

BIBLIOMETRIC ANALYSES

Do not invade, just support

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ABSTRACT

BACKGROUND: Since the first attempts for ventilation, there have been significant changes in terms of the size of devices, ventilation techniques, and technology. In time, invasive methods and huge devices were replaced by non-invasive methods and small and portable devices. Increased use of non-invasive methods was followed by enrichment of literature on the topic. This study aimed to determine the evolution of non-invasive ventilation (NIV) literature and predict future trends.

MATERIALS AND METHODS: We used the Web of Science database for search. To include all papers, we searched multiple keywords, including “non-invasive ventilation, non-invasive positive pressure, continuous positive airway pressure, CPAP, NIV.” All articles that meet the criteria published in the respiratory system, critical care medicine, anesthesiology, and emergency medicine fields during 1975–2020 were determined.

RESULTS: We made bibliometric analyses of 2847 original articles. However, the limited number of articles in the first years, published by year, exceeded a hundred with the new millennium and continues to increase. We predict that 233 and 334 papers will be published in 2021–2025, respectively. Most active countries were United States of America (576, 20.2 %), France (395, 13.8 %), Italy (293, 10.2 %). The most used keywords in NIV papers are non-invasive ventilation, continuous positive airway pressure and obstructive sleep apnea.

CONCLUSION: NIV technology and new devices are developing day by day. In addition, new areas of use have been defined by doctors. All these bring about new and different studies on NIV. We believe the present study that summarized the history and development of NIV literature will guide the authors who want to study this area (Tab. 4, Fig. 8, Ref. 19). Text in PDF www.elis.sk

KEYWORDS: bibliography, COPD, history, non-invasive ventilation, respiratory failure.

Introduction

The history of respiratory treatment began with the use of oxygen by Thomas Beddoes, the father of respiratory therapy, in the late 1700s, accelerated with the polio epidemic in the 1950s in Europe, and resulted in the discovery of highly skilled ventilators after the 1980s (1–3). During the polio epidemic, the first use of non-invasive ventilation started with negative pressure ventilators supporting ventilation by exposing the surface of the thorax to sub-atmospheric pressure. But it couldn't be widely used because of giant machines, patients' poor compliance, and its benefits weren't supported by prospective studies.

Invasive ventilation has devastating effects on patients, including using an endotracheal tube, the need for sedation because the

endotracheal tube is hard to tolerate, impaired cough, and conclusion with tracheostomy in case of prolonged intubation. The discovery of non-invasive positive-pressure ventilation met the remaining demand for non-invasive ventilation. This technique allowed to deliver needed tidal volume by a nasal, oronasal, or

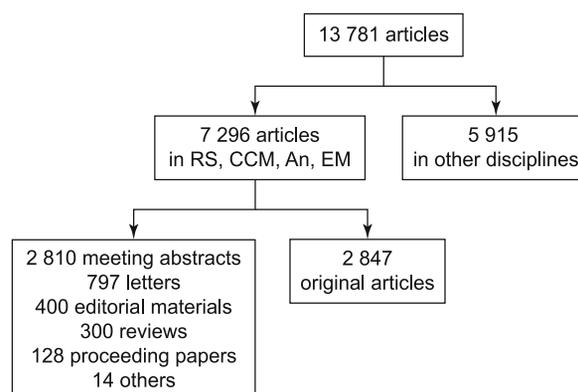


Fig. 1. Diagram of Articles. Others: book chapter, correction note, early access, biographical item, book/book review, correction addition, news item, reprint, retracted publication. An: Anesthesia, CCM: Critical Care Medicine, EM: Emergency Medicine, RS: Respiratory System.

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face mask and maintain the oral feeding and cough reflex. The improved machines allow enough volume and pressure, and they started to be used for several acute and chronic ventilatory disorders in the second half of the 1970s. The increasing number of intensive care units using non-invasive ventilators and expanding the use area bring new literature. Since then, numerous articles have been published examining non-invasive ventilation.

Bibliometrics is the analysis of scientific outputs and articles using statistical methods (4). Bibliometric analyses enable determining the most cited influential studies and journals, the most researched trending topics, the most active countries, institutions, journals, or authors in a subject or a research field (5). In addition, the general research trend of a subject in the world can be determined by introducing international collaborations.

This study aims to investigate non-invasive literature, define cornerstone papers, most productive authors, and countries, determine the top journals, and predict the future of non-invasive ventilation literature.

Materials and methods

We used the Web of Science (WoS) database for search. To include all papers about non-invasive ventilation, we searched the following keywords in WoS “non-inva-

sive ventilation, non-invasive ventilation, non-invasive mechanical ventilation, non-invasive mechanical ventilation, continuous positive airway pressure, CPAP, bilevel positive airway pressure, BPAP, BiPAP, High flow nasal cannula, HFNC, non-invasive positive pressure, NIPPV, and NIV” in the “title” section of articles.

Tab. 1. Language distribution and citations.

Language	Number of articles	Total 2847 articles	h- index	137
English	2669		Average citations per article	33,09
French	83		Sum of times cited	94202
Spanish	52		Without self-citations	78333
German	31			
Portuguese	8			
Turkish	4			

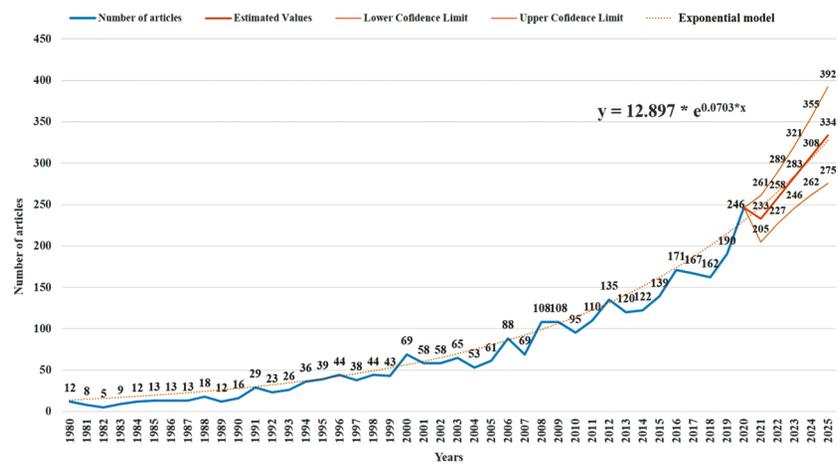


Fig. 2. Number of articles published on noninvasive ventilation by years and estimation of the number of articles that can be published in the future.

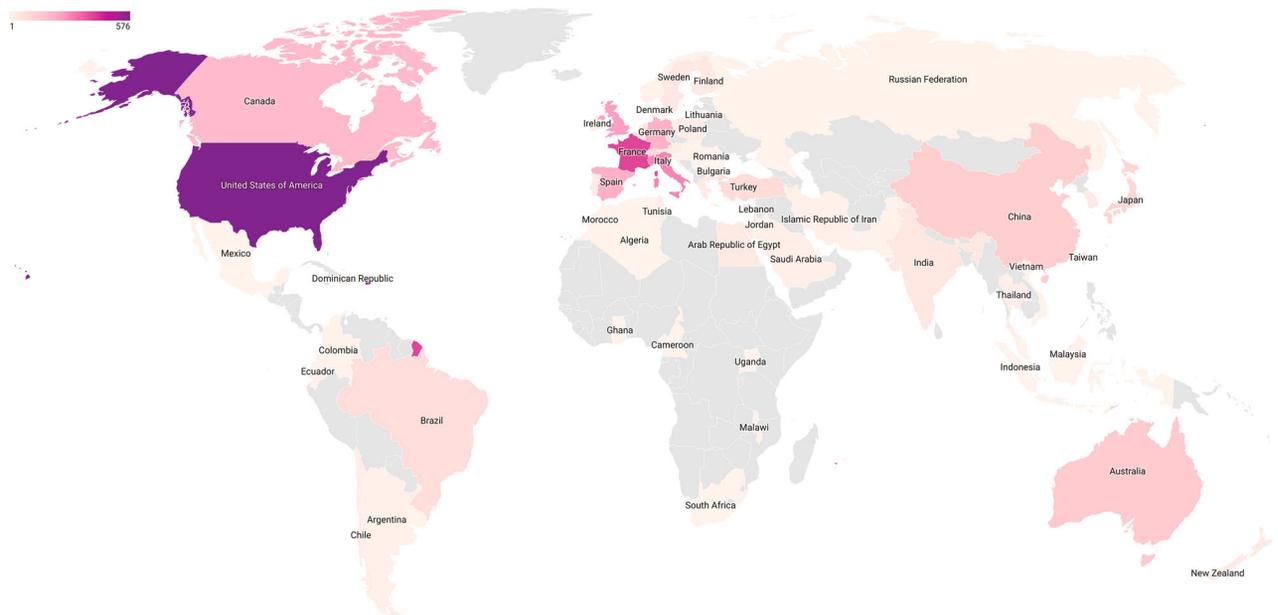


Fig. 3. World map for the distribution of articles by country on noninvasive ventilation. Footnote: In the indicator given at the bottom left of the figure, productivity increases from green to red.

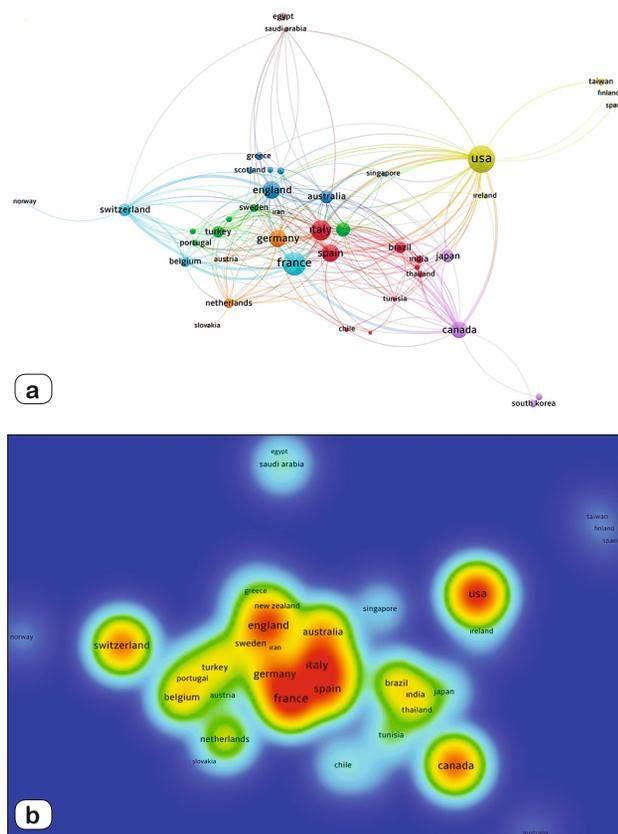


Fig. 4. a. Network visualization map for international collaboration of worldwide countries on noninvasive ventilation. The size of the circle shows the large number of articles, the thickness of the lines indicates the strength of relationship, and the colors show the different clusters. **b.** Density map for international collaboration of worldwide clusters on noninvasive ventilation. Cooperation increases from blue to red (blue-green-yellow-red).

All articles that meet the criteria published in the respiratory system, critical care medicine, anesthesiology, and emergency medicine fields during 1975–2020 were determined. (Date of access: 15.05.2021). Reproducibility codes for researchers to reach similar documents (search findings may vary depending on different access dates): (title: (“non invasive ventilation”) or title: (“noninvasive ventilation”) or title: (“non invasive mechanical ventilation”) or title: (“noninvasive mechanical ventilation”) or title: (“continuous positive airway pressure”) or title: (“CPAP”) or title: (“bilevel positive airway pressure”) or title: (“BPAP”) or title: (“BiPAP”) (“non-invasive positive pressure”) or title: (“NIPPV”) or title: (“NIV”) Refined by: web of science categories: (respiratory system or critical care medicine or anesthesiology or emergency medicine) Timespan: 1975–2020. Indexes: SCI-Expanded, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI).

VOS viewer (Version 1.6.15, Leiden University’s Centre for Science and Technology Studies) was used for bibliometric network visualizations. We used the <https://app.datawrapper.de> website for world map graphics. Statistical analyses were performed by using SPSS software version 22.0 (SPSS Inc., Chicago, IL, ABD). The normal distribution of data was tested with the Kol-

Tab. 2. Top most active journals on non-invasive mechanical ventilation.

Journals	RC	C	AC
Chest	263	16859	64.1
Respiratory Care	235	4413	18.8
Sleep and Breathing	200	2793	14.0
European Respiratory Journal	146	8155	55.9
Intensive Care Medicine	136	6768	49.8
American Journal of Respiratory and Critical Care Medicine	120	16456	137.1
Pediatric Pulmonology	96	2000	20.8
Thorax	95	8065	84.9
Respiratory Medicine	90	2380	26.4
Critical Care Medicine	84	4580	54.5
Respiration	66	1591	24.1
Revue Des Maladies Respiratoires	59	164	2.8
Respirology	54	847	15.7
Archivos de Bronconeumologia	45	350	7.8
Critical Care	36	1156	32.1
Journal of Critical Care	35	721	20.6
Pediatric Critical Care Medicine	35	789	22.5
Journal of Thoracic Disease	34	188	5.5
American Review of Respiratory Disease	32	4205	131.4
BMC Pulmonary Medicine	30	424	14.1
Respiratory Physiology & Neurobiology	29	267	9.2
Clinical Respiratory Journal	27	110	4.1
International Journal of Chronic Obstructive Pulmonary Disease	27	342	12.7
Minerva Anestesiologica	26	434	16.7
Acta Anaesthesiologica Scandinavica	24	360	15
Anesthesia and Analgesia	24	614	25.6
Anesthesiology	22	838	38.1
American Journal of Emergency Medicine	21	257	12.2
Egyptian Journal of Chest Diseases and Tuberculosis	21	17	0.8
Canadian Respiratory Journal	20	267	13.4
Lung	20	603	30.2
Anaesthesia	19	251	13.2
Emergency Medicine Journal	18	401	22.3
Indian Journal of Critical Care Medicine	17	44	2.6
Annals of Intensive Care	16	255	15.9
Anaesthesia and Intensive Care	15	108	7.2
British Journal of Anaesthesia	15	193	12.9
Annals of the American Thoracic Society	14	151	10.8
European Journal of Emergency Medicine	14	209	14.9
BMJ Open Respiratory Research	13	64	4.9
Copd-Journal of Chronic Obstructive Pulmonary Disease	13	123	9.5
Annales Francaises d Anesthesie et de Reanimation	12	143	11.9
ERJ Open Research	12	34	2.8
Heart & Lung	12	140	11.7
Jornal Brasileiro De Pneumologia	11	88	8
Respiratory Research	11	275	25
Journal of Aerosol Medicine and Pulmonary Drug Delivery	10	201	20.1
Journal of Intensive Care Medicine	10	42	4.2
Medicina Intensiva	10	87	8.7

RC – Record Count, C – Number of Citation, AC – Average Citation Per Document

Tab. 3. The most cited articles according to total citations on non-invasive mechanical ventilation.

No	Article	Author	Journal	PY	TC	AC
1	Objective measurement of patterns of nasal cpap use by patients with obstructive sleep-apnea	Kribbs NB et al	American Review of Respiratory Disease	1993	874	30.14
2	Non-invasive ventilation in acute respiratory failure - British thoracic society standards of care committee	Baudouin S et al	Thorax	2002	527	26.35
3	Long-term use of CPAP therapy for sleep apnea/hypopnea syndrome	McArdle N et al	American Journal of Respiratory and Critical Care Medicine	1999	516	22.43
4	Enhanced release of superoxide from polymorphonuclear neutrophils in obstructive sleep apnea - Impact of continuous positive airway pressure therapy	Schulz R et al	American Journal of Respiratory and Critical Care Medicine	2000	434	19.73
5	Randomized placebo-controlled trial of continuous positive airway pressure on blood pressure in the sleep apnea-hypopnea syndrome	Faccenda JF et al	American Journal of Respiratory and Critical Care Medicine	2001	419	19.95
6	Controlled trial of continuous positive airway pressure in obstructive sleep apnea and heart failure	Mansfield DR et al	American Journal of Respiratory and Critical Care Medicine	2004	399	22.17
7	Continuous positive airway pressure treatment rapidly improves insulin sensitivity in patients with obstructive sleep apnea syndrome	Harsch IA et al	American Journal of Respiratory and Critical Care Medicine	2004	384	21.33
8	Randomized placebo-controlled crossover trial of continuous positive airway pressure for mild sleep apnea/hypopnea syndrome	Engleman HM et al	American Journal of Respiratory and Critical Care Medicine	1999	383	16.65
9	Acute respiratory failure in patients with severe community-acquired pneumonia - A prospective randomized evaluation of noninvasive ventilation	Confalonieri M et al	American Journal of Respiratory and Critical Care Medicine	1999	378	16.43
10	Effects of continuous positive airway pressure on early signs of atherosclerosis in obstructive sleep apnea	Drager LF et al	American Journal of Respiratory and Critical Care Medicine	2007	366	24.4
11	Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure	Rochweg B et al	European Respiratory Journal	2017	362	72.4
12	Non-invasive positive pressure ventilation for the treatment of severe stable chronic obstructive pulmonary disease: a prospective, multicentre, randomised, controlled clinical trial	Koehnlein T et al	Lancet Respiratory Medicine	2014	348	43.5
13	Effects of nasal cpap on sympathetic activity in patients with heart-failure and central sleep-apnea	Naughton MT et al	American Journal of Respiratory and Critical Care Medicine	1995	345	12.78
14	Long-term effects of nasal continuous positive airway pressure therapy on cardiovascular outcomes in sleep apnea syndrome	Doherty LS et al	Chest	2005	337	19.82
15	Circulating nitric oxide is suppressed in obstructive sleep apnea and is reversed by nasal continuous positive airway pressure	Ip MSM et al	American Journal of Respiratory and Critical Care Medicine	2000	317	14.41
16	A multiple-center survey on the use in clinical practice of noninvasive ventilation as a first-line intervention for acute respiratory distress syndrome	Antonelli M et al	Critical Care Medicine	2007	310	20.67
17	Early noninvasive ventilation averts extubation failure in patients at risk - A randomized trial	Ferrer M et al	American Journal of Respiratory and Critical Care Medicine	2006	303	18.94

PY – Publication year, TC – Total citation, AC – Average citations per year

Active authors

Most productive authors who wrote more 30 and more articles were Nava S (n=48), Pepin JL (n=46), Stradling JR (n=39), Brochard L (n=37), Conti G (n=32), Windisch W (n=31), and Navalesi P (n=30).

Active institutions

Most generative institutions published 20 and more articles were University of Toronto (n=55), Inserm (n=40), University of Sydney (n=39), University of Barcelona (n=38), Henri-Mondor University Hospital (n=33), University of Milano (n=33), University Cattolica Sacro Cuore (n=30), Massachusetts Gen Hospital (n=29), Royal

Prince Alfred Hospital (n=27), University of Sao Paulo (n=27), University of Groningen (n=24), University of Laval (n=24), Churchill Hospital (n=23), University of California San Diego (n=23), Hospital of Clinic Barcelona (n=22), St Michaels Hospital (n=22), Harvard University (n=21), University of Paris 06 (n=21), Case Western Reserve University (n=20), University of Zurich (n=20).

Active journals

208 separate journals published 2847 articles about NIV. Journals that host ten and more articles, total citation numbers, and average citation per article are depicted in Table 2. The Citation network between these journals is presented in Figure 5.

Tab. 4. The most frequently used keywords on non-invasive mechanical ventilation.

Key words	No of uses	Key words	No of uses	Key words	No of uses
Noninvasive ventilation (NIV)	731	Asthma	26	Hypoventilation	14
Continuous positive airway pressure (CPAP)	484	Endotracheal intubation	26	Outcome	14
Obstructive sleep apnea	235	Infant (s)	26	Positive pressure ventilation	14
CPAP	180	Hypoxemia	25	Pressure support	14
Acute respiratory failure	176	Critical care	22	Pulmonary edema	14
Chronic obstructive pulmonary disease	147	Humidification	22	Respiratory therapy	14
Mechanical ventilation	127	Meta-analysis	22	Acute hypercapnic respiratory failure	13
High-flow nasal cannula	113	Sleep-disordered breathing	22	Apnea	13
Respiratory failure	113	Neuromuscular disease	20	Bronchoscopy	13
Sleep apnea	108	Obstructive sleep apnoea syndrome	20	Cardiac surgery	13
Copd	81	Acute lung injury	19	Heart rate variability	13
Respiratory insufficiency	71	Emergency department	19	Heated humidifier	13
Obstructive sleep apnoea	66	Intensive care	19	Nebulizer	13
Nasal continuous positive airway pressure	63	Positive-pressure respiration	19	Oxidative stress	13
Ventilation	53	Amyotrophic lateral sclerosis	18	Oxygen	13
Obstructive sleep apnea syndrome	52	Blood pressure	18	Pulmonary rehabilitation	13
Hypercapnia	51	Intubation	18	Reintubation	13
Noninvasive mechanical ventilation	49	Oxygen inhalation therapy	18	Emergency medical services	12
Noninvasive positive pressure ventilation	49	Randomized controlled trial	18	HFNC	12
NIV	48	Respiratory distress	18	Respiratory distress syndrome	12
Adherence	47	Treatment	18	Respiratory mechanics	12
Compliance	43	Cystic fibrosis	17	Survey	12
Children	41	Exercise	17	Tracheostomy	12
Chronic respiratory failure	39	Heart failure	17	Central sleep apnea	11
Polysomnography	39	Home mechanical ventilation	17	Dyspnea	11
Sleep	39	Nasal CPAP	17	Gas exchange	11
Weaning	38	Child	16	ICU	11
Bilevel positive airway pressure	37	Exacerbation	16	Masks	11
Obesity hypoventilation syndrome	35	Extubation	16	Nasal mask	11
Mortality	34	Hypertension	16	Patient-ventilator asynchrony	11
Osa	34	Intubation	16	Positive airway pressure	11
Pediatric (s)	34	Intensive care unit	16	Positive end-expiratory pressure	11
Pneumonia	34	Monitoring	16	Sedation	11
Oxygen therapy	33	Patient-ventilator interaction	16	Artificial respiration	10
Bronchiolitis	32	Sleepines	16	Auto-CPAP	10
Obesity	31	BIPAP	15	Complications	10
Work of breathing	31	Congestive heart failure	15	COVID-19	10
Sleep apnoea	30	Pressure support ventilation	15	High-flow oxygen therapy	10
Acute respiratory distress syndrome	29	ARDS	14	Hypoxia	10
Sleep apnea syndrome (s)	29	Cardiogenic pulmonary edema	14	Pediatric intensive care unit	10
Helmet	28	CPAP adherence	14	Prognosis	10
Quality of life	27	Face mask	14	Survival	10

Citation analysis

Among the articles published between 1980 and 2020, the first 17 articles with the highest number of citations (more than 300 citations) according to the total number of citations are presented in Table 3. In the last column of Table 3, the average number of citations per year is given.

Co-citation analysis

There were a total of 33325 studies cited in the references section of all 2847 articles analyzed. The first seven studies that

received the most co-citations from these studies (more than 150 citations) were Brochard L (1995) (Number of co-citations, NC: 297), Sullivan CE (1981) (NC: 244), Johns MW (1991) (NC: 205), Young T (1993) (NC: 185), Plant PK (2000) (NC: 183), Kramer N (1995) (NC: 153), Bott J (1993) (NC: 150) (7–13).

Trend topics

The authors used 3432 different keywords in all 2847 articles published on NIV. Of these words, 126 different keywords were used in at least ten different articles (Tab. 4). The network visu-

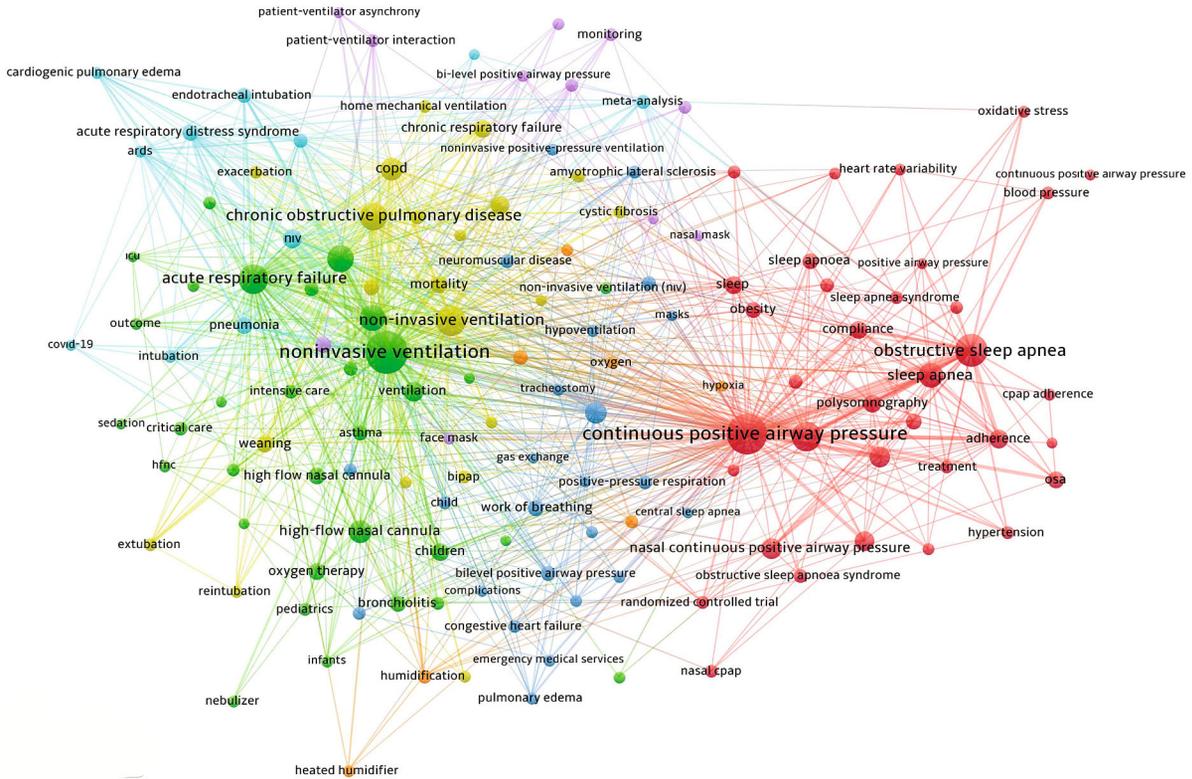


Fig. 6. Network visualization map for cluster analysis based on keyword analysis on noninvasive ventilation. Colors show clustering. Keywords in the same cluster are of the same color.

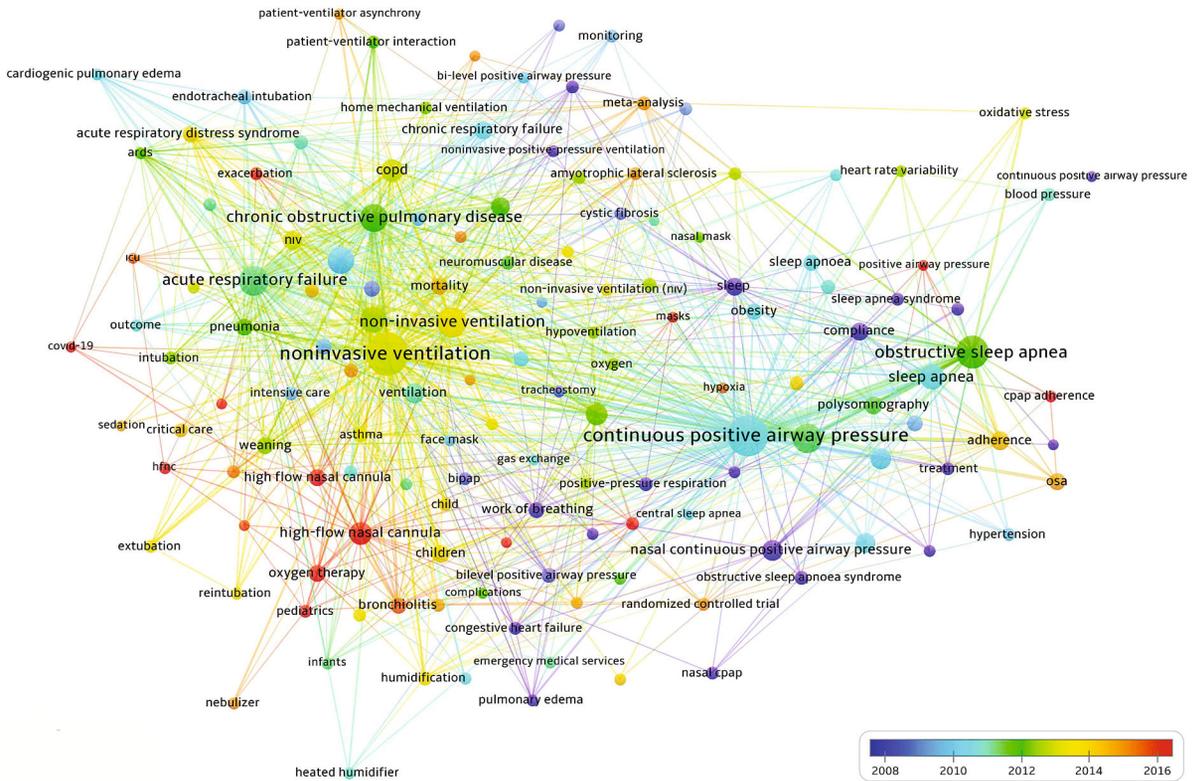


Fig. 7. Network visualization map for trends on noninvasive ventilation. Indicator shows current publications from blue to red (blue–green–yellow–red).

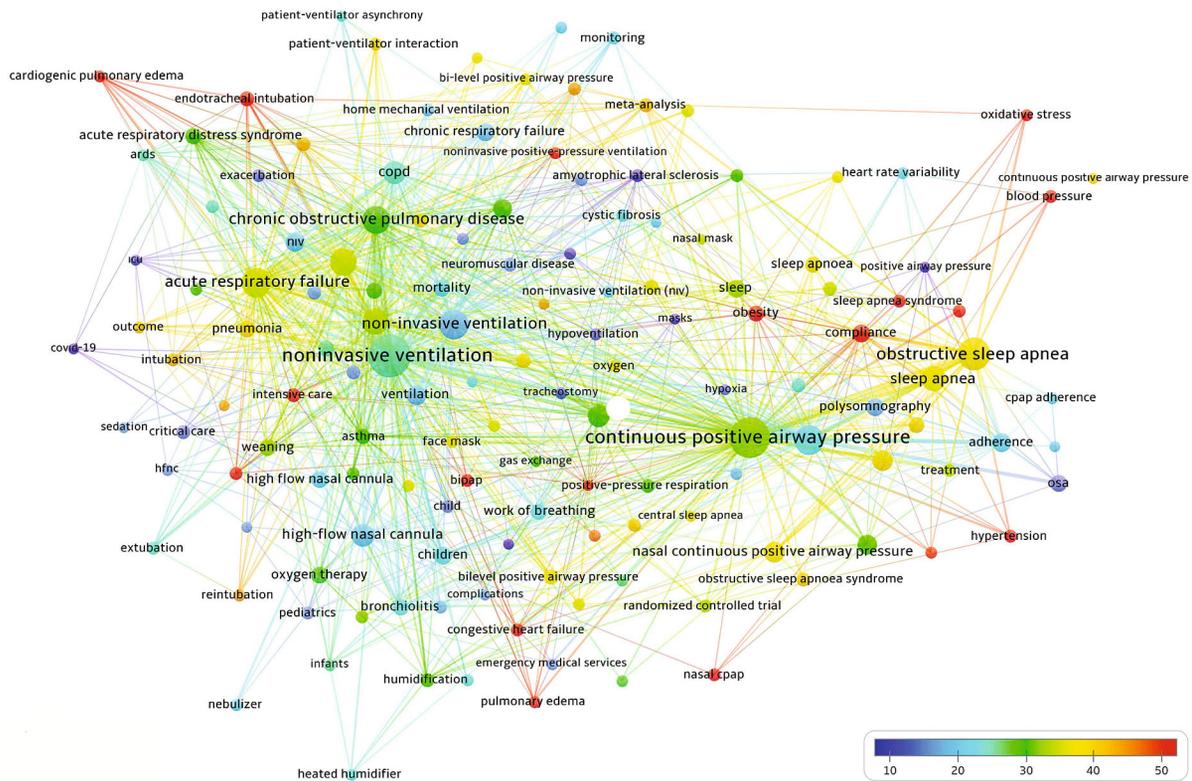


Fig. 8. Network visualization map of the most frequently cited topics on noninvasive ventilation. The number of citations from blue to red increases.

alization map of these keyword clusters is presented in Figure 6. The trend visualization network map is shown in Figure 7, and the citation network visualization map is illustrated in Figure 8.

Discussion

We found that the number of articles published about NIV is increasing day by day. As we showed in Figure 2, there were 0–50 articles (mean: 23) per year between 1980 and 1999, rising with a linear trend. The number of articles gained speed with the new millennium, and over a hundred papers were published every year after 2010. Non-linear regression analyses show that the number of articles will continue to increasing exponential trend (Fig. 2). We estimated that the number of publications would continue to increase and rise over three hundred by 2025. We think that it can be associated with two major topics. Firstly, we know that the number of intensive care units (ICU) is increasing over the years, correlating with the aging of the population and associated comorbidities. Kelly et al. stated that aging, increasing obesity, and disease candidates for treatment with new treatment modalities would require increasing ICUs (14). Considering factors such as smoking and air pollution, and microorganisms that threaten the respiratory tract (such as COVID), it is not difficult to predict that the need for intensive care and ventilators will grow. The second one is the expanding indications of NIV. Although NIV is primarily used for hypercapnic respiratory failure, especially for exacerbations of chronic obstructive pulmonary disease (COPD) and obstructive sleep apnea

(OSA), it gains new usage areas such as neuromuscular diseases, cardiogenic pulmonary edema, hypoxemic respiratory failure (such as pneumonia), weaning, post-operative state, and support of bronchoscopy (15). Other benefits compared with invasive ventilation, such as reduced complication rate, reduction in the hospital stay, and mortality, also support the use of NIV (16). Taken together, consistent with our findings, we can expect that the use of NIV and, in correlation, the number of articles on NIV will increase.

Development degree seems like a good reflector of productivity. Sixteen of the twenty most productive countries are developed countries. The remaining four are developing countries (Turkey, China, India, and Brazil) with big economies. Correlation analysis showed that economic power is one of the most influential factors on scientific productivity in NIV (5, 17, 18). When we examined the co-authorship cooperation of countries on NIV, we found that cooperation based on geographical countries does not significantly affect article production. Collaborations were generally made in small clusters and were seen in the geographical neighborhood (Italy-Spain-Tunisia) and (France-Belgium-Switzerland) clusters (Fig. 4a). The density map created according to the collaboration score between countries showed that the most collaborative countries are France, the USA, Italy, UK, Canada, Spain, Switzerland, and Germany, respectively (Fig. 4b).

The most active authors and institutions were also consistent with countries. All active authors listed above are from Europe and North America. Similarly, only one institution, the University of Sao Paulo, was located outside Europe and North America.

The journals that published the most articles on NIV were determined as Chest, Respiratory Care, Sleep and Breathing, European Respiratory Journal, Intensive Care Medicine, American Journal of Respiratory and Critical Care Medicine, Pediatric Pulmonology, Thorax, Respiratory Medicine, and Critical Care Medicine, respectively. When the citation analyzes of the journals were evaluated, the most influential journals according to the average number of citations per article they published were American Journal of Respiratory and Critical Care Medicine, American Review of Respiratory Disease, Thorax, Chest, European Respiratory Journal, Critical Care Medicine, and Intensive Care Medicine, respectively. Not surprisingly, the most preferred and most-cited journals on NIV are respiratory diseases and intensive care journals. These are also high impacted journals in their disciplines. This may guide authors who want to publish papers about NIV and reach more readers.

The most commonly used keywords were non-invasive ventilation, chronic obstructive pulmonary disease, continuous positive airway pressure, acute respiratory failure, and obstructive sleep apnea. This reflects the most frequently studied topics related to NIV, similar to Cortegiani's study (19). Cluster network visualization map gave ideas also about other interested diseases. Chronic respiratory failure, obesity, cystic fibrosis, neuromuscular disorders, pneumonia, and weaning were seemed less popular but candidate issues for new studies.

According to our knowledge, this is the first comprehensive study that examined the dynamics of literature about NIV bibliometrically. Previously, Cortegiani and colleagues planned research with a similar curiosity and defined ten impressive articles published on NIV to identify research topics related to NIV. They stated that NIV use on COPD exacerbations has solid evidence and other issues need well-designed randomized studies. They also make a suggestion list for future studies (19).

Our study has the advantage of including approximately all studies since NIV started to be used. Besides, using comprehensive statistical methods such as keyword, cluster, correlation, and regression analysis improves the power of our research. We can say that it draws a detailed framework to the history of NIV.

We did not use the Pubmed index because it does not allow us to make citation and co-citation analyses. We also did not use the Scopus index because it includes studies with low effect levels. So, we used only the WoS index. This may be a limitation of our study. But, it should also be considered that WoS is more commonly preferred in bibliometric analyses conducted in recent years.

Conclusion

NIV technology and new devices are developing day by day. In addition, new areas of use have been defined by doctors. All these bring about new and different studies on NIV. We believe the present study which summarized the history and development of NIV literature, will guide the authors who want to study this area.

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Received September 18, 2021.

Accepted November 23, 2021.