

## Research Article

# Social Attention through Altmetric Score Analysis for End-tidal Carbon Dioxide and Capnography

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### Abstract

**Objectives:** Altmetric analyses highlight key publications in terms of social media. Throughout recent years, social media platforms have been playing important roles in the promotion, spread and display of medical literature. The aim of the present study was to determine the most influential literature on end-tidal carbon dioxide or  $\text{ETCO}_2$  and capnography in the last decade and to evaluate the changing trends in altmetric attention scores over time.

**Methods:** “End-tidal  $\text{CO}_2$ ” or “Capnography” as a search term was entered into Thomson Reuter’s Web of Science database to identify all articles in the field. The 50 most-cited articles were analysed by topic trends, sources, authors, publication years, and altmetric attention scores.

**Results:** 2822 articles were screened from Web of Science. Among these, the 50 most cited articles were selected. In the analyzed articles the median (range) citation and altmetric score values were 52 (37–424) and 6 (1–212) respectively. The most cited article in the top 50 list was “Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments” published by Cook TM et al. in 2011. The highest number of articles were published in journals Journal of Applied Physiology (n=5) and Resuscitation (n=5). The altmetric scores were rather low and did not showed a linear association with the citation counts of top 50 articles on  $\text{ETCO}_2$  and capnography.

**Conclusion:** Bibliometric based altmetric analysis provide important but different perspectives regarding article impact. Future studies with the use of  $\text{ETCO}_2$  with capnography in wider indications being more recognized in social media would contribute to the current knowledge.

**Keywords:** Altmetric analysis, capnography, citation classics, end-tidal carbon dioxide

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The monitorization of End-tidal  $\text{CO}_2$  through capnography is an important noninvasive technique used in the measurement of partial  $\text{CO}_2$  pressure during ventilation. Besides monitoring lung ventilation, capnography can provide safety-critical information in regards to the circulatory

and the metabolic activities of the patient as well as facilitating the diagnosis of low cardiac output states and pulmonary embolism.<sup>[1]</sup> Since the 1988, capnographic  $\text{ETCO}_2$  has been used for an increasing number of conditions, procedures, and monitoring.<sup>[2]</sup>

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Researchers have been using different tools to be able to reach high-qualified scientific work. Times cited or citation of a scientific research is one of the commonly used important quality indicators providing information from a precise measurement. However, as the number of citations depend on the time since publication; the number of citations, solely may not be sufficient in measuring the quality of a scientific research in real time.<sup>[3]</sup> Impact factor (IF) is a citation-based indicator used for defining the quality of journals and is calculated by dividing the number of citations in the current year by the sources published in the journal during the previous two years.<sup>[4]</sup> Although IF is widely defined and accepted as a quantitative indicator of journal qualities; the limitations of IF have been the focus of criticisms by researchers.<sup>[5]</sup> Journal H-Index is another commonly used tool for measuring the quality of a journal and is provided by Web of Science, Scopus, Google Scholar and Scimago Journal & Country Rank (SJCR).<sup>[6,7]</sup>

Analysis of citations classics depending on the evaluation of the most-cited scientific studies, have been an important tool for researchers searching highly qualified material on their field. Researchers from a variety of medical expertises have been conducting bibliometric analysis.<sup>[8,9]</sup> Citation indexing for studying science has been first applied to scientific journals by Eugene Garfield, founder of the Institute of Scientific Information in the 1970s.<sup>[10]</sup> Since citations only present the impact on the scientific community, it rules out the role of other important factors depending on policy makers, patients and the public. Throughout the last decade, the increasing social media platforms have been playing important roles in the promotion, spread and display of medical literature. Altmetrics, standing for alternative metrics, close the deficit of traditional citations as they include web citations to digital research documents and usage-based indicators, such as views, downloads, comments, bookmarks and mentions from social media. "Altmetric Attention Scores" (AAS) are metrics and qualitative data that are complementary to traditional, citation-based metrics. It measures the interactions of academics, scholars, and scientists as captured by reference management tools and social media such as Facebook, Twitter, LinkedIn, blogs, etc.<sup>[11]</sup>

In the current literature, there is no study evaluating the most influential studies on  $\text{ETCO}_2$  with capnography measurement as well as the the impact of altmetric attention scores on the topic. The aim of the present study was to determine the most influential literature on capnography in the last decade and to evaluate the changing trends in altmetric attention scores over time.

## Methods

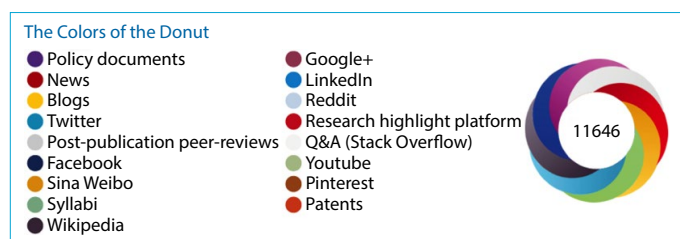
The term "End-tidal  $\text{CO}_2$ " or "Capnography" was searched on the Web of Science citation-indexing database and research platform. Article publication years were filtered from 2009 to 2019 (last decade). Full-text manuscripts in English language were sorted by number of citations and 50 most cited articles were identified from numerous manuscripts identified. The detailed evaluation of articles were performed by examining titles, first authors, years of publication, study types and topics. The IF of 2018 was recorded for each journal in which the articles were published. AAS were obtained by downloading the "Altmetric it" function from the Altmetric.com website (<https://www.altmetric.com/products/freetools/bookmarklet>). The AAS is calculated automatically using an algorithm based on the weighted number of all the attention a research output receives. The score indicates the weighted number of the amount of attention Altmetric company has received for a research outcome. The default weight and how the AAS is calculated can be found on the altmetric website.<sup>[12]</sup> AAS is based on three main factors: volume, sources, and authors. Each color of the Altmetric donut represents a different social media source of interest (Fig. 1).<sup>[13]</sup> AAS and Altmetric donuts are designed to facilitate the demonstration of the quantity and the sources of the attention in a particular research outcome.

## Statistical Analysis

In this study, categorical variables were defined using percentages and continuous variables using median and interquartile intervals (IQRs). Kruskal-Wallis test was used to compare 3 or more groups in the present non-normally distributed data.

## Results

There were 2822 articles on "End-tidal  $\text{CO}_2$ " or "Capnography" published between 2009-2019 in the search of Web of Science. Table 1 includes the top-cited 50 articles (T50) in the literature, publication by years (Fig. 2), total citation counts per years (Fig. 3), average citation per year and altmetric attention scores. Citation count ranged between 37-424 (#50



**Figure 1.** An altmetric donut representing different social media sources of interest (from Altmetric.it, 2019).

**Table 1.** Top 50 articles by metrics (T50)

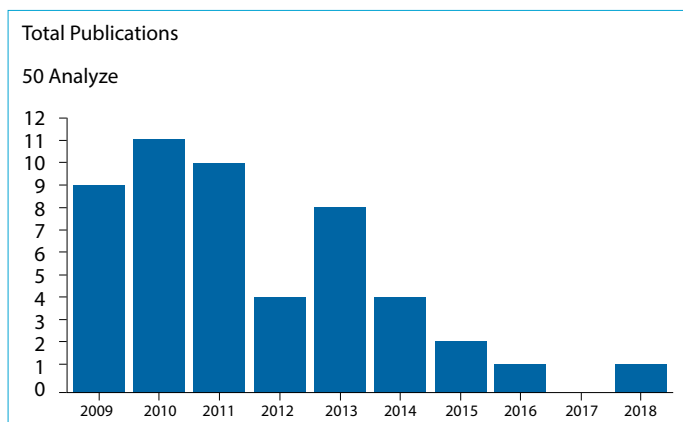
Rank	Title	Year	First Author	Times Cited	Average Citation per Year	Altmetric Score
1.	Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments	2011	Cook TM	424	47.11	39
2.	Relationship between respiration, end-tidal CO <sub>2</sub> , and BOLD signals in resting-state fMRI	2009	Chang C	148	13.45	17
3.	Cerebral blood flow velocity underestimates cerebral blood flow during modest hypercapnia and hypocapnia	2014	Coverdale NS	136	22.67	5
4.	Capnographic monitoring of respiratory activity improves safety of sedation for endoscopic cholangiopancreatography and ultrasonography	2009	Qadeer MA	131	11.91	4
5.	Does end tidal CO <sub>2</sub> monitoring during emergency department procedural sedation and analgesia with propofol decrease the incidence of hypoxic events? A randomized, controlled trial	2010	Deitch K	112	11.20	27
6.	Tracheal rapid ultrasound exam (TRUE) for confirming endotracheal tube placement during emergency intubation	2011	Chou HC	97	10.78	4
7.	End-tidal and arterial carbon dioxide measurements correlate across all levels of physiologic dead space	2010	McSwain SD	79	7.90	
8.	On the assessment of cerebrovascular reactivity using hypercapnia BOLD MRI	2009	Yezhuvath US	79	7.18	3
9.	Capnography enhances surveillance of respiratory events during procedural sedation: a meta-analysis	2011	Waugh JB	73	8.11	139
10.	A sudden increase in partial pressure end-tidal carbon dioxide (PETCO <sub>2</sub> ) at the moment of return of spontaneous circulation	2010	Pokorna M	73	7.30	13
11.	Patient safety incidents associated with airway devices in critical care: a review of reports to the UK National Patient Safety Agency	2009	Thomas AN	71	6.45	6
12.	Factors complicating interpretation of capnography during advanced life support in cardiac arrest-A clinical retrospective study in 575 patients	2012	Heradstveit BE	69	8.62	2
13.	Respiratory changes with seizures in localization-related epilepsy: Analysis of periictal hypercapnia and airflow patterns	2010	Seyal M	67	6.7	
14.	End-tidal carbon dioxide is better than arterial pressure for predicting volume responsiveness by the passive leg raising test	2013	Monnet X	65	9.29	87
15.	Capnographic monitoring reduces the incidence of arterial oxygen desaturation and hypoxemia during propofol sedation for colonoscopy: a randomized controlled study (ColoCap Study)	2012	Beitz A	64	8.0	1
16.	Quantitative relationship between end-tidal carbon dioxide and CPR quality during both in-hospital and out-of-hospital cardiac arrest	2015	Sheak KR	63	12.6	24
17.	High-flow nasal cannula oxygen for bronchiolitis in a pediatric ward: a pilot study	2013	Bressan S	62	8.86	4

Table 1. CONT.

Rank	Title	Year	First Author	Times Cited	Average Citation per Year	Altmetric Score
18.	The effects of reduced end-tidal carbon dioxide tension on cerebral blood flow during heat stress	2009	Brothers R	61	5.54	
19.	Continuous estimates of dynamic cerebral autoregulation during transient hypocapnia and hypercapnia	2010	Dineen NE	59	5.9	
20.	End-tidal CO <sub>2</sub> : An important parameter for a correct interpretation in functional brain studies using speech tasks	2013	Scholkmann F	55	7.86	3
21.	Rationale of Dead Space Measurement by Volumetric Capnography	2012	Tusman G	55	6.87	
22.	Characterization of regional heterogeneity in cerebrovascular reactivity dynamics using novel hypocapnia task and BOLD fMRI	2009	Bright MG	55	5.0	
23.	The prognostic value of end tidal carbon dioxide during cardiac arrest: A systematic review	2013	Touma O	54	7.71	44
24.	Blood-oxygen level dependent MRI measures of cerebrovascular reactivity using a controlled respiratory challenge: reproducibility and gender differences	2010	Kassner A	54	5.40	7
25.	Precise control of end-tidal carbon dioxide and oxygen Improves BOLD and ASL cerebrovascular reactivity measures	2010	Mark CI	53	5.30	3
26.	Comparison of cerebral vascular reactivity measures obtained using breath-holding and CO <sub>2</sub> inhalation	2013	Tancredi FB	52	7.43	1
27.	Does cerebral oxygen delivery limit incremental exercise performance?	2011	Subudhi AW	51	5.67	1
28.	Using laboratory models to test treatment morphine reduces dyspnea and hypercapnic ventilatory response	2011	Banzett RB	51	5.67	
29.	Capnography outside the operating rooms	2013	Kodali BS	49	7.00	15
30.	Effect of acute hypoxia on blood flow in vertebral and internal carotid arteries	2013	Ogoh S	47	6.71	1
31.	Anaesthesia in prehospital emergencies and in the emergency room	2010	Paal P	47	4.70	3
32.	Airway challenges in critical care	2011	Nolan JP	46	5.11	12
33.	Cardiopulmonary exercise testing to detect chronic thromboembolic pulmonary hypertension in patients with normal echocardiography	2014	Held M	45	7.50	1
34.	Strategies for the prevention of airway complications - a narrative review	2018	Cook TM	44	22.0	212
35.	Non-invasive assessment of fluid responsiveness by changes in partial end-tidal CO <sub>2</sub> pressure during a passive leg-raising maneuver	2012	Monge G	44	5.50	5
36.	All India Difficult Airway Association 2016 guidelines for the management of unanticipated difficult tracheal intubation in adults	2016	Myatra SN	42	10.5	6
37.	Efficacy of chest compressions directed by end-tidal CO <sub>2</sub> feedback in a pediatric resuscitation model of basic life support	2014	Hamrick JL	42	7.00	8
38.	Accuracy of postoperative end-tidal pCO <sub>2</sub> measurements with mainstream and sidestream capnography in non-obese patients and in obese patients with and without obstructive sleep apnea	2009	Kasuya Y	42	3.82	

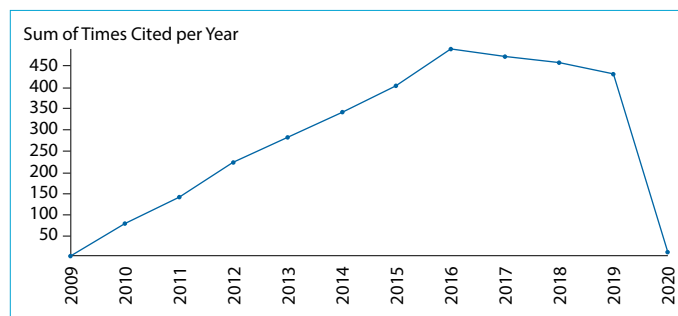
**Table 1. CONT.**

Rank	Title	Year	First Author	Times Cited	Average Citation per Year	Altmetric Score
39.	Regional changes in brain blood flow during severe passive hyperthermia: effects of Pa-CO <sub>2</sub> and extracranial blood flow	2013	Bain AR	41	5.86	1
40.	Validation of Bohr dead space measured by volumetric capnography	2011	Tusman G	41	4.56	2
41.	Capnography is superior to pulse oximetry for the detection of respiratory depression during colonoscopy	2010	Cacho G	41	4.10	
42.	Volumetric capnography: the time has come	2014	Suarez-Sipmann F	40	6.67	8
43.	Out-of-theatre tracheal intubation: prospective multicentre study of clinical practice and adverse events	2011	Bowles TM	40	4.44	3
44.	Time for capnography - everywhere	2011	Whitaker DK	40	4.44	6
45.	Spontaneous fluctuations in cerebral blood flow regulation: contribution of Pa-CO <sub>2</sub>	2010	Panerai RB	40	4.00	
46.	Activation of the retrotrapezoid nucleus by posterior hypothalamic stimulation	2009	Fortuna MG	39	3.54	
47.	A role of end-tidal CO <sub>2</sub> monitoring for assessment of tracheal intubations in very low birth weight infants during neonatal resuscitation at birth	2009	Hosono S	39	3.54	1
48.	Mapping the end-tidal CO <sub>2</sub> response function in the resting-state BOLD fMRI signal: Spatial specificity, test-retest reliability and effect of fMRI sampling rate	2015	Golestani AM	38	7.60	16
49.	Capnography/capnometry during mechanical ventilation: 2011	2011	Walsh BK	37	4.11	11
50.	Impact of modified treatment in echocardiographically confirmed pseudo-pulseless electrical activity in out-of-hospital cardiac arrest patients with constant end-tidal carbon dioxide pressure during compression pauses	2010	Prosen G	37	3.70	26



**Figure 2.** Distribution of total publication by years (from Web of Science database, 2019).

and #1 in Table 1). The median (IQR) citation was 52 (29). AAS could not be obtained in 11 articles. Among the rest of the articles, AAS ranked between 1-212 (#47 and #34 in Table 1). The median (IQR) AAS was 6 (13). The most cited article in the T50 (#1) was “Major complications of airway manage-



**Figure 3.** Distribution of total citation by years (from Web of Science database, 2019).

ment in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments” published by Cook TM et al. in 2011; while the highest AAS (#34) belonged to the article “Strategies for the prevention of airway complications - a narrative review” published by Cook TM et al. in 2018. Four of the top 10 articles in T50 were among the top 10 articles with the highest AAS. The median

(IQR) altmetric score of the top 10 AAS was 33 (78). According to Table 1, the highest number of publications were performed in year 2010 (n=11), followed by years 2011 (n=10) and 2009 (n=9). Only 8 articles on end-tidal was published in years after 2013. T50 articles were published in 31 journals with the number of articles ranging from 1 to 5 per journal. In 9 of the journals, there was more than 1 publication on the present topic (Table 2). The highest number of articles were published in journals Journal of Applied Physiology (n=5), Resuscitation (n=5), Anesthesia (n=4) and Neuroimage (n=4). One article was published in the journal Gastroenterology having the highest impact factor as well as highest H-index among T50 journal list. The SCImago Journal and Country Rank category was Q1 in 42 journals and Q2 in 8 journals. The publication language was English for all articles.

The majority of the articles in T50 (n=39) were original researches, followed by 5 reviews and 3 guidelines/advisory documents (Table 3). While the majority of the original studies were basic clinical studies (n=31), non-randomized clinical trials were performed in 4 articles and randomized controlled clinical trials were conducted in 3 articles. There was one article having performed meta-analysis. Editorial (n=1), correspondence (n=1) and commentary (n=1) articles were also in our T50. Two of the randomized controlled trials (#5, #15) investigated the role of capnographic monitorization in preventing arterial oxygen desaturation occurring during sedation. The median (IQR) values for AAS and citations were 4 (15) and 55 (33) for original researches. The median (IQR) values for AAS and citations were 4 (15) and 58 (48) for basic science studies.

**Table 2.** Journals with top-50 articles, ranked according to times cited

Journal name	Number of articles	IF*	Q category**	H Index**
Journal of Applied Physiology	5	3.26	Q1	211
Resuscitation	5	5.86	Q1	123
Anaesthesia	4	5.43	Q1	106
Neuroimage	4	5.43	Q1	320
Journal of Physiology-London	2	4.54	Q1	216
Anesthesiology	2	6.52	Q1	214
British Journal of Anaesthesia	2	6.50	Q1	159
Intensive Care Medicine	2	15.01	Q1	176
Respiratory Care	2	2.07	Q2	77
Gastroenterology	1	20.77	Q1	368
Annals of Emergency Medicine	1	4.68	Q1	141
NMR in Biomedicine	1	3.03	Q1	104
Journal of Clinical Anesthesia	1	1.81	Q2	65
Journal of Emergency Medicine	1	1.21	Q1	70
Epilepsia	1	5.07	Q1	174
American Journal of Gastroenterology	1	10.23	Q1	234
European Journal of Pediatrics	1	2.24	Q1	86
Anesthesia and Analgesia	1	3.46	Q1	187
Journal of Magnetic Resonance Imaging	1	3.61	Q1	142
Magnetic Resonance in Medicine	1	4.08	Q1	209
Journal of Cerebral Blood Flow and Metabolism	1	6.04	Q1	177
American Journal of Respiratory and Critical Care Medicine	1	15.24	Q1	343
Experimental Physiology	1	2.73	Q2	87
Respiration	1	2.59	Q2	70
Annals of Intensive Care	1	3.77	Q1	36
Indian Journal of Anaesthesia	1	N/A	Q2	22
Journal of the American Heart Association	1	4.45	Q1	60
Revista Espanola de Enfermedades Digestivas	1	1.63	Q2	34
Current Opinion in Critical Care	1	3.12	Q1	79
Journal of Perinatal Medicine	1	1.56	Q2	60
Journal of International Medical Research	1	1.02	Q2	51

\*IF: Impact Factor; 2018 Journal Citation Reports, Web of Science Group, 2020 \*\*2020 Scimago Journal and Country Rank.

Among T50, 27 articles examined the role of ETCO<sub>2</sub> measurement through respiratory physiology. The median (IQR) values for AS and citations were 3 (9) and 49 (14), consecutively. The use of ETCO<sub>2</sub> in advanced life support (n=10), airway management (n=7) and sedation (n=6) were the other common subjects in T50. The highest median (IQR) AS value 11 (27) was observed in the articles on advanced life support subject and the highest median (IQR) number of citations 73 (66) were observed in the articles on subject sedation (Table 4). There were no statistically significant differences between the groups according to the article topics.

## Discussion

Capnography has been an important tool for physicians since the 1980s through its extensive use in cardiac arrest (providing information in regards to compression quality, return of spontaneous circulation, endotracheal tube placement, prognosis) and procedural sedation.<sup>[14]</sup> Capnography has also been used in the assessment of subjects with trauma, metabolic acidemia, sepsis and pulmonary embolism. The guidelines define capnography as the gold standard in the monitorization of ventilation and highly recommended its use for all unconscious anaesthetised patients regardless of the airway device

used or the location.<sup>[15-17]</sup> Due to the widely utilization of online social media among researchers, academic institutions, scientific journals as well as the general population; altmetric qualifications have become more important in determining the online impact of publications.<sup>[11, 18]</sup> In the current study evaluating the most influential publications on capnography, the altmetric scores representing interest in social media and in online scientific community were rather low and did not demonstrate a linear association with the citation counts of top 50 articles on capnography. This study is the first study on the specific topic evaluating the most influential articles on the topic as well as the association of altmetrics and traditional bibliometrics of this scale.

The most cited publication on capnography was the study by Cook TM et al.<sup>[19]</sup> being the second part of Fourth National Audit Project which investigated the major complications of airway management in ICU and emergency department settings. As failure to use capnography was associated with deaths or persistent neurological injuries in 74% cases; extended utilization of capnography in airway management was recommended. A more recent study, a review by Cook TM et al.<sup>[20]</sup> published in 2018 was the publication with highest altmetric attention score, in which capnography was again recommended among

**Table 3.** Study types with median values

Type-Subtype	Number of articles	AS, median (IQR)	Citations, median (IQR)
All articles	50	6 (13)	52 (29)
Original research	39	4 (15)	55 (33)
Basic science research	31	4 (15)	58 (48)
Non-randomized clinical trial	4		
Randomized controlled clinical trial	3		
Meta-analysis	1		
Review	5		
Guidelines and advisory documents	3		
Editorial	1		
Correspondence	1		
Commentary	1		

IQR: interquartile range; AS: altmetric score.

**Table 4.** Top-50 cited articles according to main subjects

Article topic	Number of articles	AS, median (IQR)	Citations, median (IQR)
Respiratory physiology	27	3 (9)	49 (14)
Advanced life support	10	11 (27)	58 (25)
Airway management	7	6 (35)	46 (55)
Sedation	6	4 (81)	73 (66)

IQR: interquartile range; AS: altmetric score.

strategies for the prevention of airway complications. The existence of the similar issues in regards to failure in using capnography through years 2011-2018 as pointed by these two articles of Cook TM et al. also suggest the importance of capnography being the subject of succeeding publications as well.

The most common topic in the T50 articles was respiratory physiology. Mainly, the effects in ventilator responses and cerebrovascular reactivity was evaluated in these studies. The remaining topics were parallel with the most common indications of capnography: advanced life support, airway management and sedation.

Altmetrics are important tools for reflecting real-time data which allows the researchers to be aware of the medias publications are shared as well as discussed.<sup>[11]</sup> It also provides the opportunity for a high quality publication to get recognized at early phases, before high number of citations. It is recommended to be used complementary to traditional citation-based metrics. However, since altmetrics are relatively new in the scientific field, the real impact and the reliability would be assessed in the light of future studies over time. In the present study, among T50, 30 articles were published between years 2009-2011 and there has been a decline in the trend of the number of most-cited articles after 2013. The relatively low altmetric attention score may be attributed to the low numbers of published articles on capnography in the recent years. This opinion is also supported by the article being published recently and having the highest altmetric score. Furthermore, since capnography is an advanced professional term, the target audience in social media is limited with healthcare professionals.

There are several strengths and limitations of the current study. Firstly, it was the first bibliometric and altmetric study to evaluate the most influential publications on a life-saving strategy, capnography. The lack of altmetric attention scores in 11 articles was a limitation of the study.

## Conclusion

In conclusion, the present study provides a detailed list of 50 most cited articles on capnography and social media interest using the Altmetric.com database. Our findings confirm the well defined indications of capnography as well as the need of more frequently use of it in daily practices as pointed out by recent publications. Future studies with the use of capnography in wider indications being more recognized in social media would contribute to the current knowledge.

## Disclosures

**Ethics Committee Approval:** All authors declare that the research was conducted in accordance with the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects." This study did not need to be approved by an ethics committee because it performed altmetric and bibliometric analysis of the currently published classical studies.

**Peer-review:** Externally peer-reviewed.

**Conflict of Interest:** None declared.

**Authorship Contributions:** Concept – C.G., Me.D., S.K., M.D.; Design – C.G., Me.D., S.K., M.D.; Supervision – C.G., Me.D., S.K., M.D.; Materials – C.G., Me.D., S.K., M.D.; Data collection &/or processing – C.G., Me.D., S.K., M.D.; Analysis and/or interpretation – C.G., Me.D., S.K., M.D.; Literature search – C.G., Me.D., S.K., M.D.; Writing – C.G., Me.D., S.K., M.D.; Critical review – C.G., Me.D., S.K., M.D.

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