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Research trends and global productivity on mechanical ventilation with the impact of COVID-19: a bibliometric analysis in the period 1980-2021

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ABSTRACT

Aim: Although the number of global studies on mechanical ventilation (MV) therapy, which plays an important role in the life process of patients in the intensive care unit, has increased, there is still no bibliometric research on this subject in the literature. This study, it was aimed to determine trend topics and global productivity by holistically analyzing scientific articles on MV published between 1980 and 2021 using various statistical methods and bibliometric approaches.

Material and Method: Articles on MV published between 1980 and 2021 were downloaded from the Web of Science (WoS) database and analyzed using various statistical methods. Spearman's correlation coefficient was used for correlation studies. Network visualization maps were used to identify the most effective studies with global collaborations, trend topics, and citation analysis.

Results: The study, which was in the category of 5323 articles out of a total of 10135 publications, was analyzed. The first 3 countries that contributed the most to the literature were the USA (n=1740), France (448), and Canada (386). The most active author was Laurent Brochard (n=50). The top 3 most active institutions were Assistance Publique Hopitaux Paris (224), University of Toronto (216), and League of European Research Universities (169). The top 3 journals that published the most articles were Critical Care Medicine (289), Chest (204), and Intensive Care Medicine (166). Gross Domestic Product (GDP) was highly effective in article productivity ($r=0.719$, $p<0.001$).

Conclusion: In this study on MV, it was shared the statistical analysis information of 5323 articles published since 1980. With the developing technology, the usage area of MV is increasing and this situation is also reflected in the publications in the literature. It was also observed that the number of studies on MV increased with the COVID-19 (SARS CoV-2) pandemic. This study, which includes the bibliometric analysis of MV by summarizing the literature, will guide the authors who want to study in this area.

Keywords: Bibliography, COVID-19, intensive care unit, mechanical ventilation, respiratory failure

INTRODUCTION

Mechanical ventilation (MV) is the process of providing respiratory function artificially with the help of a device called a 'mechanical ventilator'. The primary purpose of MV is to normalize and/or stabilize the patient's gas exchange by increasing ventilation and oxygenation in patients with respiratory failure (1). MV plays a very important role in the management of patients with acute respiratory distress syndrome (ARDS), chronic obstructive pulmonary disease (COPD), acute severe asthma, sepsis, hypoxemia, COVID-19, and newborn babies with respiratory problems (2-4). If MV is performed through an instrument such as an endotracheal tube or a tracheostomy tube, it is called "invasive ventilation" (1). Pulmonary barotrauma, volutrauma, atelectotrauma, biotrauma, ventilator-induced lung injury, and ventilator-associated pneumonia are the main complications of invasive mechanical ventilation (IMV) (5). In medically fit patients, face or nasal masks are used for non-invasive mechanical ventilation (NIMV). Due to the complications of MV, NIMV is increasingly being used in clinical practice in order to avoid the use of endotracheal intubation or tracheostomy (6).

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Separating patients from MV is a major challenge in intensive care units (ICUs). The best methods to separate patients from MV in patients recovering from respiratory failure have been tried to be defined for years. With increasing recognition of the risks and economic consequences of long-term ventilation, research continues to identify strategies based on clinical experience to reduce MV duration. However, ongoing clinical uncertainty regarding the optimal separation strategy still continues (7). It has been suggested to switch from simple maneuvers to more complex methods such as multivariate scoring systems and computerized decision support models to identify patients ready for extubation (4,7). The search for an accurate way of predicting success in weaning a patient from MV continues (8). Various clinical scores have been developed to predict the weaning success of MV in different samples (4,8-10).

Successful weaning and recovery from IMV are important to improve outcomes in critically ill patients. Current international guidelines recommend daily assessment of readiness for extubation with a spontaneous breathing trial, regular breaks in sedation, early mobilization, and protocoled rehabilitation to aid weaning (11,12). Yeung et al. (6) as a result of a meta-analysis of twenty-five studies involving 1609 patients, it was reported that the use of NIMV to differentiate from MV reduces hospital mortality, the incidence of ventilator-associated pneumonia, and length of stay in the ICU. It has also been reported that NIMV as a weaning strategy seems to be most beneficial in patients with COPD.

MV is used to treat 30-40% of patients admitted to ICU (12). Esteban et al. (12) determined that in a cohort of 15757 consecutive adult patients admitted to 361 ICUs who underwent MV for more than 12 hours, 5183 patients (33%) received MV for a mean duration of 5.9±7.2 days. The mean (SD) length of stay in the ICU was 11.2±13.7 days. The overall mortality rate in the ICU was 30.7% (1590 patients) for the entire population, 52% (120) for patients ventilated for ARDS, and 22% (115) for patients ventilated for exacerbation of COPD. The survival rate of patients who received MV for more than 12 hours was 69% (12). Lim et al. (13) as a result of the meta-analysis of 69 studies describing 57420 adult COVID-19 patients undergoing IMV, the reported case fatality rates (CFRs) were estimated to be 45% (95% confidence interval [CI], 39-52%). Among studies in which age-stratified CFR was available, pooled CFR estimates ranged from 47.9% (95% CI, 46.4–49.4%) in younger patients (age ≤40 yr) to 84.4% (95% CI, 83.3–85.4%) in older patients (age >80 yr) (13).

Chang et al. (14), as a result of the meta-analysis of 28 studies including 12437 COVID-19 ICU admissions from 7 countries between December 2019 and 1 May 2020, found that the pooled ICU admission rate was 21% [95% CI 0.12-0.34] and reported the need for IMV in 69% of these cases [95% CI 0.61-0.75]. ICU and IMV mortality was 28.3% [95% CI 0.25-0.32], 43% [95% CI 0.29-0.58]. In addition, ICU and IMV duration 7.78 [95% CI 6.99-8.63] and 10.12 [95% CI 7.08-13.16] determined as days (14).

Bibliometrics is the analysis of scientific publications using various statistical methods (15-17). Thanks to the studies revealed as a result of the statistical and bibliometric analysis of the information obtained from thousands of articles in the literature, the most active countries, institutions, journals, and authors, international collaborations are revealed, and trend topics that have been studied in recent years can be determined (18-21).

Although the number of global studies on MV therapy, which plays an important role in the life process of patients in the ICU, has increased, there is still no bibliometric research on this subject in the literature. It was aimed to identify trend topics and global productivity by holistically analyzing scientific articles published on MV between 1980 and 2021 using various statistical methods and bibliometric approaches in this study.

MATERIAL AND METHOD

Since our research article is a bibliometric study, there is no need for an ethics committee approval.

Search Strategy

Web of Science Core Collection (WoS by Clarivate Analytics) database was used for the literature review. The search process was determined as 1980-2021 (publishes before 1980 are not available in WoS). All publications with MV in their titles were found. In order for researchers to access similar documents (search findings may vary according to different access dates, access date: April 1, 2022), repeatability codes are: (Title ("mechanical ventilation") Timespan: 1980-2021). As a result of cluster analysis, citation analysis, and trend topic determination analysis VOSviewer (Version 1.6.16, Leiden University's Center for Science and Technology Studies, Netherlands) package program was used to create bibliometric network visualizations (22).

Statistical Analysis

The website (https://app.datawrapper.de) was used to create the world map showing the distribution of articles by country. The Exponential Smoothing estimator using seasonal smoothing was used in Microsoft Office Excel to estimate the number of articles that could be published in the next 5 years based on past publication trends. Statistical analyzes were performed with SPSS (Version 22.0, SPSS Inc., Chicago, IL, USA) package program. The normal distribution test of the data was analyzed with the Shapiro-Wilks test. Correlation analyzes were performed

to determine whether some economic development indicators (Gross Domestic Product (GDP), Gross Domestic Product per capita (GDP per capita), Human Development Index (HDI)) of countries have an effect on MV (data were obtained from the world bank (23). Correlation analyzes were analyzed using the Spearman correlation coefficient as the data were not normally distributed. For a statistically significant relationship, $p<0.05$ was accepted.

RESULTS

As a result of the literature review, there were a total of 10135 publications on MV published in all research areas in the WoS database between 1980 and 2021. Of these publications, 52.5% (n=5323) were articles, 25.5% (n=2593) were meeting abstracts, 7.1% (n=723) were letters, 5.8% (n=595) were review articles, 4.1% (n=419) were proceedings papers and the remainders were in other publication types (editorial materials, book chapters, corrections, notes, early access, news items, books, book reviews, discussions, biographical items, retracted publications, bibliographies, data papers) (**Figure 1**). Bibliometric analyzes were carried out with 5323 articles published in the article category out of a total of 10135 publications. 92.1% (n=4902) of these articles were in English and the remainders were in other languages (Spanish (129), German (113), French (n=110), Turkish (30), Portuguese (23), Korean (7), Italian (4), Polish (2), Serbian (2), Norwegian (1)) were published. The h-index of 5323 articles was 155, the average citations per article were 26.99, and the sum of times cited was 143,660 (without self-citations: 127,185) (**Table 1**). Most of the articles were scanned in SCI-Expanded (n=4688, 88%) and Emerging Sources Citation Index (ESCI) (n=528, 9.9%). Few articles were indexed in the Social Sciences Citation Index (SSCI).

Table 1. Language distribution and citations

Language	Number of articles			
English	4902	Total 5323 articles	h- index	155
Spanish	129			
German	113		Average citations per article	26.99
French	110			
Turkish	30			
Portuguese	23		Sum of times cited	143660
Korean	7			
Italian	4			
Polish	2		Without self-citations	127185
Serbian	2			
Norwegian	1			

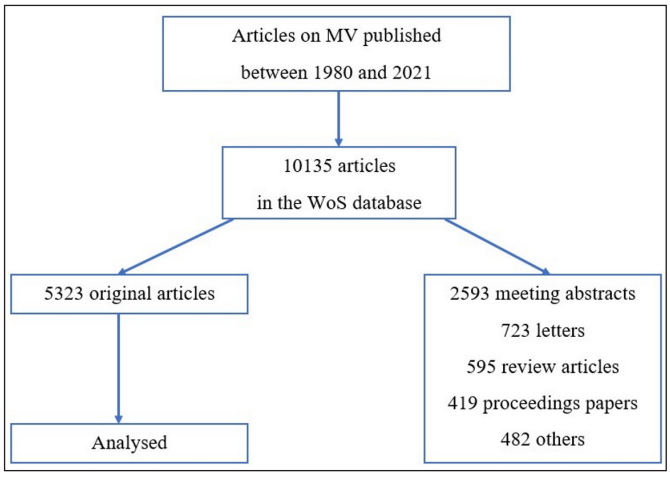

Figure 1. Diagram of Articles. Others: Editorial materials, book chapters, corrections, notes, early access, news items, books, book reviews, discussions, biographical items, retracted publications, bibliographies, and data papers

Active Research Areas

The top 10 research areas with the most research on MV were Critical Care Medicine (1557, 29.2%), Respiratory System (1271, 23.8%), Medicine General Internal (585, 10.9%), Anesthesiology (463, 8.6%), Pediatrics (433, 8.1%), Nursing (256, 4.8%), Surgery (219, 4.1%), Cardiac Cardiovascular Systems (215, 4%), Physiology (151, 2.8%), and Medicine Research Experimental (138, 2.5%).

Development of Publications

The distribution of the number of articles published on MV by year is shown in **Figure 2**. The values related to the results of the Exponential Smoothing estimation model, which takes into account the seasonal correction used to estimate the number of articles that would be published in the next 5 years, were shown in **Figure 2**. According to the estimation model results, it was estimated that 362 (CI %: 294-431) articles on MV would be published in 2022 and 477 (CI %: 392-562) articles will be published in 2026 (**Figure 2**).

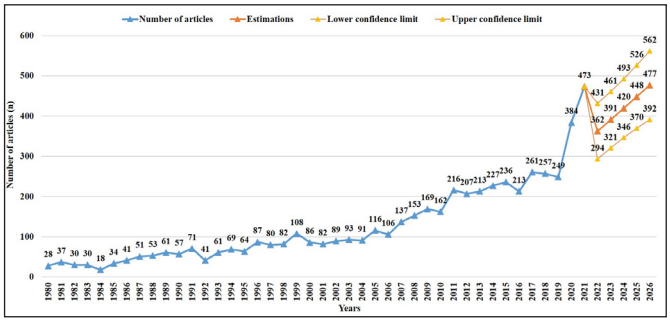

Figure 2. Bar chart showing the distribution of articles published in the mechanical ventilation by years and estimations for the number of articles for the next five years

Active Countries

The distribution of the number of articles by world countries was shown in **Figure 3**. The first 17 countries that contributed the most to the literature by publishing

more than 100 articles were found as follows; USA (number of articles, n=1740), France (448), Canada (386), Germany (384), China (343), Spain (329), Italy (291), United Kingdom (274), Brazil (214), Netherlands (179), Australia (153), Japan (149), Turkey (143), Switzerland (141), Taiwan (136), Sweden (124), and South Korea (104) (**Figure 3**).

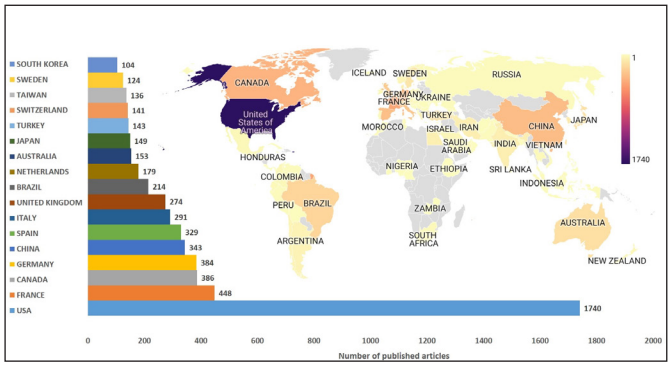

Figure 3. Global productivity world map showing the distribution of published articles on mechanical ventilation by country and bar chart showing the top 17 most active countries

Cluster analysis was performed among 60 countries that have published at least 5 articles from 99 countries that have published articles on MV, and whose authors have international cooperation, and it was shown in **Figure 4.a**. According to the results of the clustering analysis, 7 different clusters related to international cooperation were formed (Colors for Cluster 1: red, Cluster 2: green, Cluster 3: blue, Cluster 4: yellow, Cluster 5: purple, Cluster 6: turquoise, Cluster 7: orange). In addition, the total link strength (international cooperation score) scores showing the cooperation power of 60 countries were calculated and the international cooperation density map created according to these scores was shown in **Figure 4.b** (The first 15 countries with the highest score: USA=636, Canada=461, Germany =357, Spain=343, Italy=335, France=299, England (in United Kingdom)=267, Netherlands=194, Brazil=186, Australia=164, Argentina=144, Greece=135, Switzerland=134, China= 133, Belgium=125).

Correlation Analysis

A positive moderate statistically significant correlation was found between the number of articles produced by countries on MV and GDP, GDP per capita, and HDI values (respectively, r=0.719, p<0.001; r=0.688, p<0.001, r=0.657, p< 0.001).

Active Authors

The top 10 most active authors on MV were Brochard L. (50), Powers SK. (39), Rose L. (37), Esteban A. (36), Schultz MJ. (33) Slutsky AS. (33), Pelosi P. (32), Schonhofer B. (26), Nava S. (25), and Tobin MJ. (25).

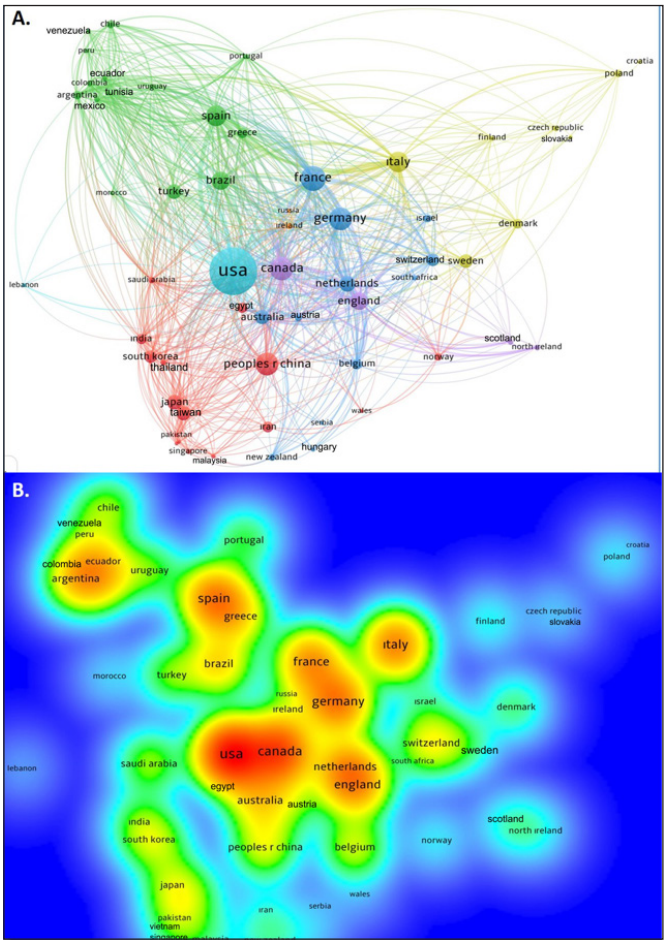

Figure 4. a. Network visualization map of results of cluster analysis showing international cooperation between countries on mechanical ventilation. Footnote: Each color represents a different Cluster. As the number of articles published by the countries increases, the size of the circles representing the countries also increases. The lines show the countries with which they cooperate. b. Density map showing the intensity of international cooperation of countries on mechanical ventilation. Footnote: The strength of the international cooperation score increases from blue to red (blue-green-yellow-red)

Active Institutions

The top 15 most active institutions in MV were; Assistance Publique Hopitaux Paris (224), University of Toronto (216), League of European Research Universities (169), Harvard University (166), Institut National De La Sante Et De La Recherche Medicale (163), University of California System (129), University De Paris (114), US Department of Veterans Affairs (114), Veterans Health Administration (113), Pennsylvania Commonwealth System of Higher Education (111), State University System of Florida (88), University of Texas System (86)), Saint Michaels Hospital Toronto (85), Massachusetts General Hospital (81) and Sorbonne University (79).

Active Journals

5323 articles on MV were published in 1250 different journals. The first 60 journals that contributed the most to the literature by publishing 15 or more articles from these journals, the total number of citations received by the journals and the average number of citations per article were presented in **Table 2**.

Table 2. The 60 most active journals that have published 15 or more articles on mechanical ventilation

Journals	RC	C	AC	Journals	RC	C	AC
Critical Care Medicine	289	16909	58.5	Journal of Trauma-Injury Infection and Critical Care	24	886	36.9
Chest	204	12052	59.1	Medizinische Klinik	24	66	2.8
Intensive Care Medicine	166	8064	48.6	Scientific Reports	24	140	5.8
Respiratory Care	136	2416	17.8	Anaesthesia and Intensive Care	23	325	14.1
American Journal of Respiratory and Critical Care Medicine	112	15027	134.2	BMC Pulmonary Medicine	23	207	9.0
Critical Care	99	3700	37.4	Thorax	23	1352	58.8
Journal of Critical Care	98	1473	15.0	Journal of Intensive Care Medicine	22	135	6.1
Plos One	62	805	13.0	Minerva Anestesiologica	22	344	15.6
Anesthesiology	60	3412	56.9	Pediatric Research	22	340	15.5
Pediatric Pulmonology	59	1116	18.9	Respiration	22	337	15.3
American Journal of Critical Care	58	1272	21.9	Annales Francaises D Anesthesie et de Reanimation	21	78	3.7
American Review of Respiratory Disease	50	7420	148.4	Schweizerische Medizinische Wochenschrift	21	66	3.1
Journal of Applied Physiology	48	2250	46.9	Egyptian Journal of Chest Diseases and Tuberculosis	20	52	2.6
Journal of Pediatrics	46	2043	44.4	Building and Environment	19	363	19.1
European Respiratory Journal	45	2670	59.3	Journal of Clinical Monitoring and Computing	19	108	5.7
Pediatric Critical Care Medicine	45	1099	24.4	Indian Journal of Critical Care Medicine	19	86	4.5
Acta Anaesthesiologica Scandinavica	39	494	12.7	Anaesthesist	18	68	3.8
Anesthesia and Analgesia	39	1238	31.7	Annals of the American Thoracic Society	18	198	11.0
Critical Care Clinics	34	621	18.3	Respiratory Physiology & Neurobiology	18	205	11.4
Respiratory Medicine	33	962	29.2	Energy and Buildings	17	268	15.8
Medicina Intensiva	30	180	6.0	Journal of Cardiothoracic and Vascular Anesthesia	17	251	14.8
JAMA-Journal of The American Medical Association	29	5332	183.9	Journal of Veterinary Emergency and Critical Care	17	123	7.2
American Journal of Physiology-Lung Cellular and Molecular Physiology	28	1164	41.6	Reanimation	17	6	0.4
Annals of Intensive Care	28	382	13.6	Acta Paediatrica	16	188	11.8
British Journal of Anaesthesia	28	749	26.8	American Journal of Emergency Medicine	16	227	14.2
Heart & Lung	28	450	16.1	Anaesthesia	16	191	11.9
Revue Des Maladies Respiratoires	28	87	3.1	Journal of Thoracic Disease	16	95	5.9
Medicine	26	138	5.3	Tuberculosis and Respiratory Diseases	16	56	3.5
Archivos de Bronconeumologia	24	280	11.7	Chinese Medical Journal	15	148	9.9
Clinics in Chest Medicine	24	278	11.6	Jornal Brasileiro de Pneumologia	15	119	7.9

C: Record count, C: Number of citation, AC: Average citation per document

Citation Analysis

Among the 5323 articles published on MV, the first 25 articles with the highest number of citations (with more than 450 citations) according to the total number of citations were presented in **Table 3**. In the last column of **Table 3**, the average number of citations the articles received per year was given.

Co-citation Analysis

There were 86393 studies in the references section of 5323 articles published on MV. Among these studies, the studies with more than 150 citations and the highest number of co-citations were respectively Brower et al. (2000) (Number of co-citation: NC=389), Boles et al. (2007) (NC=240), Knaus et al. (1985) (NC=213), Esteban et al. (2002) (NC=202), Esteban et al. (1995) (NC=189), Yang and Tobin (1991) (NC=187), Amato et al. (1998) (NC=175) and Ely et al. (1996) (NC=161) (24-27,12,8,28,7).

Keyword Analysis and Trend Topics

In all of the 5323 articles published on MV, 6990 different keywords were used. Among these keywords, 100 different keywords used in at least 16 different articles were shown in **Table 4**. The cluster network visualization map showing the results of the clustering analysis performed between these keywords was shown in **Figure 5**. As a result of the cluster analysis, it was determined that MV subjects formed 7 different clusters (Colors for Cluster 1: red, Cluster 2: green, Cluster 3: blue, Cluster 4: yellow, Cluster 5: purple, Cluster 6: turquoise, Cluster 7: orange). A trend network visualization map performed to identify trend topics was shown in **Figure 6**. The citation network visualization map performed to reveal the most cited topics was shown in **Figure 7**.

Table 3. The top 25 most cited articles with more than 450 citations on mechanical ventilation

No	Article	Author	Journal	PY	TC	AC
1	Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation	Kress JP. et al.	New England Journal of Medicine	2000	1736	75.48
2	Effect of mechanical ventilation on inflammatory mediators in patients with acute respiratory distress syndrome - A randomized controlled trial	Ranieri VM. et al.	JAMA-Journal of the American Medical Association	1999	1242	51.75
3	Characteristics and outcomes in adult patients receiving mechanical ventilation - A 28-day international study	Esteban A. et al.	JAMA-Journal of the American Medical Association	2002	1032	49.14
4	High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation	Simonnet A. et al.	Obesity	2020	942	314
5	Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously	Ely EW. et al.	New England Journal of Medicine	1996	878	32.52
6	A comparison of 4 methods of weaning patients from mechanical ventilation	Esteban A. et al.	New England Journal of Medicine	1995	792	28.29
7	A prospective-study of indexes predicting the outcome of trials of weaning from mechanical ventilation	Yang KL. And Tobin MJ.	New England Journal of Medicine	1991	772	24.13
8	Effect of a nursing-implemented sedation protocol on the duration of mechanical ventilation	Brook AD. et al.	Critical Care Medicine	1999	643	26.79
9	Mechanical ventilation guided by esophageal pressure in acute lung injury	Talmor D. et al.	New England Journal of Medicine	2008	631	42.07
10	Risk-factors for pneumonia and fatality in patients receiving continuous mechanical ventilation	Craven DE. et al.	American Review of Respiratory Disease	1986	628	16.97
11	Nosocomial pneumonia in patients receiving continuous mechanical ventilation - prospective analysis of 52 episodes with use of a protected specimen brush and quantitative culture techniques	Fagon JY. et al.	American Review of Respiratory Disease	1989	620	18.24
12	A comparison of noninvasive positive-pressure ventilation and conventional mechanical ventilation in patients with acute respiratory failure	Antonelli M. et al.	New England Journal of Medicine	1998	606	24.24
13	Comparison of 3 methods of gradual withdrawal from ventilatory support during weaning from mechanical ventilation	Brochard L. et al.	American Journal of Respiratory and Critical Care Medicine	1994	576	19.86
14	An official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: mechanical ventilation in adult patients with acute respiratory distress syndrome	Fan E. et al.	American Journal of Respiratory and Critical Care Medicine	2017	571	95.17
15	The use of continuous IV sedation is associated with prolongation of mechanical ventilation	Kollef MH. et al.	Chest	1998	551	22.04
16	A protocol of no sedation for critically ill patients receiving mechanical ventilation: a randomised trial	Strom T. et al.	Lancet	2010	541	41.62
17	Daily cost of an intensive care unit day: The contribution of mechanical ventilation	Dasta JF. et al.	Critical Care Medicine	2005	522	29
18	Dexmedetomidine vs midazolam or propofol for sedation during prolonged mechanical ventilation two randomized controlled trials	Jakob SM. et al.	JAMA-Journal of The American Medical Association	2012	515	46.82
19	Multiple system organ failure - Is mechanical ventilation a contributing factor?	Slutsky AS; Tremblay LN	American Journal of Respiratory and Critical Care Medicine	1998	515	20.6
20	Ventilator-associated lung injury in patients without acute lung injury at the onset of mechanical ventilation	Gajic O. et al.	Critical Care Medicine	2004	504	26.53
21	Severe impairment in lung-function induced by high peak airway pressure during mechanical ventilation - an experimental-study	Kolobow T. et al.	American Review of Respiratory Disease	1987	499	13.86
22	Patient-ventilator asynchrony during assisted mechanical ventilation	Thille AW. et al.	Intensive Care Medicine	2006	497	29.24
23	How is mechanical ventilation employed in the intensive care unit? An international utilization review	Esteban A. et al.	American Journal of Respiratory and Critical Care Medicine	2000	480	20.87
24	A comparison of sucralfate and ranitidine for the prevention of upper gastrointestinal bleeding in patients requiring mechanical ventilation	Cook D. et al.	New England Journal of Medicine	1998	475	19
25	Effect of failed extubation on the outcome of mechanical ventilation	Epstein SK. et al.	Chest	1997	465	17.88

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

Table 4. The 100 most frequently used keywords in articles on mechanical ventilation

Keywords	Number of uses	Keywords	Number of uses	Keywords	Number of uses
mechanical ventilation	1557	positive end-expiratory pressure	49	continuous positive airway pressure	21
intensive care unit (s)	252	prognosis	49	respiratory muscles	21
weaning	247	critical illness	45	weaning from mechanical ventilation	21
noninvasive (or non-invasive) ventilation, noninvasive (or non-invasive) mechanical ventilation	216	chronic respiratory failure	44	asthma	20
respiratory failure	183	extubation	44	mechanical ventilators	20
critical care	169	tidal volume	43	length of stay	19
mortality	153	diaphragm	42	monitoring	19
intensive care	124	survival	42	newborn	19
prolonged mechanical ventilation	119	lung injury	41	obesity	19
outcome (s)	118	bronchopulmonary dysplasia	38	complications	18
ventilation	115	sepsis	37	endotracheal intubation	18
tracheostomy	112	ICU	36	inflammation	18
acute respiratory distress syndrome	105	quality of life	36	pneumothorax	18
COVID-19	105	risk factors	36	spontaneous breathing trial	18
acute respiratory failure	91	cardiac surgery	35	atelectasis	17
ventilator weaning	87	respiratory distress syndrome	33	barotrauma	17
home mechanical ventilation	86	respiratory mechanics	33	cancer	17
sedation	78	epidemiology	32	controlled mechanical ventilation	17
respiration	77	mechanical	31	delirium	17
chronic obstructive pulmonary disease	75	dexmedetomidine	29	endotracheal tube	17
ventilator-induced lung injury	75	ventilator	28	Guillain-Barre syndrome	17
pneumonia	74	child	27	midazolam	17
acute lung injury	72	lung	27	neonate	17
pediatric (s)	70	nursing	27	positive-pressure respiration	17
artificial	67	Sars-CoV-2	27	pulmonary hypertension	17
ARDS	63	oxidative stress	25	surfactant	17
artificial respiration	63	propofol	25	ultrasonography	17
invasive mechanical ventilation	62	amyotrophic lateral sclerosis	24	ultrasound	17
children	60	extracorporeal membrane oxygenation	24	infant	16
COPD	56	hemodynamics	24	lung mechanics	16
respiration, artificial	55	ventilators	24	nitric oxide	16
respiratory insufficiency	55	hypercapnia	23	spontaneous breathing	16
ventilator-associated pneumonia	53	PEEP	23		
intubation	50	critically ill	22		

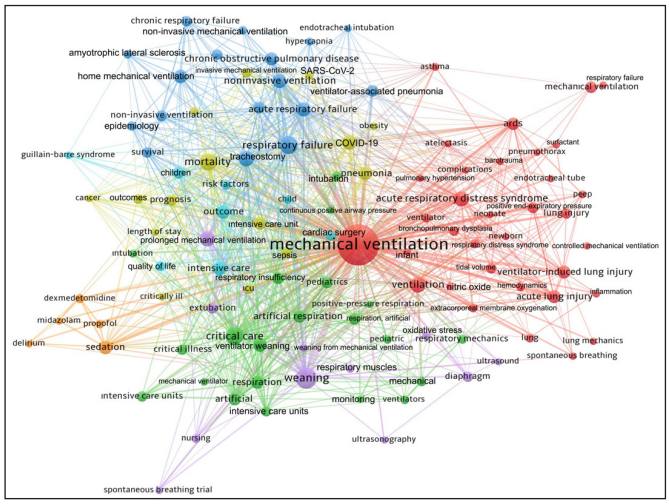

Figure 5. Network visualization map for cluster analysis based on keyword analysis performed to identify clustering of mechanical ventilation. Footnote: Each color represents a different cluster. Keywords in the same cluster are of the same color. The larger the number of times the keyword is used in articles, the larger the circle it represents

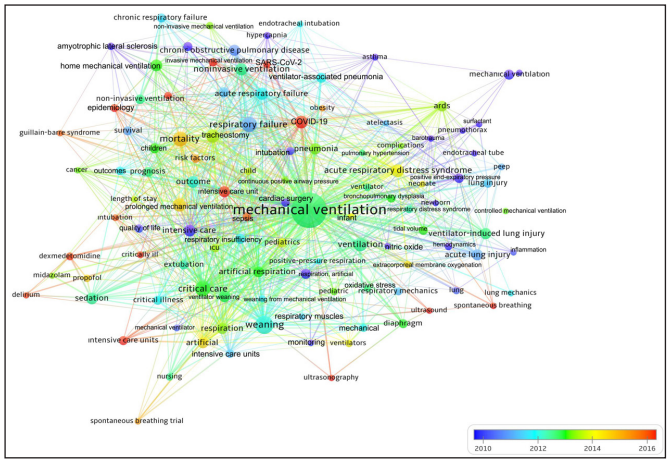

Figure 6. Network visualization map based on keyword analysis to identify past and current trends on mechanical ventilation. Footnote: In the indicator given in the lower right corner of the figure, the topicality of the article increases from blue to red (blue-green-yellow-red). The larger the number of times the keyword is used in articles, the larger the circle it represents

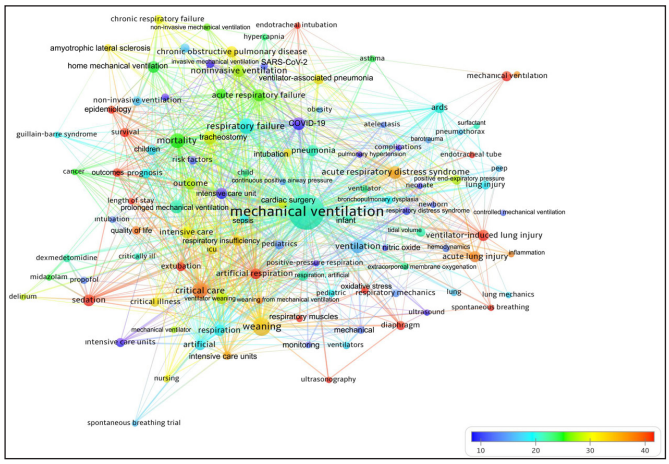

Figure 7. Network visualization map based on keyword analysis performed to identify the most cited topics on mechanical ventilation. Footnote: In the indicator given in the lower right corner of the figure, the number of citations received by the subject increases from blue to red (blue-green-yellow-red). The larger the number of times the keyword is used in articles, the larger the circle it represents

DISCUSSION

MV has accelerated the development of modern ICUs and has become a life-saving treatment (29). The history of MVs is around 200 years. MVs in the form of negative pressure ventilation first appeared in the early 1800s, while positive pressure devices began to be used in the 1900s. On the other hand, Today's typical ICU ventilator started being developed in the 1940s (30). Today, with the development of technology, ventilators can be used invasively and non-invasively. In addition, patient-specific settings can be made to provide ventilation support to patients. The COVID-19 pandemic, caused by SARS-CoV-2, emerged in late 2019 and has negatively affected all humanity as a global health problem as of 29 November 2021 (31-35). With the COVID-19 pandemic, the importance of MV has emerged once again due to respiratory support, which is one of the most important parts of the treatment for respiratory failure in patients with COVID-19 pneumonia (14,36,37). This situation was seen with the increase of publications on MV during the pandemic period.

When the number of articles published on MV by years was evaluated, 4 different trend periods were determined. The first period was the period 1980–2004. During this period, an average of 62 articles (between 18-108) were published annually. The second period was the 2005–2010 period. During this period, an average of 141 articles (between 106-169) were published annually. The third period was the period 2011–2019. In this process, an average of 231 articles (between 207-261) were published annually. The fourth period was the period 2020–2021. 384 articles were published in 2020 and 473 articles in 2021. The fact that there is an increasing publication trend over the years can be explained by the increase in the number of intensive care beds all over the world and the parallel increase in MV applications. The remarkable increase in the number of articles published in the last 2 years can be explained by the serious increase in MV application due to the COVID-19 pandemic. When the number of articles that can be published in the next five years obtained with the exponential smoothing estimator, which takes into account seasonal correction, is evaluated, it has been determined that the number of articles to be published on MV will continue with an increasing trend. This situation also shows that there may be a faster increase due to COVID-19 and similar pandemics that primarily affect the respiratory system.

When the publication distributions of the countries are examined, 14 of the first 17 active countries that contribute the most to the literature on MV article productivity are developed countries (USA, France, Canada, Germany, Spain, Italy, United Kingdom, Netherlands, Australia, Japan, Switzerland, Taiwan, Sweden, and South Korea) were determined. 3 of the 17 active countries (China,

Brazil, and Turkey) were developing countries. However, these countries have large economies, too. When the results of the correlation analysis were evaluated, a high level of correlation was found between article productivity and GDP, and a moderately significant correlation was found between GDP per capita and HDI values. This situation, in line with the literature, showed that the economic size and level of development of countries are effective factors in article productivity (16-18). In addition, the fact that these countries have more intensive care beds and have a significant share in the production of MV devices can explain more studies have been conducted in these countries.

When the density map created according to the total cooperation score between the countries was evaluated, it was determined that the first 15 countries with the most intensive cooperation were USA, Canada, Germany, Spain, Italy, France, England (in the United Kingdom), Netherlands, Brazil, Australia, Argentina, Greece, Switzerland, China, and Belgium, respectively. When the co-authorship cooperation of countries on MV is examined, it is seen that regional international collaborations based on the geographical neighborhood are common in article production (Countries in similar regions in the same cluster: (Austria, Belgium, Germany, France, Hungary, Netherlands, Serbia, Switzerland) (England, North Ireland, Scotland), (Croatia, Czech Republic, Denmark, Finland, Italy, Poland, Slovakia, Sweden), (Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay, Venezuela), (China, Japan, South Korea, Malaysia, Singapore, Taiwan, Thailand, Indonesia) (Saudi Arabia, Egypt, Iran, Pakistan, India)).

The journals that publish the most articles on MV were Critical Care Medicine, Chest, Intensive Care Medicine, Respiratory Care, American Journal of Respiratory and Critical Care Medicine, Critical Care, Journal of Critical Care, Plos One, Anesthesiology, Pediatric Pulmonology, American Journal of Critical Care ve American Review of Respiratory Disease. We can recommend that authors who are in the research process of MV and want to publish on MV should consider the journals presented in **Table 2**. When the citation analyses of the journals that have published at least 5 articles on this subject are evaluated, the most effective journals according to the average number of citations per article they publish were New England Journal of Medicine (Average Citation Per Article, AC=534), Annals of Internal Medicine (AC=206), JAMA-Journal of the American Medical Association (AC=184), Lancet (AC=181), American Review of Respiratory Disease (AC=148), American Journal of Respiratory and Critical Care Medicine (AC=134), BMJ-British Medical Journal (AC=119), and Lancet Respiratory Medicine (AC=107). We can recommend that researchers who want to see more impact on their work to be published should primarily consider these journals.

When the analyzed articles were evaluated according to the total number of citations they received, it was determined that the most cited study was the study by Kress et al. (38) titled "Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation" published in the New England Journal of Medicine. The second study was the study by Ranieri et al. (39) titled "Effect of mechanical ventilation on inflammatory mediators in patients with acute respiratory distress syndrome-A randomized controlled trial" published in the JAMA-Journal of the American Medical Association. The third study was Esteban et al. (27)'s study titled "Characteristics and outcomes in adult patients receiving mechanical ventilation - a 28-day international study" published in the JAMA-Journal of the American Medical Association. When the analyzed articles were evaluated according to the average number of citations they received per year, it was determined that the most effective study was the article titled "High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation" by Simonnet et al. (40). The second study was the article titled "Elevated levels of IL-6 and CRP predict the need for mechanical ventilation in COVID-19" by Herold et al. (41). The third study was Fan et al. (3)'s Guideline on Mechanical Ventilation in Adult Patients with ARDS. The studies that received the highest number of co-citations from all analyzed articles were Brower et al. (24), Boles et al. (25), Knaus et al. (26), Esteban et al. (27), Esteban et al. (12), Yang and Tobin (8), Amato et al. (28), Ely et al. (7). We can recommend researchers interested in this subject read these publications first. It can be explained by the fact that the number of citations received per year in a very short period of time is in studies containing COVID 19 cases, the clinical uncertainties associated with the COVID 19 disease still contain question marks, and there are not enough data on effective MV strategies.

When the keyword analysis findings were evaluated, it was seen that MV subjects formed 7 different main clusters as a result of the cluster analysis. The most studied subjects from past to present were intensive care unit, weaning, non-invasive mechanical ventilation, respiratory failure, critical care, mortality, outcome (s), prolonged mechanical ventilation tracheostomy, acute respiratory distress syndrome, COVID-19, home mechanical ventilation, sedation, respiration, chronic obstructive pulmonary disease, ventilator-induced lung injury. The most cited keywords were sedation, artificial respiration, ventilator-induced lung injury, epidemiology, outcomes, survival, extubation, diaphragm, oxidative stress, ultrasonography, respiratory muscles, length of stay, quality of life,

endotracheal intubation, endotracheal tube, spontaneous It was determined that he had breathing, acute lung injury, inflammation, weaning from mechanical ventilation, acute respiratory distress syndrome. According to the results of the analysis made to determine the trend topics, the trend keywords studied in recent years were COVID-19 (SARS CoV-2), intensive care unit, dexmedetomidine, epidemiology, delirium, invasive mechanical ventilation, spontaneous breathing, ultrasound/ultrasonography, critically ill, sepsis, intubation, risk factors, Guillain-Barre syndrome, and obesity. Based on these findings, subjects such as sedation, inflammatory process, lung injury, and the outcome can be evaluated as topics that are still up-to-date and can be research topics. In addition, it should not be a surprise that point-of-care USG, which has been widely used in recent years on MV effects and follow-up, is included in the keywords.

As a result of our literature review on MV, we could not find any bibliometric study on this subject. It can be said that this study is the first bibliometric study on this subject. In addition, the use of many statistical approaches such as trend keyword analysis, international cooperation analysis, and correlation analysis, apart from citation analysis, can be said to be the superior aspects of this study.

As a limitation of this study, it can be said that we only used the WoS database to obtain the analyzed articles. However, in many bibliometric studies carried out in the literature, only the WoS database was preferred. According to the Scopus database, WoS indexes the articles published in more influential journals (Only journals scanned in SCI-expanded, ESCI, and SSCI indexes). On the other hand, citation analyzes cannot be performed in the PubMed database (16-19).

CONCLUSION

In this comprehensive bibliometric research we conducted on MV, we shared the statistical analysis information of 5323 articles published since 1980. It has been determined that the most studied trend topics in recent years are COVID-19 (SARS CoV-2), intensive care unit, dexmedetomidine, epidemiology, delirium, invasive mechanical ventilation, spontaneous breathing, ultrasound/ultrasonography, critically ill, sepsis, intubation, risk factors, Guillain-Barre syndrome, and obesity. With the developing technology, the usage area of MV is increasing and this situation is also reflected in the publications in the literature. It was also observed that the number of studies on MV increased with the COVID-19 (SARS CoV-2) pandemic. This study, which includes the bibliometric analysis of MV by summarizing the literature, will guide the authors who want to study in this area.

ETHICAL DECLARATIONS

Ethics Committee Approval: Since our research article is a bibliometric study, there is no need for an ethics committee approval.

Informed consent: For this type of study, formal consent is not required.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The author has no conflicts of interest to declare.

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REFERENCES

1. Phinizy PA, Bolton JJ, Tamasitis JF. Invasive ventilation: a discussion of equipment and troubleshooting. Emergency Management of the Hi-Tech Patient in Acute and Critical Care 2021: 289-311.
2. Bonnesen B, Jensen JS, Jeschke KN, et al. Management of COVID-19-associated acute respiratory failure with alternatives to invasive mechanical ventilation: high-flow oxygen, continuous positive airway pressure, and noninvasive ventilation. Diagnostics (Basel) 2021; 2; 11: 2259.
3. Fan E, Del Sorbo L, Goligher EC, et al. Mechanical ventilation in adult patients with acute respiratory distress syndrome. Am J Respir Crit Care Med 2017; 195: 1253-63.
4. Liu W, Tao G, Zhang Y, et al. A Simple weaning model based on interpretable machine learning algorithm for patients with sepsis: a research of MIMIC-IV and eICU Databases. Front Med (Lausanne) 2022; 8: 814566.
5. Nguyen TK, Mai DH, Le AN, Nguyen QH, Nguyen CT, Vu TA. A review of intraoperative lung-protective mechanical ventilation strategy. Trends in Anaesthesia and Critical Care 2021; 37: 9-17.
6. Yeung J, Couper K, Ryan EG, Gates S, Hart N, Perkins GD. Non-invasive ventilation as a strategy for weaning from invasive mechanical ventilation: a systematic review and Bayesian meta-analysis. Intensive Care Med 2018; 44: 2192-204.
7. Ely EW, Baker AM, Dunagan DP, et al. Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. N Engl J Med 1996; 19; 335: 1864-9.
8. Yang KL, Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. N Engl J Med 1991; 324: 1445-50.
9. Nemer SN, Barbas CS, Caldeira JB, et al. A new integrative weaning index of discontinuation from mechanical ventilation. Crit Care 2009; 13: R152.
10. Huaringa AJ, Wang A, Haro MH, Leyva FJ. The weaning index as predictor of weaning success. J Intensive Care Med 2013; 28: 369-74.
11. Girard TD, Alhazzani W, Kress JP, et al. Liberation from mechanical ventilation in critically ill adults. rehabilitation protocols, ventilator liberation protocols, and cuff leak tests. Am J Respir Crit Care Med 2017; 195: 120-33.
12. Esteban A, Frutos F, Tobin MJ, et al. A comparison of four methods of weaning patients from mechanical ventilation. Spanish Lung Failure Collaborative Group. N Engl J Med 1995; 332: 345-50.

13. Lim ZJ, Subramaniam A, Ponnapa Reddy M, et al. Case fatality rates for patients with COVID-19 requiring invasive mechanical ventilation. A Meta-analysis. Am J Respir Crit Care Med 2021; 203: 54-66.
14. Chang R, Elhusseiny KM, Yeh YC, Sun WZ. COVID-19 ICU and mechanical ventilation patient characteristics and outcomes-A systematic review and meta-analysis. PLoS One 2021; 16: e0246318.
15. Bektan Kanat B, Yavuzer H. Top 100 articles on vitamin D: bibliometric versus altmetric analysis. Bratisl Lek Listy 2022; 123: 160–71.
16. Zengin M, Karaca O, A bibliometric analysis of academic publications about intoxication in the period from 1975 to 2020: a global and medical view. Osmangazi J Med 2022; 44: 148-61.
17. Doğan G, Karaca O. Análise bibliométrica no campo da anestesiologia no período de 2009-2018 [A bibliometric analysis of the field of anesthesia during 2009-2018]. Braz J Anesthesiol 2020; 70: 140-52.
18. Kiraz S, Demir E. Global scientific outputs of schizophrenia publications from 1975 to 2020: a bibliometric analysis. Psychiatr Q 2021; 92: 1725-44.
19. Zengin M, Karcioglu AM. Do not invade, just support. Bratisl Lek Listy 2022; 123: 218-26.
20. Baldemir R, Ülger G. A holistic investigation of the global outcomes of spontaneous pneumothorax during 1980-2021, including the COVID-19 pandemic: a bibliometric approach. Medicine (Baltimore) 2022; 101: e29113.
21. Zengin M, Baldemir R. Investigation of the global outcomes of acute respiratory distress syndrome with the effect of COVID-19 in publications: a bibliometric analysis BETWEEN 1980 and 2020. Kırıkkale Üniversitesi Tıp Fakültesi Derg 2021; 23: 279-92.
22. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 2010; 84: 523-38.
23. The World Bank. Website https://data.worldbank.org/indicator/NY.GDP.MKTP.CD, [accessed 1 February 2022].
24. Acute Respiratory Distress Syndrome Network, Brower RG, Matthay MA, et al. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med 2000; 342: 1301-8.
25. Boles JM, Bion J, Connors A, et al. Weaning from mechanical ventilation. Eur Respir J 2007; 29: 1033-56.
26. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. Crit Care Med 1985; 13: 818-29.
27. Esteban A, Anzueto A, Frutos F, et al. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. JAMA 2002; 287: 345-55.
28. Amato MB, Barbas CS, Medeiros DM, et al. Effect of a protective-ventilation strategy on mortality in the acute respiratory distress syndrome. N Engl J Med 1998; 338: 347-54.
29. Slutsky AS. History of mechanical ventilation. from Vesalius to ventilator-induced lung injury. Am J Respir Crit Care Med 2015; 191: 1106-15.
30. Kacmarek RM. The mechanical ventilator: past, present, and future. Respir Care 2011; 56: 1170-80.
31. Daş T, Buğra A. How did research article publications on the COVID-19 pandemic progress in the Q1 ranked SCImage index journals in 2020? J Health Sci Med 2022; 5: 368-73.
32. Tanoglu EG, Esen MF. Evaluation of studies on molecular biology and genetics related to COVID-19 with data mining. J Health Sci Med 2021; 4: 960-6.
33. Mutlu P, Mirici A, Gönlügür U, et al. Evaluating the clinical, radiological, microbiological, biochemical parameters and the treatment response in COVID-19 pneumonia. J Health Sci Med 2022; 5: 544-51.
34. Çolak S, Tekgöz E, Çınar M, et al. Efficacy of tocilizumab in severe COVID-19: a retrospective study. J Health Sci Med 2022; 5: 592-9.
35. Aydemir S, Hoşgün D. The role of serum lipoprotein levels in predicting independent short-term mortality in COVID-19 patients. Anatolian Curr Med J 2022; 4; 162-6.
36. Ertürk T, İnangil D, Pakdil EL, et al. Medical device related pressure injuries in COVID-19 patients followed up in an intensive care unit. J Health Sci Med 2022; 5: 227-33.
37. Grasselli G, Cattaneo E, Florio G, et al. Mechanical ventilation parameters in critically ill COVID-19 patients: a scoping review. Crit Care 2021; 25: 115.
38. Kress JP, Pohlman AS, O'Connor MF, Hall JB. Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation. N Engl J Med 2000; 342: 1471-7.
39. Ranieri VM, Suter PM, Tortorella C, et al. Effect of mechanical ventilation on inflammatory mediators in patients with acute respiratory distress syndrome: a randomized controlled trial. JAMA 1999; 282: 54-61.
40. Simonnet A, Chetboun M, Poissy J, et al. High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation. Obesity (Silver Spring) 2020; 28: 1195-9.
41. Herold T, Jurinovic V, Arnreich C, et al. Elevated levels of IL-6 and CRP predict the need for mechanical ventilation in COVID-19. J Allergy Clin Immunol 2020; 146: 128-3