Archives of Academic Emergency Medicine. 2021; 9(1): e68

OPEN ACCESS

REVIEW ARTICLE

Screening Performance Characteristics of Ultrasonography in Confirmation of Endotracheal Intubation; a Systematic Review and Meta-analysis

Mehrdad Farrokhi[1*], Bardia Yarmohammadi[2], Amir Mangouri[3], Yasaman Hekmatnia[4], Yaser Bahramvand[5], Moein Kiani[6], Elham Nasrollahi[5], Milad Nazari-Sabet[7], Niusha Manoochehri-Arash[8], Maria Khurshid[9†], Shima Mosalanejad[10], Vida Hajizadeh[11], Reza Amani-Beni[12], Masoumeh Moallem[13], Maryam Farahmandsadr[14]

1. Eris Research Institute, Tehran, Iran.
2. School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
3. Department of Vascular and Endovascular Surgery, Sina Hospital, Tehran University of Medical Sciences, Tehran, Iran.
4. Islamic Azad University, Sari Branch, School of Medicine, Sari, Iran.
5. School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran.
6. School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran.
7. Department of General Surgery, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.
8. Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
9. Department of Internal Medicine, Berkshire Medical Center, Pittsfield, Massachusetts, USA.
10. Department of Internal Medicine, Faculty of Medicine, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran.
11. School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.
12. School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.
13. Department of Emergency Medicine, School of Medicine, Tehran Medical Sciences Branch, Islamic Azad University, Tehran, Iran.
14. School of Medicine, Jahrom University of Medical Sciences, Jahrom, Iran.

Received: August 2020; Accepted: September 2021; Published online: 26 October 2021

Abstract: **Introduction:** Recent studies have suggested that point-of-care ultrasonography can be used for confirming the placement of endotracheal tube. This systematic review and meta-analysis aimed to investigate the sensitivity and specificity of ultrasonography for confirming endotracheal tube placement. **Methods:** In this meta-analysis, systematic search of the previous published papers investigating the diagnostic accuracy of ultrasonography for confirmation of endotracheal tube placement was performed. Seven electronic databases, including PubMed, Scopus, Google Scholar, EBSCO, EMBASE, Web of Science, and Cochrane Database were searched up to July 2021, for all relevant articles published in English on this topic. Meta-DiSc version 1.4 software was used for statistical analysis. **Results:** The estimated pooled sensitivity and specificity of ultrasonography for confirmation of endotracheal tube location were 0.98 (95% CI: 0.98–0.99) and 0.94 (95% CI 0.91–0.96), respectively. The pooled positive likelihood ratio and negative likelihood ratio were 5.94 (95% CI 4.41–7.98) and 0.03 (95% CI: 0.02-0.04), respectively. The diagnostic odds ratio of ultrasonography was 281.47 and the area under hierarchical summary receiver operating characteristic (HSROC) revealed an appropriate accuracy of 0.98. **Conclusion:** Ultrasonography has high diagnostic accuracy and can be used as a promising tool for confirmation of endotracheal tube placement, especially in critically ill patients or when capnography is not available, or its result is equivocal.

Keywords: Airway management; intubation; meta-analysis; sensitivity and specificity; ultrasonography

Cite this article as: Farrokhi M, Yarmohammadi B, Mangouri A, Hekmatnia Y, Bahramvand Y, Kiani M, Nasrollahi E, Nazari-Sabet M, Manoochehri-Arash N, Khurshid M, Mosalanejad S, Hajizadeh V, Amani-Beni R, Moallem M, Farahmandsadr M. Screening Performance Characteristics of Ultrasonography in Confirmation of Endotracheal Intubation; a Systematic Review and Meta-analysis. Arch Acad Emerg Med. 2021; 9(1): e68, https://doi.org/10.22037/aaem.v9i1.1360.

*Corresponding Author: Mehrdad Farrokhi; Eris Research Institute, Tehran, Iran. Email: dr.mehrdad.farrokhi@gmail.com, Phone Number:

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

1. Introduction

Securing a definitive airway in critically ill patients is a necessary procedure performed in intensive care unit (ICU), out of hospital, and in the emergency department (ED) settings. Direct assessment of the endotracheal tube passage through the cords is commonly performed via primary localization, followed by a confirming method (1, 2). However, direct visualization of endotracheal tube passing through the cord may be misleading during difficult intubations, which may lead to esophageal intubation in emergency cases. Unrecognized esophageal intubations are associated with catastrophic consequences such as neurological complications or death. Therefore, different techniques are often used to confirm the appropriate placement of endotracheal tube, but not all of them are all of them are not reliable enough to confirm the tracheal intubation (3, 4). It has been suggested that both clinical evaluations and confirmatory methods including auscultation, chest expansion following ventilation, bronchoscopy, chest X-ray, capnography, and end-tidal carbon dioxide (ETCO2) assessment should be used to confirm the location of endotracheal tube. In this regard, ETCO2 has not been suggested for patients with cardiac arrest or embolism. Similarly, capnography has some limitations, including low reliability in patients with embolism or cardiac arrest, or recent bag-valve-mask use (5-7). Due to the abovementioned limitations, combined with growing application of ultrasound by emergency medicine (EM) physicians and ease of use of point-of-care ultrasonography, many studies have been performed to assess the reliability of ultrasonography for approving the placement of endotracheal tube. However, most of these investigations had small sample sizes with different gold standards, resulting in conflicting findings. Accumulating lines of evidence have recently suggested that point-of-care ultrasonography can be used as an adjunct for confirming the placement of endotracheal tube, especially in critical situations such as cardiac arrest or when other confirmation methods are not available (8-10). However, before approval of ultrasonography as a promising technique for confirmation of endotracheal tube placement, it is necessary to pool the results of previously published studies. Therefore, in this systematic review and meta-analysis, we aimed to assess the screening performance characteristics of ultrasonography in confirmation of endotracheal tube placement.

+989384226664.
† **Corresponding Author:** Maria Khurshid; Department of Internal Medicine, Berkshire Medical Center, Pittsfield, Massachusetts, USA. Email: drmkhurshid@yahoo.com.

2. Methods

2.1. Data Sources and Searches

We performed a systematic search of the previous published papers investigating the diagnostic accuracy of ultrasonography for confirmation of endotracheal tube placement. We searched PubMed, Scopus, Google Scholar, EBSCO, EMBASE, Web of Science, and Cochrane Databases from inception to July 2021. The systematic search was carried out using medical subject heading (MeSH) terms for "ultrasonography" and "intubation". In this regard, we used "sono", "sonography", "ultrasonography", "ultrasound", "endotracheal intubation", "esophageal intubation", and "intubation". Our search had no restrictions with respect to location of study or publication date. Furthermore, in this meta-analysis, we only assessed human studies.

2.2. Selection Criteria

In this meta-analysis we included studies investigating the diagnostic accuracy of bedside ultrasound to confirm endotracheal tube placement following emergency or elective intubation in adult subjects. The included studies were required to compare the findings of ultrasonography with a gold standard technique, such as fiberoptic bronchoscopy or capnography, for confirmation of endotracheal tube placement. Retrospective design studies, case reports, case series, and reviews were excluded and clinical trials, case-control or cohort design studies were included in this study. Investigations performed using mannequins, cadavers, or pediatric patients were excluded from the study. Two independent reviewers (M.F and B.Y) assessed the studies according to the above-mentioned criteria and any discrepancy between them was resolved by a third reviewer (M.K). In order to avoid possible duplicates, we searched the first author's name, as well as the place and the period of the subjects' enrolment. In the case of different versions of the same study, only the most recent was considered.

2.3. Data Extraction

Data were extracted by two reviewers and included characteristics of the studies (the first author, publication date, sample size, male percentage, mean age of participants, and location of intubation), ultrasonic technique, transducer type, percentage of esophageal intubation, gold standard for confirmation of endotracheal tube placement, and diagnostic accuracy parameters of ultrasonography (number of true positive, true negative, false positive, and false negative). The process of data extraction was performed by two investigators independently and finally, inconsistencies regarding included studies were resolved by a third reviewer.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

2.4. Data Synthesis

Meta-DiSc version 1.4 software and Comprehensive Meta-Analysis software version 3 were used for statistical analysis. The heterogeneity among the included studies was investigated using Q-statistic and I2 index. If the value of I2 was higher than 50% or P-value was less than 0.10, the random model was used to estimate the sensitivity and specificity of ultrasonography for confirmation of endotracheal tube placement. Alternatively, if the value of I2 was less than 50% and P-value was higher than 0.10, the sensitivity and specificity of ultrasonography were calculated using fixed model. Egger's test and funnel plot were used to evaluate publication bias.

3. Results

3.1. Search Results

Figure 1 summarizes the flow of studies in this review according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations. A total of 9542 studies were identified in our preliminary search. After removal of 1682 duplicates, abstracts of the remaining 7860 studies were assessed by two independent reviewers (M.F and B.Y). The full-text of 142 articles were evaluated for eligibility and 107 article were excluded according to the exclusion criteria. Finally, 33 articles evaluating 2840 patients were included in our meta-analysis.

3.2. Characteristics of Included Studies

The characteristics of the 33 included studies are summarized in table 1. Studies were performed between 2007 and 2020, with the sample sizes ranging from 19–150 subjects. Most of the included studies were performed in Iran (seven studies). Twenty-nine studies were prospective observational studies and 4 were controlled trials. Five studies were conducted in ICUs, 10 were performed in operating rooms, and 18 were carried out in EDs. The prevalence of esophageal intubation was estimated to be 8.4% (95% CI: 6.5-10.8; Figure 2).

3.3. Publication Bias and Quality Assessment

Assessment of publication bias based on Egger's test showed that there was a statistically significant publication bias (P<0.01). Moreover, the funnel plot of included studies revealed significant asymmetry (Figure 3). Quality assessment of the included studies was performed using QUADAS-2 tool (Table 2).

3.4. Diagnostic Accuracy Indices

The estimated pooled sensitivity and specificity of ultrasonography for confirmation of endotracheal tube location were 0.98 (95% CI: 0.98–0.99) and 0.94 (95% CI 0.91–0.96), respectively (Figure 4 and Figure 5). The pooled positive likelihood ratio and negative likelihood ratio were 5.94 (95% CI 4.41–7.98) and 0.03 (95% CI: 0.02-0.04), respectively (Figure 6 and Figure 7). Furthermore, the diagnostic odds ratio of ultrasonography was 281.47 (95% CI: 168.91–469.06) (Figure 8). The area under hierarchical summary receiver operating characteristic curve (HSROC) revealed an appropriate accuracy of 0.98 (Figure 9). Subgroup analysis based on transducer type and location of intubation (ICU or ED, or operating room) showed acceptable sensitivity and specificity.

4. Discussion

The results showed that the estimated pooled sensitivity and specificity of ultrasonography for confirmation of endotracheal tube location were 0.98 and 0.94, respectively. The diagnostic odds ratio of ultrasonography was 281.47 and the area under HSROC revealed an appropriate accuracy of 0.98. Our findings confirm the efficacy of ultrasonography as an adjunct for assessment of endotracheal tube location during intubation. It should be noted that these results are important since capnography has been considered to have low accuracy, especially in subjects with critical conditions. Similarly, ultrasonography has been approved by advanced cardiac life support guidelines as an adjunct for capnography to confirm endotracheal tube placement (11). Furthermore, most confirmatory techniques need some ventilation, which is associated with higher rates of aspiration and gastric distention in cases with wrong location of endotracheal tube (5, 12). On the other hand, ultrasonography does not increase risk of aspiration or gastric distention and has some advantages including being available in different locations, noninvasive, and rapid for confirmation of endotracheal tube placement. In a similar study, Adhikari et al. (13) have performed a systematic search in different databases to identify studies evaluating efficacy of ultrasonography for confirmation of endotracheal tube placement. Their systematic search yielded 5 eligible studies. In this study, the authors estimated 91% sensitivity (95% CI, 74% to 97%) and 97% specificity (95% CI, 89%to 99%) for ultrasonography, which are lower than those found in our study.

In another study, a systematic search was carried out in EMBASETM, MEDLINE, LILACS, The Cochrane Library, KoreaMed, OpenGrey, and the World Health Organization International Clinical Trials Registry from their inception to 2014, which yielded 11 studies with 969 patients (14). They reported pooled sensitivity and specificity of ultrasonography in confirming the placement of the tube as 0.98 and 0.98, respectively. Although their estimated pooled sensitivity was similar to that found in our study, their pooled specificity was higher than ours. These differences can partially be ex-

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

plained by the difference in the number of included studies, sample sizes of patients, and also causes of patient hospitalization.

Although our findings confirmed the efficacy of ultrasonography as a promising adjunct for confirmation of endotracheal tube placement, it should be noted that there are some significant limitations for ultrasonography. First, the efficacy of ultrasonography is dependent on the operator and ultrasonography by different operators may result in different ultrasonographic image qualities and decisions. Therefore, ultrasonography operators must obtain necessary skills before performing ultrasonography for confirmation of endotracheal tube location. Furthermore, ultrasonography cannot be performed easily in situations where there is only one operator, because that operator may be the technician performing endotracheal intubation. Therefore, in these cases, the static techniques is superior to dynamic technique. Moreover, the placement of ultrasonographic transducer on the trachea when a tube is entering the trachea may be associated with a more difficult intubation as it might deviate its path. In this regard, it has been suggested that the pressure of transducer on trachea should be reduced by ultrasonography operator to prevent deviation of endotracheal tube during intubation. If ultrasonography increases the risk of difficult intubation, the procedure should be performed using static technique. From another point of view, ultrasonography may be difficult for some intubations including cases with different airway anatomy, neck edema, cervical collar, subcutaneous emphysema, and neck masses. Unlike ultrasonography, capnography requires four to five ventilations to confirm the location of endotracheal tube placement, so ultrasonography is faster than capnography. However, the efficacy of capnography is not dependent on the experience of operator and training does not affect the accuracy of this method (15).

It is now well established that ultrasonography has several strong points for confirmation of endotracheal tube location. Deviation of endotracheal tube into the esophagus can be easily identified before initiation of ventilation because ultrasonography is carried out in real time during intubation. Since ultrasonography has an appropriate specificity for identification of esophageal intubation, this method can be used in cases with indefinite result of capnography to reduce the total number of intubation attempts. Furthermore, ultrasonography does not interfere with chest compression and intubation can be performed during cardiopulmonary resuscitation. However, further studies with larger sample sizes using appropriate gold standards are required to establish ultrasonography as a promising diagnostic test for assessment of endotracheal tube location.

5. Limitations

Different methods of confirmation were used as gold standard to indicate sensitivity and specificity of sonography for confirmation of endotracheal tube placement.

6. Conclusion

The results showed that ultrasonography has high diagnostic accuracy and can be used as a promising tool for confirmation of endotracheal tube placement, especially in critically ill patients or when capnography is not available, or its result is equivocal.

7. Declarations

7.1. Acknowledgments

The authors thank all those who contributed to this study.

7.2. Conflict of Interest

None.

7.3. Funding/Support

None.

7.4. Authors' contribution

All authors contributed to study design, data collection, writing draft of study.

7.5. Data Availability

Not applicable.

References

1. James SL, Castle CD, Dingels ZV, Fox JT, Hamilton EB, Liu Z, et al. Global injury morbidity and mortality from 1990 to 2017: results from the Global Burden of Disease Study 2017. Injury Prevention. 2020;26(Supp 1):i96-i114.
2. Organization WH. Global status report on road safety 2018: summary Genova: World Health Organization; 2018.
3. Roth GA, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2018;392(10159):1736-88.
4. Mohammadi M, Imani M, Tajari F, Akbari F, Rashedi F, Ghasemi A, et al. Human and vehicle factors in motor vehicle crashes and severity of related injuries in South East Iran. J Health Scope. 2012;1(2):61-5.
5. Shahraz S, Bartels D, Puthenpurakal JA, Motlagh ME. Adverse health outcomes of road traffic injuries in Iran

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

after rapid motorization. Archives of Iranian medicine. 2009;12(3):284-94.
6. Moradi A, Salamati P, Vahabzadeh E. Social Factors Associated With Risky Driving on the Intercity Roads of Tehran Province, Iran: A Case-Cohort Study. Archives of Trauma Research. 2016(In Press).
7. Bakhtiyari M, Delpisheh A, Monfared AB, Kazemi-Galougahi MH, Mehmandar MR, Riahi M, et al. The road traffic crashes as a neglected public health concern; an observational study from Iranian population. Traffic injury prevention. 2015;16(1):36-41.
8. Bakhtiyari M, Mehmandar MR, Riahi SM, Mansournia MA, Sartipi M, Bahadorimonfared A. Epidemiologic Pattern of Fatal Traffic Injuries among Iranian Drivers; 2004–2010. Iranian journal of public health. 2016;45(4):503.
9. Mehmandar M, Soori H, Amiri M, Norouzirad R, Khabzkhoob M. Risk factors for fatal and nonfatal road crashes in iran. Iranian Red Crescent medical journal. 2014;16(8):e10016-e.
10. Lankarani KB, Heydari ST, Aghabeigi MR, Moafian G, Hoseinzadeh A, Vossoughi M. The impact of environmental factors on traffic accidents in Iran. Journal of injury and violence research. 2014;6(2):64.
11. National Heart L, and Blood Institute (NHLBI),. Quality Assessment Tool for Observational Case-Control Studies USA: National Library of Medicine; 2014 [Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.
12. Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, et al. GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. Journal of clinical epidemiology. 2011;64(4):383-94.
13. Group GW. Grading quality of evidence and strength of recommendations. Bmj. 2004;328(7454):1490.
14. Bakhtiyari M, Mehmandar MR, Khezeli M, Latifi A, Jouybari TA, Mansournia MA. Estimating the avoidable burden and population attributable fraction of human risk factors of road traffic injuries in iran: application of penalization, bias reduction and sparse data analysis. International journal of injury control and safety promotion. 2019;26(4):405-11.
15. Bakhtiyari M, Mehmandar MR, Mirbagheri B, Hariri GR, Delpisheh A, Soori H. An epidemiological survey on road traffic crashes in Iran: application of the two logistic regression models. International journal of injury control and safety promotion. 2014;21(2):103-9.
16. Dastoorpoor M, Idani E, Khanjani N, Goudarzi G, Bahrampour A. Relationship Between Air Pollution, Weather, Traffic, and Traffic-Related Mortality. Trauma monthly. 2016;21(4):e37585.
17. Ghaem H, Soltani M, Yadollahi M, ValadBeigi T, Fakhrepour A. Epidemiology and Outcome Determinants of Pedestrian Injuries in a Level I Trauma Center in Southern Iran; A Cross-Sectional Study. Bulletin of emergency and trauma. 2017;5(4):273-9.
18. Hasani J, Khorshidi A, Erfanpoor S, Nazparvar B, Nazari SSH. Comparison of risk factors for pedestrian fatality in urban and suburban traffic accidents. Archives of trauma research. 2018;7(2):39-44.
19. Hosseinpour M, Mohammadian-Hafshejani A, Esmaeilpour Aghdam M, Mohammadian M, Maleki F. Trend and Seasonal Patterns of Injuries and Mortality Due to Motorcyclists Traffic Accidents; A Hospital-Based Study. Bulletin of emergency and trauma. 2017;5(1):47-52.
20. Khorshidi A, Ainy E, Hashemi Nazari SS, Soori H. Temporal Patterns of Road Traffic Injuries in Iran. Archives of trauma research. 2016;5(2):e27894.
21. Lankarani KB, Heydari ST, Aghabeigi MR, Moafian G, Hoseinzadeh A, Vossoughi M. The impact of environmental factors on traffic accidents in Iran. Journal of injury & violence research. 2014;6(2):64-71.
22. Mehmandar M, Soori H, Amiri M, Norouzirad R, Khabzkhoob M. Risk factors for fatal and nonfatal road crashes in iran. Iranian Red Crescent medical journal. 2014;16(8):e10016.
23. Moradi A, Soori H, Kavosi A, Eshghabadi F, Hashemi Nazari SS, Rahmani K. Human factors influencing the severity of traffic accidents related to pedestrians in Tehran. Iran Occupational Health. 2018;15(3):55-65.
24. Mousazadeh Y, Sadeghi-Bazargani H, Janati A, Pouraghaei M, Rahmani F. Prediction of mortality risk in patients with traffic injury: A case study in tabriz hospitals, Iran. Archives of trauma research. 2019;8(2):104-9.
25. Nasiri N, Sharifi H, Rezaeian M, Sanji Rafsanjani M, Sharifi A, Vazirinejad R. Determining factors affecting deaths caused by traffic accidents in the south of Kerman Province. Iranian Journal of Epidemiology. 2019;15(1):20-8.
26. Paravar M, Hosseinpour M, Salehi S, Mohammadzadeh M, Shojaee A, Akbari H, et al. Pre-hospital trauma care in road traffic accidents in kashan, iran. Archives of trauma research. 2013;1(4):166-71.
27. Shadmani FK, Soori H, Mansori K, Karami M, Ayubi E, Khazaei S. Estimation of the population attributable fraction of road-related injuries due to speeding and passing in Iran. Epidemiology and health. 2016;38.
28. Sherafati F, Homaie-Rad E, Afkar A, Gholampoor-Sigaroodi R, Sirusbakht S. Risk Factors of Road Traffic Accidents Associated Mortality in Northern Iran; A Single Center Experience Utilizing Oaxaca Blinder Decomposition. Bulletin of emergency and trauma. 2017;5(2):116-

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

21.
29. Soori H, Ainy E, Zayeri F, Mehmandar M. Comparison of road traffic death occurrence within urban and metropolitan roads focusing on environmental factors. Hakim Research Journal. 2013;15(4):339-45.
30. Taravatmanesh L, Mortazavi SM, Baneshi MR, Poor MS, Saeedifar A, Zolala F. Epidemiology of road traffic accidents in Rafsanjan city, Iran. Electronic physician. 2018;10(5):6859-63.
31. Tavakoli Kashani A, Rabieyan R, Besharati MM. Modeling the effect of operator and passenger characteristics on the fatality risk of motorcycle crashes. Journal of injury & violence research. 2016;8(1):35-42.
32. Yadollahi M, Ghiassee A, Anvar M, Ghaem H, Farahmand M. Analysis of Shahid Rajaee hospital administrative data on injuries resulting from car accidents in Shiraz, Iran: 2011–2014 data. Chinese Journal of Traumatology - English Edition. 2017;20(1):27-33.
33. Yousefzadeh-Chabok S, Razzaghi A. The relationship between socio-economic status and the consequences of deathes and injury severity in road traffic crash patients. Iran Occupational Health. 2019;16(2):1-10.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

Table 1: Characteristic of studies included in the meta-analysis

Author	Year	Sample Size	Location	Mean Age	Male (%)	Ultrasonic Technique	Transducer Type	Esophageal Intubation (%)	Gold Standard
Chowdhury et al. (3)	2020	120	OR	39.02	28	Dynamic	Linear	4.1	CAP+A
Chen et al. (1)	2020	118	ICU	71.5	60.2	Dynamic	NR	10.2	DV+FB
Men et al. (16)	2019	68	OR	60.4	54	Static	Curvilinear	17.6	A+FB
Patil et al. (17)	2019	91	ICU	NR	NR	Dynamic	Linear	2	CAP
Afzalimoghadam et al. (18)	2019	90	ED	59.2	58.9	Dynamic	Linear	3.3	CAP
Zamani et al. (19)	2018	100	ED	57.5	73	Dynamic	Linear	6	CAP
Kad et al. (20)	2018	100	OR	NR	NR	Static	Linear	2	A
et al. (21)	2018	40	ICU	55.7	65	Dynamic	Curvilinear	10	FB
Inangil et al. (22)	2018	50	OR	42.9	56	Dynamic	Linear	6	CAP
Arya et al. (23)	2018	75	ICU	63.4	55.3	Dynamic	Linear	16	CAP
Arafa et al. (24)	2018	107	OR	41.4	63.6	Dynamic	Linear	7.5	CAP
Zamani et al. (25)	2017	150	ED	58.5	56	Static	Linear	11.3	O+AS+DV+A
Yang et al. (26)	2017	93	OR	53.5	46	Static	Linear	9.7	CAP+A
Thomas et al. (27)	2017	100	ED	50.8	59	Static	Linear	5	CAP
Rahmani et al. (28)	2017	75	ED	61.1	62.7	Dynamic	Linear	0	DV
Masoumi et al. (8)	2017	100	ED	64.5	65	Static	Curvilinear	6	CAP
Lahham et al. (9)	2017	72	ED	57.7	56.9	Dynamic	Linear	4.2	CAP
Abhishek et al. (5)	2017	100	OR	38.9	NR	Static	Linear	5	CAP
Khosla et al. (29)	2016	20	ICU	70.5	100	Static	Linear	0	CAP+A
Karacabey et al. (a) (10)	2016	85	ED	67.2	NR	Dynamic	Linear	38.2	CAP
Karacabey et al. (b) (10)	2016	30	ED	NR	NR	Dynamic	Linear	NR	CAP
Abbasia et al. (30)	2015	120	ED	50	61.5	Dynamic/Static	Linear	11.7	DV+A+CAP
Sun et al. (31)	2014	96	ED	68.8	67.6	Dynamic	Curvilinear	7.3	CAP+A
Hoffman et al. (32)	2014	101	ED	58	NR	Dynamic/Static	Linear	10	DV+CAP
Saglam et al. (33)	2013	69	ED	NR	NR	Static	Linear	7.2	CAP
Hosseini et al. (34)	2013	57	ED	59	60	Static	Curvilinear	21	DV+A+O
Chou et al. (a) (35)	2013	89	ED	69.9	69	Dynamic	Curvilinear	7.6	CAP+A
Adi et al. (36)	2013	107	ED	NR	NR	Static	Linear	5.6	CAP
Noh et al. (37)	2012	19	ED	NR	NR	Dynamic	Linear	15.7	CAP
Mulsu et al. (38)	2011	150	OR	40.5	50.7	Dynamic	Linear	50	CAP+A
Chou et al. (b) (39)	2011	83	ED	67.6	54.5	Static	Curvilinear	15.7	CAP
Chou et al. (c) (39)	2011	29	ED	NR	NR	Static	Curvilinear	10.3	CAP
Park et al. (40)	2009	30	ED	59.6	56.7	Dynamic	Linear	10	CAP+A
Werner et al. (41)	2007	66	OR	38.9	21.2	Dynamic	Linear	57.6	DV+CAP
Milling et al. (42)	2007	40	OR	52.5	17.5	Dynamic	Curvilinear	12.5	CAP+A

OR: operation room; ICU: intensive care unit; ED: emergency department; NR: not reported; CAP: capnography; A: auscultation; DV: direct visualization; FB: fiberoptic bronchoscopy.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

Table 2: Quality assessment of the included studies using QUADAS-2 tool

Study	RISK OF BIAS				APPLICABILITY CONCERNS		
	Patient selection	Index test	Reference standard	Flow & timing	Patient selection	Index test	Reference standard
Chowdhury et al.	☺	☺	☺	☺	☺	☺	☺
Chen et al.	☺	☺	☺	☺	☺	☺	☺
Men et al.	☺	☺	☺	☺	☺	☺	☺
Patil et al.	☺	☺	☺	☺	☺	☺	☺
Afzalimoghadam et al.	☺	☺	☺	☺	☺	☺	☺
Zamani et al.	☺	☺	☺	☺	☺	☺	☺
Kad et al.	☺	☺	☺	☺	☺	☺	☺
Kabil et al.	☺	☺	☺	☺	☺	☺	☺
Inangil et al.	☺	☺	☺	☺	☺	☺	☺
Arya et al.	☺	☺	☺	☺	☺	☺	☺
Arafa et al.	☺	☺	☺	☺	☺	☺	☺
Zamani et al.	?	☺	☺	☺	☺	☺	☺
Yang et al.	☺	☺	☺	☺	☺	☺	☺
Thomas et al.	☺	?	☺	☺	☺	☺	☺
Rahmani et al.	☺	☺	☺	☺	☺	☺	☺
Masoumi et al.	?	☺	☺	☺	☺	☺	☺
Lahham et al.	?	☺	☺	☺	☺	☺	☺
Abhishek et al.	?	☺	☺	☺	☺	☺	☺
Khosla et al.	☺	☺	☺	☺	☺	☺	☺
Karacabey et al. (a)	☺	☺	☺	☺	☺	☺	☺
Karacabey et al. (b)	☺	☺	☺	☺	☺	☺	☺
Abbasia et al.	☹	☺	☺	☺	☺	☺	☺
Sun et al.	☺	☺	☺	?	☺	☺	☺
Hoffman et al.	?	☺	☺	☺	☺	☺	☺
Saglam et al.	☹	☺	☺	☺	☺	☺	☺
Hosseini et al.	☺	☺	☺	☺	☺	☺	☺
Chou et al. (a)	?	☺	☺	☺	☺	☺	☺
Adi et al.	?	☺	☺	☺	☺	☺	☺
Noh et al.	?	☺	☺	?	☺	☺	☺
Mulsu et al.	☺	☺	☺	☺	☺	☺	☺
Chou et al. (b)	?	☺	☺	☺	☺	☺	☺
Chou et al. (c)	?	☺	☺	☺	☺	☺	☺
Park et al.	?	☺	☺	☺	☺	☺	☺
Werner et al.	?	☺	☺	☺	☺	☺	☺
Milling et al.	?	☺	☺	☺	☺	☺	☺

☺: Low Risk; ☹: High Risk; ?: Unclear Risk

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

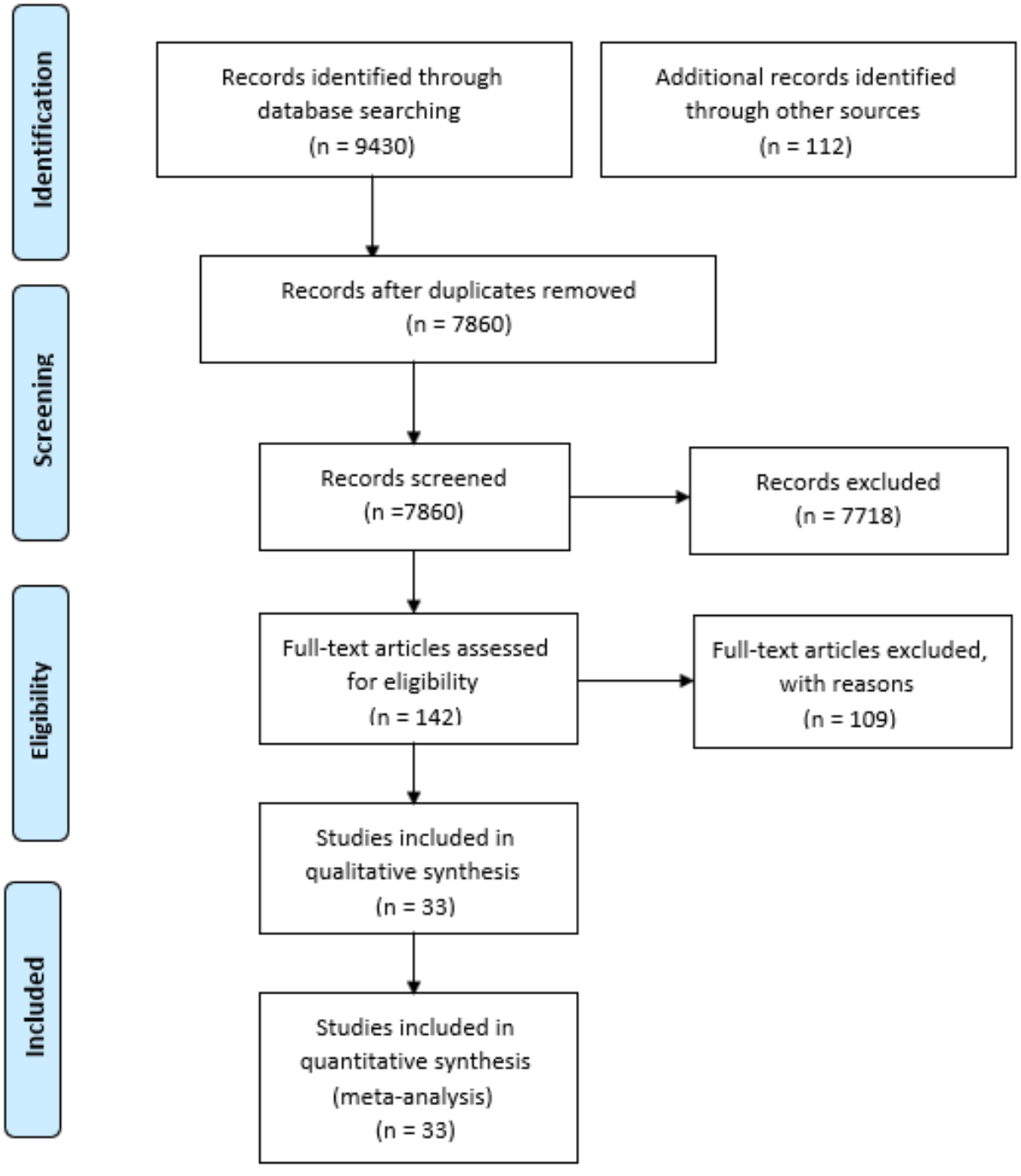

Figure 1: PRISMA flowchart of the literature search and selection of studies that reported accuracy of ultrasonography for confirmation of endotracheal placement.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

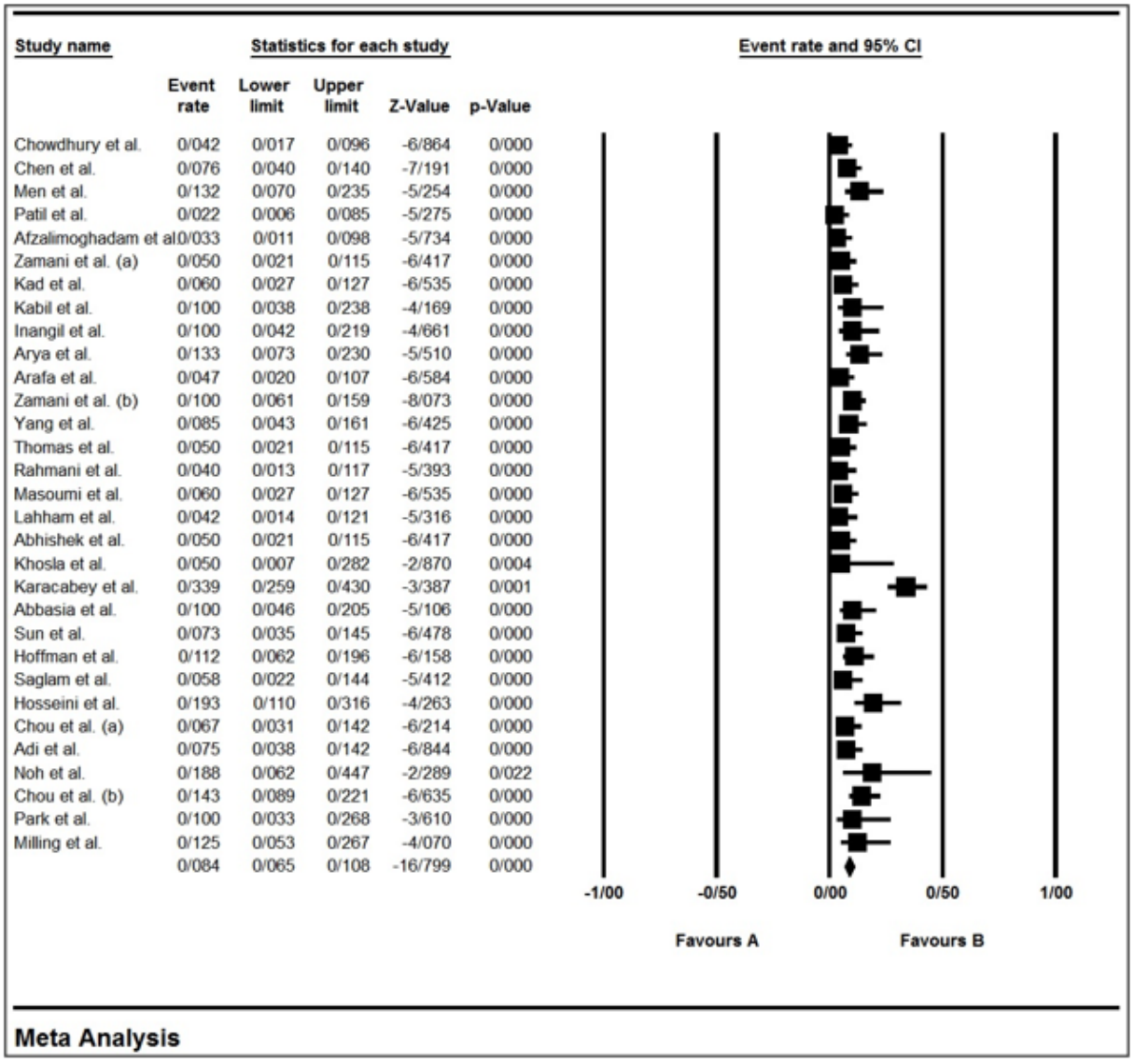

Figure 2: Forest plot of prevalence of esophageal intubation.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

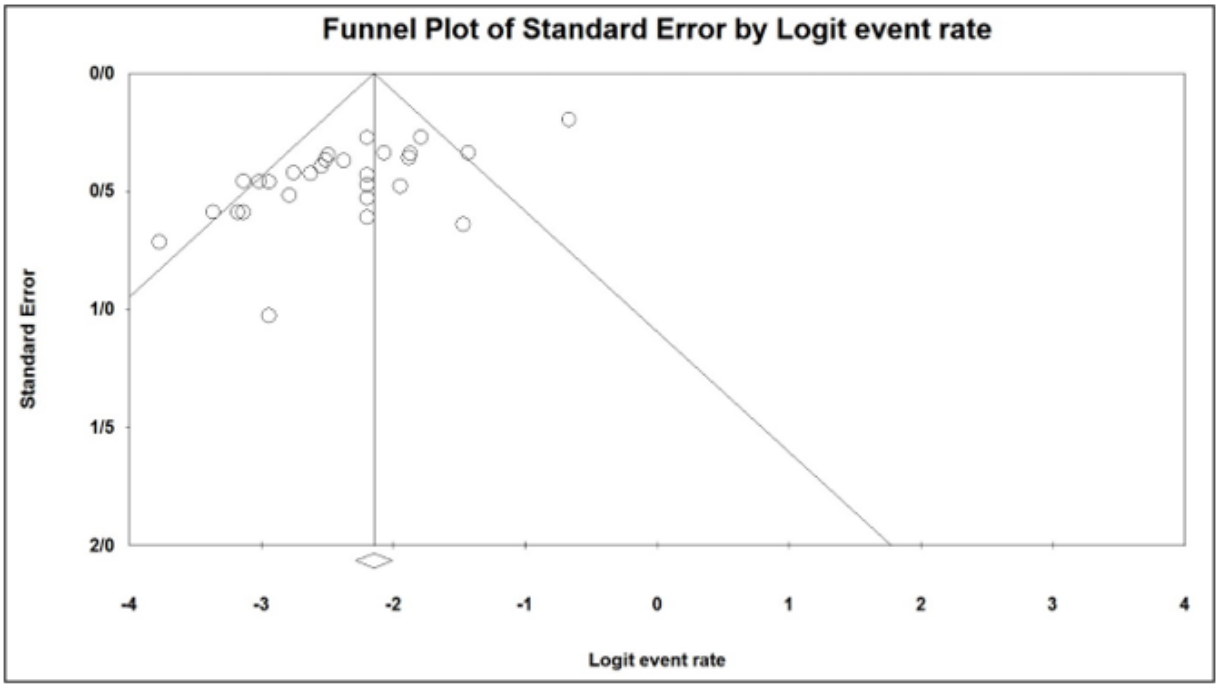

Figure 3: Publication bias of the included studies for analysis of the rate of esophageal intubation confirmed using ultrasonography.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

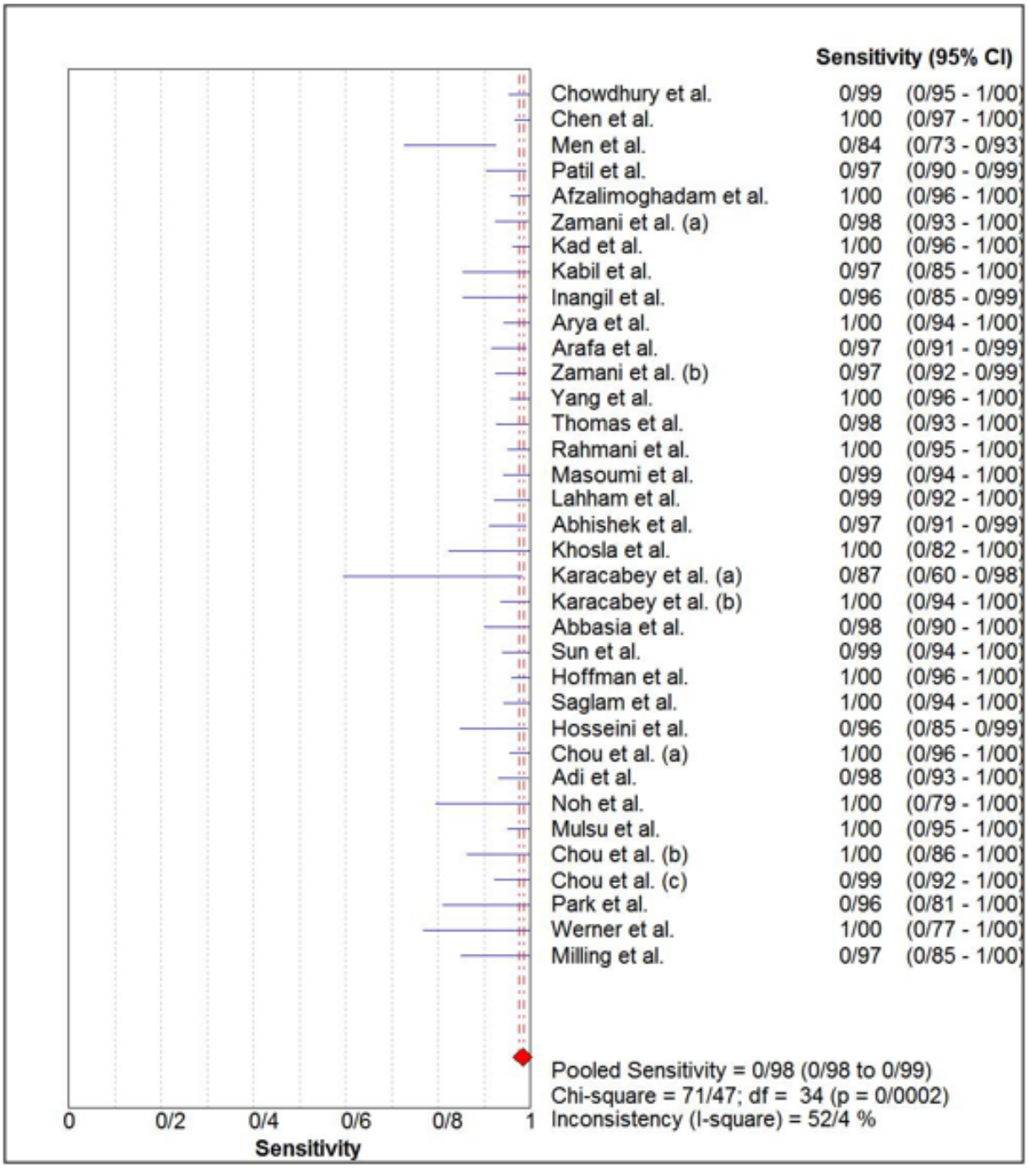

Figure 4: Forest plot of the overall sensitivity of ultrasonography for confirmation of endotracheal tube placement.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

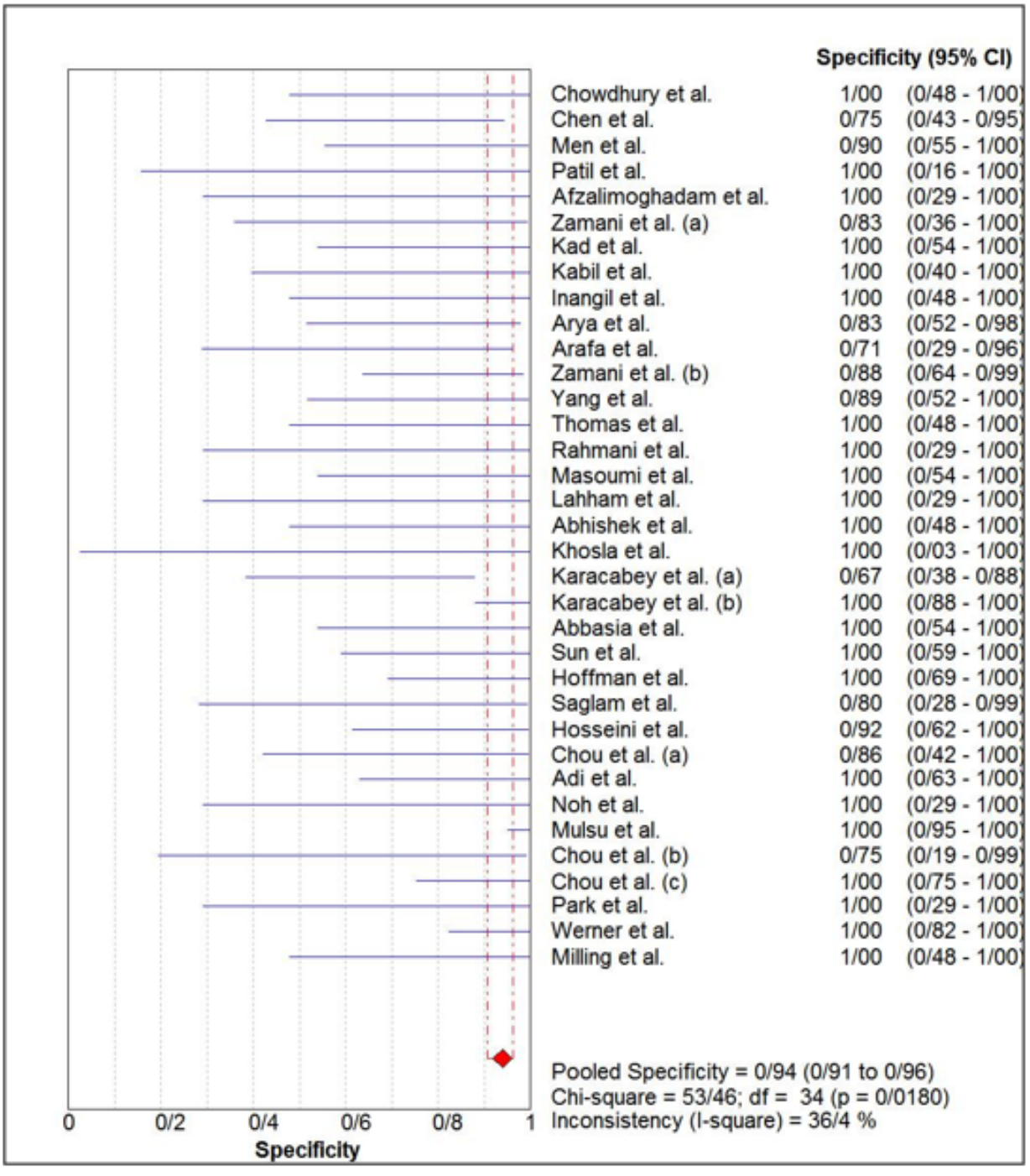

Figure 5: Forest plot of the overall specificity of ultrasonography for confirmation of endotracheal tube placement.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

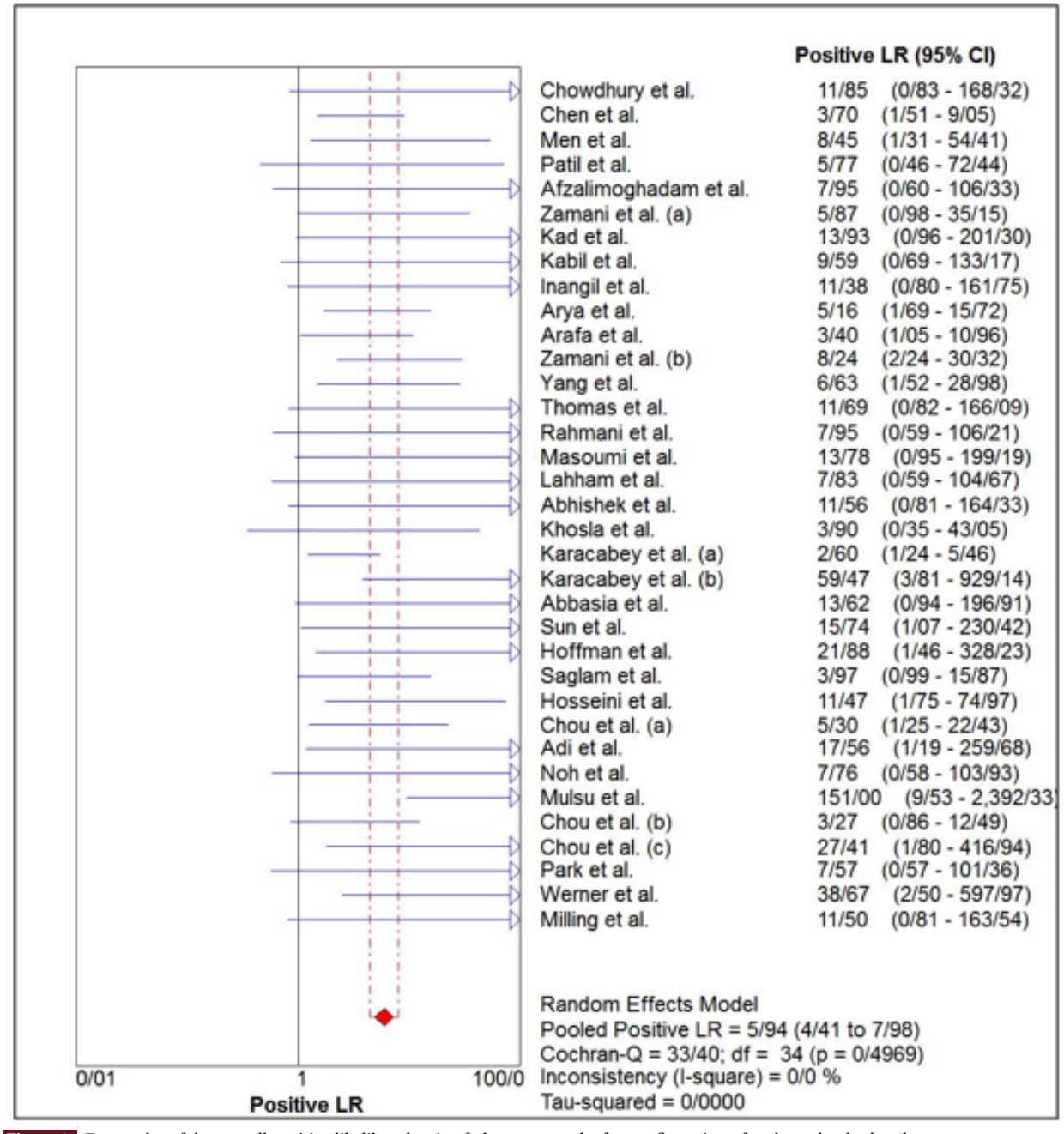

Figure 6: Forest plot of the overall positive likelihood ratio of ultrasonography for confirmation of endotracheal tube placement.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

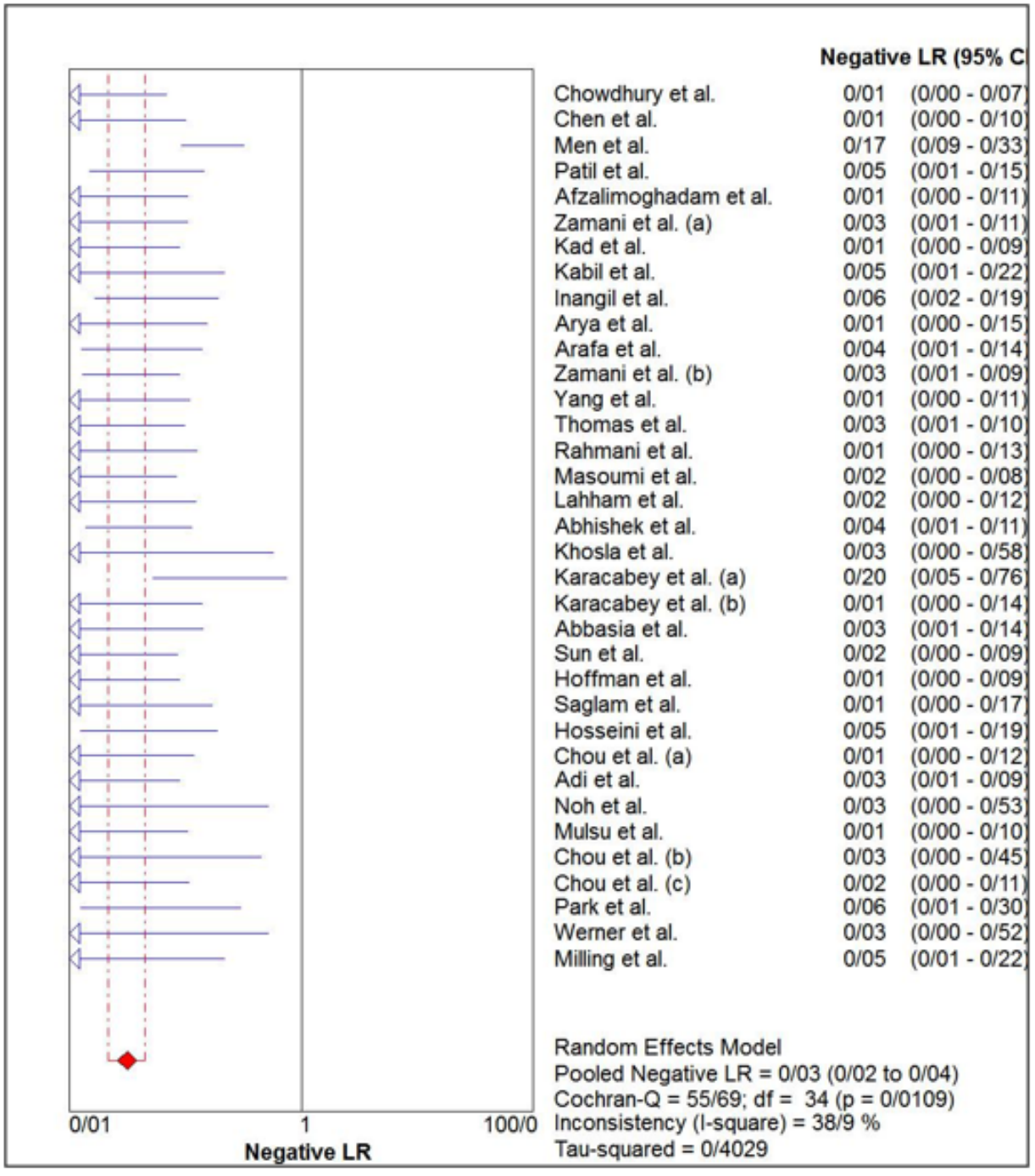

Figure 7: Forest plot of the overall negative likelihood ratio of ultrasonography for confirmation of endotracheal tube placement.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

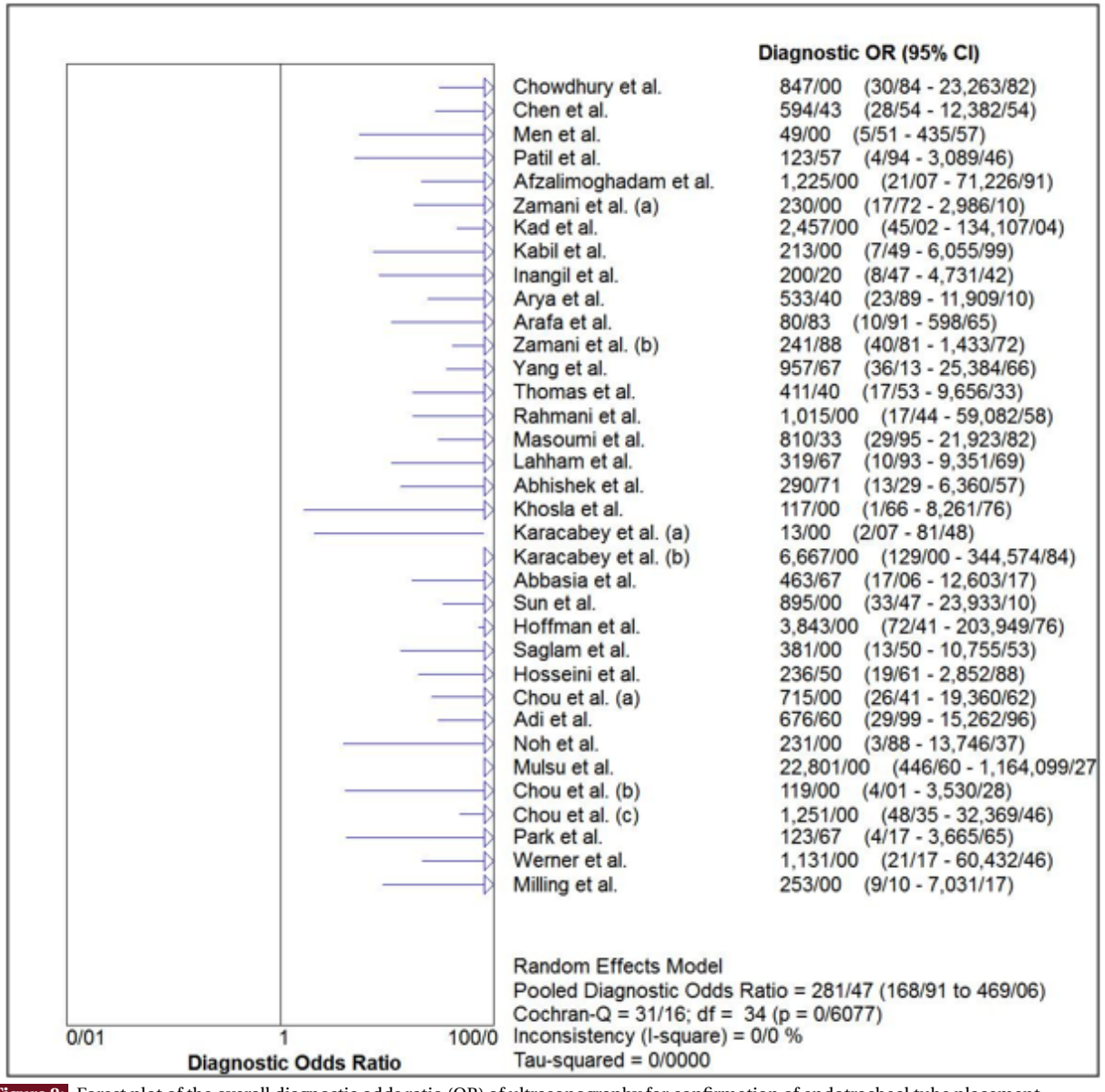

Figure 8: Forest plot of the overall diagnostic odds ratio (OR) of ultrasonography for confirmation of endotracheal tube placement.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem

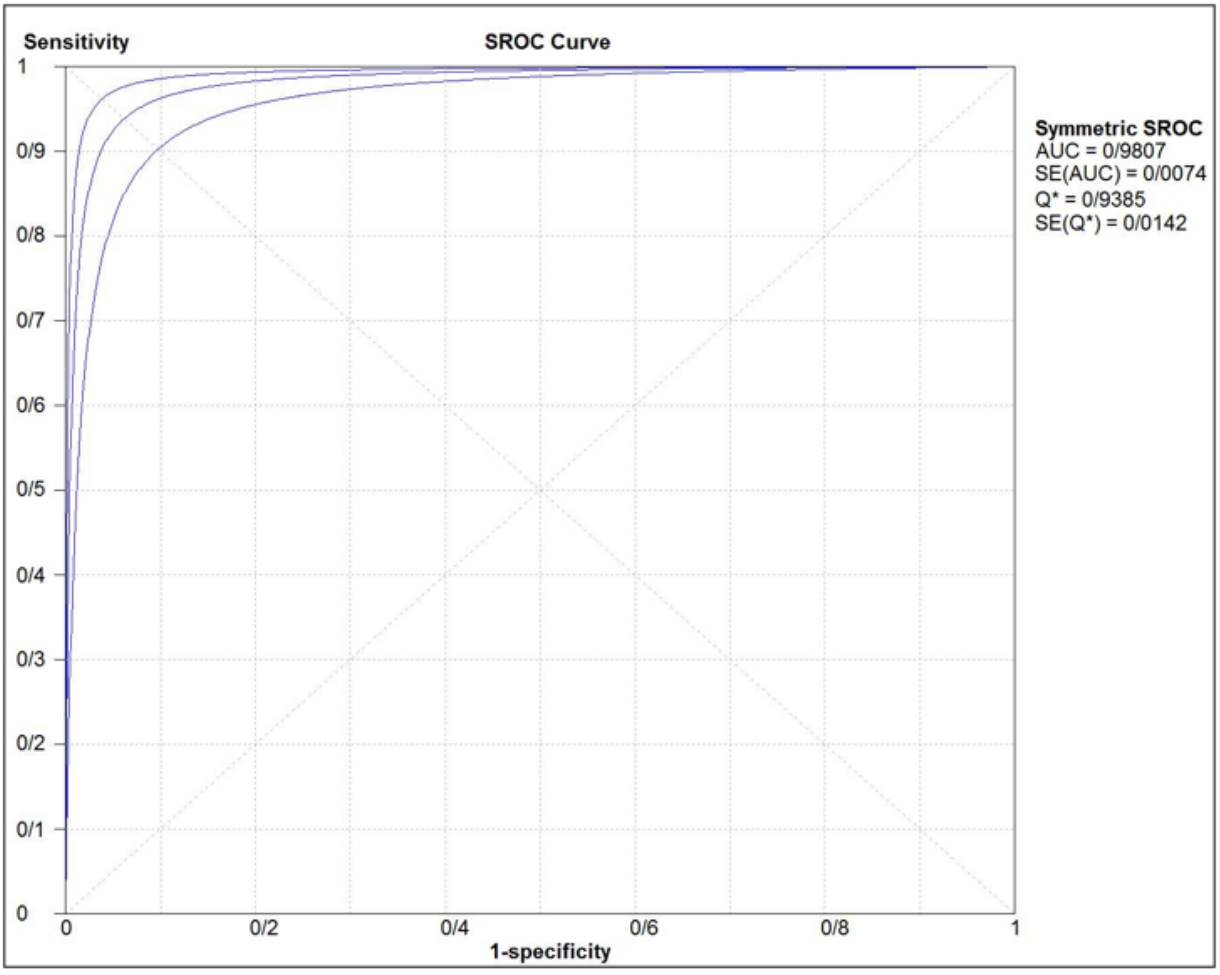

Figure 9: Hierarchical summary receiver-operating characteristic curve (HSROC) indicating accuracy of ultrasonography for confirmation of endotracheal tube placement.

This open-access article distributed under the terms of the Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).
Downloaded from: http://journals.sbmu.ac.ir/aaem