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Research Article

SCIENTIFIC ANALYSIS OF ANESTHESIA MONITORING TO INCREASE SAFETY OF ANESTHETICS

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ABSTRACT

A scientometric analysis was used to assess progress in anesthesia monitoring over the last 40 years. There were two scientometric indexes: popularity indexes (general and specific), which measure how many articles are related to a particular topic. Anesthesia or anesthesia monitoring; IC, an index that measures growth in publications on a particular topic; IE, an index that measures how many PubMed-indexed publications are published on a particular topic. We assessed 66 monitoring-related publications. In the past 42 years, anesthesia monitoring articles have increased more than 13-fold, from 652 articles in 1974-1978 to 3,394 articles in 2009-2013. Articles on general anesthetics rose at a much slower rate. Comparison of the related GPIs showed a significant difference: anesthesia monitoring showed stable growth while general anesthesia showed constant declines. In 18 of 48 subjects introduced after 1975, the SPI index increased significantly between 2009 and 2013: Bispectral Index, Transesophageal Echocardiography, Electromyography, Pulse Oximetry, Entropy, Train-of-four, Capnography, Pulse Contour, electromyography monitoring. The IC and IE indexes of only one of these topics were high, suggesting significant progress. In order to balance low safety margins of anesthetic agents, rapid growth in monitoring was critical.

Keywords:- Anesthetics, Anesthesia, Regional Anesthesia, Morbidity And Mortality Associated With Anesthesia.

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INTRODUCTION

Inhalational anesthetics have low safety margins, especially when compared with other classes. In spite of efforts to improve these agents' safety margins, little has been accomplished. Inhalation anesthetics have therapeutic indices between 2 and 4.2, while mortality from anesthesia has declined dramatically over the past 40 years, according to Goodman and Gilman. According to one study in this field, anesthesia-related deaths decreased from 357 per million (1990s–2000s) to 34 per million. Improved anesthesia administration techniques could also contribute to a decline in anesthesia-related mortality, if not new, safer drugs. [1] Based on a scientometric analysis of mortality rates for the last 40 years, no new methods of anesthesia have been identified. [2] This study evaluated progress in anesthesia monitoring that could have improved anesthetic safety. Indicators based on scientometric analysis were used. The higher perceived safety of anesthetic interventions, the more frequently they are monitored in relevant literature. [3]

METHODS

Using scientometric indexes, the progress of anesthesia monitoring was assessed. Multiple publications have reported using these indexes to assess various classes of drugs. [4–9] The four indexes are listed below.

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Index of general popularity

Over a five-year (or ten-year) period, the GPI represents the percentage of articles on a specific topic.

Index of specific popularity

In anesthesia monitoring, SPI shows the percentage of articles published on a specific topic compared to all topics published over a five-year period.

Change index

The IC measures the change in articles over a five-year (or ten-year) period. In order to represent a specific threshold, an index value of ≥50 was chosen to represent a specific threshold. A decrease in interest in a particular topic reflects a general change in interest in the topic as a whole.

Expectations index

The IE measures the proportion of articles on a particular topic in the top 20 journals – relative to all articles in all biomedical journals covered by PubMed over the last five years, indicating the level of interest in these journals. A value of ≥10 represents high expectations. Journal Citation Report for 2013 indicated that 20 top journals were ranked by impact factor as well as the journal specialty area. There were ten journals in anesthesia, pharmacology, pain, and surgery, along with ten journals in general biomedical science: Anaesthesiology, Annals of Internal Medicine, Journal of the American College of Surgeons, British Journal of Anaesthesia, British Journal of Surgery, and British Medical Journal. Medical Journal, Clinical Investigation, Law & Medicine, Nature, Nature Medicine, Nature Reviews Drug Discovery, Pain, Proceedings of the National Academy of Science of the United States of America, Science, and Surgery.

Using the PubMed Web site of the National Library of Medicine, which covers >21 articles on biomedicine, the articles were counted. In the search box, several anesthesia monitoring terms were entered. Topics were selected from a variety of sources, and all types of articles were considered. [10–15]

A total of 35 topics have been investigated: acceleromyography AND anesthesia monitoring; arterial pressure AND anesthesia monitoring; the “bispectral index” AND anesthesia monitoring; body temperature AND anesthesia monitoring; Impedance and anesthesia monitoring, capnography and anesthesia monitoring, catheterization, Swan-Ganz, and anesthesia monitoring; central venous pressure AND anesthesia monitoring; cerebral oximetry AND anesthesia monitoring; electroencephalography AND anesthesia monitoring; echocardiography and transesophageal anesthesia monitoring; electrocardiography AND anesthesia monitoring; electromyography AND anesthesia monitoring; entropy AND anesthesia monitoring; "end-tidal concentration" AND anesthesia; anesthesia AND inhalation; fluid therapy AND goal-directed AND anesthesia; monitoring of heart rate and anesthesia; respiration pressure and anesthesia; kinemyography and anesthesia; mechanomyography and anesthesia; Narcottrends and anesthesia monitoring; Anesthesia monitoring and neuromuscular monitoring; Phonomyography AND anesthesia monitoring; AND anesthesia monitoring; “pulse oximetry” AND anesthesia monitoring; SNAP II AND anesthesia monitoring; respiratory rate AND anesthesia monitoring; SEDline AND anesthesia monitoring; spectral edge frequency AND anesthesia monitoring; train-of-four AND anesthesia monitoring; ultrasound, Doppler, AND anesthesia monitoring; ventilation monitoring AND anesthesia monitoring.

Using scientometric indexes, a particular topic was selected if it had at least >50 articles published between 2009 and 2013.

Compared to Mortality [MeSH term] and Morbidity [MeSH term] SPIs for general or regional anesthesia monitoring. A common form of anesthesia morbidity is cardiac arrest and respiratory insufficiency. Anesthesia types perceived as more dangerous should have a higher SPI.

RESULTS

Tables 1 and 2 present the 66 topics on anesthesia monitoring that had at least one publication in 2009–2013. Anesthesia monitoring publication growth over five years is shown in figure 1. From 592 articles between 1974 and 1978 to 76788 articles between 2009 and 2013, the growth was exponential. Anesthesia monitoring publications were compared to publications in general anesthetics in order to put their growth into context.

Figure 2 shows GPI. A positive GPI change was always observed during anesthesia monitoring, whereas a negative change was observed during general anesthetics. GPI decreased by 27% for general anesthesia and increased by 78% in the period 1984-1993. Since the 1940s, many new methods of monitoring have been introduced, contributing to anesthesia monitoring's rapid growth. As a result of subsequent publications on a topic, Figure 1 shows when some monitoring methods were introduced (arrows).

Table 1 lists anesthesia monitoring topics before 1980. During 2009-2013, there were 826 articles about arterial pressure and 786 articles about heart rate. Table 2 lists the topics related to anesthesia monitoring that were introduced after 1980. Only ten of these topics had more than 100 articles between 2009 and 2013. Spectral index is one of the most popular topics. At the very beginning of a topic development, different anesthesia

monitoring publications grow differently. Table 3 shows that there is a 4 to 21 year interval between the 10th and 100th publication on related topics. Bispectral index and pulse oximetry grew most rapidly, while CVP and Swan-Ganz catheter developed least quickly.

As of 2009–2013, scientometric indexes were calculated based on a monitoring topic's number of articles multiplied by > 50. The results are shown in Table 4. The SPI with bispectral index is the most impressive. Transesophageal echocardiography is the second most popular topic. Figures 3 and 4 illustrate SPI's time course over the extended period. Anesthesia monitoring topics are presented. From 1974–1978 to 2009–2013, the SPI didn't change much for most important topics, especially heart rate monitoring. Anesthesia monitoring after 1980 is illustrated in figure 4. Bispectral index and transesophageal echocardiography have dramatically increased. Pulse oximetry's SPI peaked between 1989 and 1993; it then declined.

The IE and IC only show significant progress when it comes to monitoring pulse contours: from 2009 to 2013, the IC was 76 and the IE was 17.9. In two monitoring areas with a long history - neuromuscular monitoring and processed electroencephalography - the IE continued to be high. However, the IE for transesophageal echocardiography was only 6.0 in 2009–2013.

We found an association between perceived safety of general (versus regional) anesthesia and anesthesia monitoring. 5.7 percent of articles on general anesthesia include anesthesia monitoring, indicating a combined SPI. Regional anesthesia and anesthesia monitoring had a combined SPI of 3.7. Mortality rates for general and regional anesthesia were 8.3 and 4.9, respectively. The rates of morbidity, heart arrest, and respiratory insufficiency were lower with regional anesthesia.

Table 1: Articles on general topics of anesthesia monitoring from 2009–2013

N	Topic search terms	Number of articles
1	Assuring that arterial pressure and anesthesia are monitored	826
2	A monitoring system for anesthesia AND a monitoring system for heart rate	786
3	The monitoring of electroencephalography and anesthesia during the procedure	664
4	The monitoring of cardiac output and the monitoring of anesthesia	542
5	Monitoring of the neuromuscular system and anesthesia	436
6	The monitoring of electrocardiography and anesthesia during the procedure	290
7	The monitoring of the respiratory rate and anesthesia during anesthesia	264
8	The monitoring of the central venous pressure and anesthesia during surgery	206
9	Anesthesia and body temperature monitoring are both important components of anesthesia monitoring	166

Table 2: Articles published after 1980 on specific topics of anesthesia monitoring during 2009–2013

N	Topic search terms	Number of articles
1	Anesthesia monitoring AND "Bispectral index"	526
2	Monitoring of anesthesia, echocardiography, and transesophageal echocardiography	282
3	Monitoring of electromyography and anesthesia	188
4	Anesthesia monitoring AND pulse oximetry	164
5	Monitoring of anesthesia AND entropy	158
6	Anesthesia monitoring AND a train-of-four	154
7	Anesthesia monitoring, ultrasonography, and Doppler	152
8	Monitoring of capnography and anesthesia	132
9	(Pulse contours or pulse pressures) AND anesthesia monitoring	130
10	Neuromuscular monitoring AND electrical stimulation	108
11	The use of fluid therapy and goal-directed anesthesia	96
12	Monitoring of anesthesia AND acceleromyography	66
13	Monitoring of anesthesia AND cerebral oximetry	60
14	Anesthesia monitoring, Swan-Ganz catheterization, and catheterization	58
15	END-TIDAL CONCENTRATION AND ANESTHESICS, INHALUTION AND ANAESTHESIA MONITORING	28
16	Monitoring of anesthesia and narcotics	26

17	The "spectral edge frequency" AND the monitoring of anesthesia	<10
18	Monitoring of anesthesia AND mechanomyography	<10
19	Monitoring of cardiography, impedance, and anesthesia	<10
20	Monitoring of anesthesia AND kinemyography	<10
21	Monitoring of anesthesia and phonomyography	<10
22	Monitoring of SEDline AND anesthesia	<10
23	Monitoring of anesthesia with SNAP II	<10
24	“Inspiratory pressure” AND monitoring during anesthesia	<10

Table 3: Anesthesia monitoring SPIs and perceived safety of general vs regional anesthesia

Main topic	General anesthesia				Regional anesthesia			
	General anesthesia only	Main topic and general anesthesia	SPI*		Regional anesthesia only	Main topic and regional anesthesia	SPI*	As percentage of SPI for general anesthesia
Anesthesia monitoring	5499^{+}	1032	5.7		4055^{+}	442	3.7	114
Mortality	5499^{+}	1596	8.3		4055^{+}	638	4.9	106
Morbidity	5499^{+}	3062	14.9		4055^{+}	1564	10.6	138
Heart arrest	5499^{+}	204	0.10		4055^{+}	106	0.7	134
Respiratory insufficiency	5499^{+}	408	2.8		4055^{+}	112	0.8	78

Table 4: Monitoring and training of anesthesiologists versus anesthesia-related mortality

Period	Anesthesia mortalitya		Anesthesia monitoringb			Anesthesiologists’ trainingc	
	Sole mortality	Contributory mortality	Number of new articles	% of total (11,292)		Number of new board certificates	% of total (94106)
	714	1368	256d	2%		13718 e	16%
	104	468	4048	19%		25560	28%
	68	170	18,280	82%		54828	59%

DISCUSSION

Monitoring of anesthesia has increased more than eleven-fold over the past 40 years. When measured as a percentage of all anesthesia articles, the increase in publications in monitoring contrasted with the decline in general anesthesia. In a previous scientometric assessment of anesthetic drugs, there had been no new anesthetics for 30–40 years, indicating that safety margins had improved. Anesthesia mortality has decreased dramatically over the past 40 years. [3, 16-21] At the same time, American Society of Anesthesiologists (ASA) scores indicate an increase in risk status among surgery patients. There has also been a dramatic increase in open heart surgeries with higher safety requirements. Anesthesia monitoring may have contributed to anesthesia's increased safety.

The introduction of anesthesia monitoring methods came long before anesthesia mortality dropped dramatically. Monitoring blood pressure or heart rate did not change much between 2009–2013 and 1974–1978. Anesthesia mortality changed coincided with the introduction of only one monitoring method - neuromuscular blockade monitoring. In retrospect, the introduction neuromuscular blocking agents compensated – at least partly – the low safety margin of anesthetics: By reducing general anesthetic doses, muscle relaxation can be achieved safely. Myorelaxation monitoring is required for neuromuscular blocking agents to be administered. A study from 1954 found a sixfold increase in complications following anesthesia with curare. In the 1970s and 1980s, a dramatic reduction in anesthesia-related mortality coincided with electromyography, electrical nerve stimulation, and train-of-four monitoring. It is clear that neuromuscular blockade monitoring is important, but quantitative monitoring has not yet gained widespread popularity, especially for reversing blockade. Anesthesia mortality and morbidity could be further reduced with neuromuscular monitoring. [22] It is likely that this problem is the reason why the IE indexes for neuromuscular monitoring topics have been relatively stable: electrical nerve stimulation.

Based on the high SPI, transesophageal echocardiography is highly popular. Contrary to neuromuscular monitoring, echocardiography's IE index declined from 23.5 in 1994–1998 to 5.0 in 2009–2013. [23, 24] Could this be because ultrasonography has been

widely used in many medical fields for a long time? IE and IC values with pulse contour (pulse pressure) monitoring were high between 2009 and 2013.

Electroencephalogram monitors are unique among anesthesia monitoring techniques. It was not until the introduction of the bispectral index in 1994 that electroencephalographic monitors became widely used. [25] The use of general anesthetics is directly related to the basic understanding of how they work, for which there is no theory. [26] Various algorithms for processing electroencephalography don't even clearly reflect the components of general anesthesia. [27–30] Bispectral index and entropy monitoring techniques are closely related to general anesthesia's most important (and controversial) concepts. Due to this, they probably have high IE values despite having low IC values. Bispectral index's IE value in 2009–2013 was 20.2, but IC was negative (-19). The IE of entropy in 2009–2013 was 21.5 and the IC only 1.

There is an association between anesthesia type perceived safety and anesthesia monitoring. The lower the perceived safety, the greater the association. According to Table 5, regional anesthesia monitoring is less common than general anesthesia monitoring. There is a lower anesthesia-related mortality with regional anesthesia than with general anesthesia (about a third, according to some studies). [31–33]

A comparison of anesthesia monitoring with other factors, such as anesthesiologists' education, might be useful in light of the above-mentioned dramatic decrease in anesthesia mortality. Anesthesia monitoring articles were not common before the 1970s. During the 1970s and 1980s, they almost quadrupled. Over the same period, the number of anesthesiologists almost doubled. Standardization and rigorous scrutiny of anesthesia training were introduced, residency training lengthened, and fellowships were developed. Other factors to consider include human factors [34, 35] (human abilities required to succeed in complex environments) and external pressure, as health care organizations are constantly changing. [36-40]

Anesthetics have a low safety margin, making them one of the most dangerous drugs in practice, especially inhalational anesthetics. The anesthesiologist has attempted to improve anesthesia safety through many means. This has included coadministering different anesthetics to reduce individual agent doses ("balanced anesthesia"), combining anesthetics with adjuvants, advances in anesthesia monitoring, and better training for anesthesia providers. In 1986, the American Society of Anesthesiologists adopted this approach as a national standard. Among the first specialties to adopt national safety standards was anesthesiology. The Anesthesia Patient Safety Foundation was formed in 1986, followed by the National Patient Safety Foundation. The advancement of monitoring in anesthesia has become and remains an essential component of patient safety. "Ideal Anesthesia" evolved into "Optimal Monitoring System".

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