23] 2018	USA	Retrospective	104	<12 years	NR	Trauma, seizure, respiratory, drowning, cardiac/respiratory arrest	NR
28	Vilke[22] 2002	USA	Retrospective	324	<15 years	123 (38)	Trauma	Endotracheal tube confirmation at the receiving hospitals is at the discretion of the receiving physician, and usually includes a combination of breath sounds, oxygen saturation, end tidal CO2 monitoring, and direct visualization.

Table 1. Study Characteristics *(continued)*

	Study ID	Study Setting	Study Design	Total Pediatric Population	Inclusion Criteria	Gender, Male n (%)	Clinical Condition	Definition of Successful Intubation
29	Aijian[58] 1989	USA	Retrospective	63	<19 years	33 (53)	Cardiopulmonary arrest	NR
30	Boswell[53] 1995	USA	Retrospective	63	<14 years	NR	Head injuries	NR
31	Brownstein[52] 1996	USA	Retrospective	654	<15 years	NR	Trauma or other medical condition	NR
32	Kumar[37] 1997	USA	Retrospective	47	<18 years	NR	Cardiopulmonary arrest	NR
33	Lavery[36] 1992	USA	Retrospective	453	<18 years	NR	Trauma	NR
34	Losek[35] 1989	USA	Retrospective	63	<18 years	NR	Trauma or other medical condition	Clear visualization of the glottis and vocal cords, use of appropriately sized endotracheal tubes, and maintaining the tube's position during transport
35	Losek[34] 1994	USA	Retrospective	179	<18 years	NR	Cardiopulmonary arrest	NR
36	Nakayama[32] 1990	USA	Retrospective	63	<18 years	NR	Trauma	NR
37	Pointer[30] 1989	USA	Retrospective	36	<15 years	NR	Trauma or other medical condition	Success was defined as the resulting ability to ventilate
38	Sing[27] 1996	USA	Retrospective	40	<18 years	NR	Trauma or other medical condition	NR

Table 1. *(continued).* Study Characteristics
Abbreviation: ED, emergency department.