

Anesthesia Personnel's Experiences With Digital Anesthesia Information Management Systems: A Literature Review

Ann-Chatrin L. Leonardsen, PhD, RN, NA

Anne Marie Gran Bruun, MNSc, RN, NA

Berit T. Valeberg, PhD, RN, NA

Traditionally, anesthetic records were in paper format. An increasing volume of complex data, legislation, and quality improvement initiatives related to clinical documentation have promoted the transition to digital records. Anesthesia information management systems (AIMS) have been designed to directly extract patient information from the anesthesia workstation and transmit the data into documentation systems and databases. The purpose of this review was to explore existing literature on anesthesia personnel's experiences with digital AIMS. Literature searches were conducted in PubMed, Cumulative Index to Nursing & Allied Health Literature, Embase, and The Cochrane Database of Systematic Reviews. A total of 473 records were identified, of which 40 records were read in full-text. Seven records under-

went quality appraisal, representing research from 1991 to 2018, all with a quantitative design. In total, 379 anesthesia personnel were included. Five studies were conducted in the United States; 1, in Korea; and 1, in Germany. Results were collated into the themes user satisfaction, technical aspects, physical placement of the system, paper-based vs electronic data entry, quality of care, and suggestions for improvement. Findings indicate both positive and negative effects of AIMS. Anesthesia personnel's experiences should be included in the planning, development, and implementation of digital data entry systems.

Keywords: Anesthesia personnel, anesthesiology, information management systems, experiences.

Anesthesia includes controlling a patient's level of awareness, response to pain, memory, and muscle tone during and after invasive procedures.¹ According to the Norwegian Standard for the Safe Practice of Anaesthesia,² monitoring during anesthesia must as a minimum include clinical assessment of respiratory and circulatory function. During general anesthesia, monitoring devices must include electrocardiography (ECG), capnography, pulse oximetry, blood pressure monitoring, and multigas monitoring, all with appropriate alarms. Moreover, vital signs must be documented regularly, depending on the patient's condition and the complexity of the intervention. In addition, expected and undesired events, and pharmacologic interventions that occur during the perioperative period must be included in the documentation.² This is in line with recommendations from the American Society of Anesthesiologists.³

The capture and documentation of observations and interventions in anesthesia practice has been through extensive changes through decades. The increasing

volume of complex data, legislation, and quality improvement initiatives related to clinical documentation have promoted the transition to digital records from the traditional paper-based records.⁴ *Anesthesia information management systems* (AIMS) is a collective term for

systems that collect patient information directly from the anesthesia workstation, and transmit the data directly into documentation systems and databases.⁵ Benefits have been reported to include enhanced quality of care and patient safety, as well as increasing the ability to conduct translational research.^{6,7}

Clinical monitoring includes visual inspection, auscultation, and palpation, which is not automatically transferred information. Moreover, changes in clinical signs may be subtle, and often occur ahead of abnormalities in parameters as measured by monitoring devices. Hence, monitoring devices cannot replace clinical observations and documentation of these, or vice versa, but should be seen as a supplementary to each other.^{8,9} Clinical monitoring is not limited to observation of vital parameters but also involves cognitive and behavioral skills, to assess the context, the patient's condition, the team, or available equipment and medications.¹⁰

Earlier research mainly focused on the practical use of AIMS rather than how they are implemented and used alongside clinical monitoring.¹¹⁻¹³ The purpose of this review was to identify studies focusing on anesthesia personnel's experiences with using digital AIMS.

Methods

We performed our literature searches, in collaboration

P	I	C	O
Nurse anesthesia	Digital	Manual versus digital information	Patient safety
Nurse anaesthesia	Technology	management systems	Documentation
Anesthetist	Electronic medical record		Task diversion
Anaesthetist	Documentation		Quality assurance
Anesthesia	Anesthesia information		Safe clinical practice
Anaesthesia	management systems		
Anesthesiology			
Anaesthesiology			
Nurse anesthetist			
Nurse anaesthetist			
Experiences			

Table 1. Search Terms Used for Literature Review of Anesthesia Personnel’s Experiences With Digital Anesthesia Information Management Systems^a

Abbreviation: PICO, Population, Intervention, Comparison, Outcome.

^aBoolean operators AND* and OR* were used.

with a specialist librarian, in the databases PubMed, Cumulative Index to Nursing & Allied Health Literature (CINAHL), Embase, and The Cochrane Database of Systematic Reviews from February 1, 2020, to March 10, 2020. We did not limit the search to a specific timeframe or to a specific study design. References were handled using reference management software (EndNote X8, Clarivate Analytics).¹⁴ The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines¹⁵ were followed.

The search strategies were developed based on the Population-Intervention-Comparison-Outcome (PICO) framework¹⁶ (Table 1). Inclusion criteria were anesthesia personnel (physicians undergoing anesthesia training, anesthesiologists, and nurse anesthetists), digital monitoring/AIMS, Scandinavian or English language, and peer-reviewed articles. Exclusion criteria were simulation studies/nonclinical settings, conference abstracts, unpublished material, dissertations, and systematic reviews or meta-analyses.

The primary search revealed 74 studies in PubMed, 372 studies in CINAHL, 27 in Embase, and none in The Cochrane Database of Systematic Reviews. In total, 473 abstracts were read and evaluated for relevancy by inclusion and exclusion criteria, by the first author (A.-C.L.L.). The abstract review identified 40 articles that from the inception, fulfilled the inclusion criteria. These articles underwent full-text assessment by 2 authors simultaneously, blinded to each other. Assessments were then compared and discussed until consensus was achieved. The final sample for undergoing quality appraisal contained 7 articles (Figure).

The Critical Appraisal Checklist for Analytical Cross Sectional Studies was used¹⁷ to assess the methodologic quality of the studies and to determine the extent to which the studies addressed the possibility of bias in their design, conduct, and analysis. The scoring system

ranges from 0 (very low quality) to 8 (very good quality). Two authors independently, and blinded to each other, performed the quality assessment. Results were then compared and discussed until agreement was reached. All steps in the selection process, the appraisal, and data extraction were performed by 3 independent researchers, fulfilling the requirements recommended by Higgins et al.¹⁸ Any differences or uncertainties were discussed by the authors until agreement was reached.

Findings from the results section of each article were inductively approached, and the authors tried to identify similarities that could be collated into themes or aspects that could be interpreted to contain the same meaning. Themes were discussed in an iterative process among the authors until consensus was reached.

Results

The 7 included studies represent research from the period 1991 to 2018.^{12,19-24} All the studies had a quantitative design for exploring anesthesia personnel’s experiences or satisfaction with digital AIMS, 2 of them in combination with observational studies exploring the actual utilization of digital AIMS. In total 86 anesthesiologists, 41 anesthesia residents, 186 nurse anesthetists, and 1 unidentified anesthetic assistant were included, in addition to a sample of 66 anesthesiologists/nurse anesthetists (study not presenting these separately). Only 2 studies reported the participants’ working experience (range, 1-17 years). Five of the studies were conducted in the United States, 1 study was done in Korea, and 1 was performed in Germany. Table 2 presents descriptive characteristics of the included studies.

As Table 2 shows, the article quality appraisal score varied from 1 (of 8 possible points; n=1) to 6 (n=3) points. Three articles scored 4 points of 8 possible. Results from the included studies are presented under the following themes: user satisfaction, technical aspects, physical

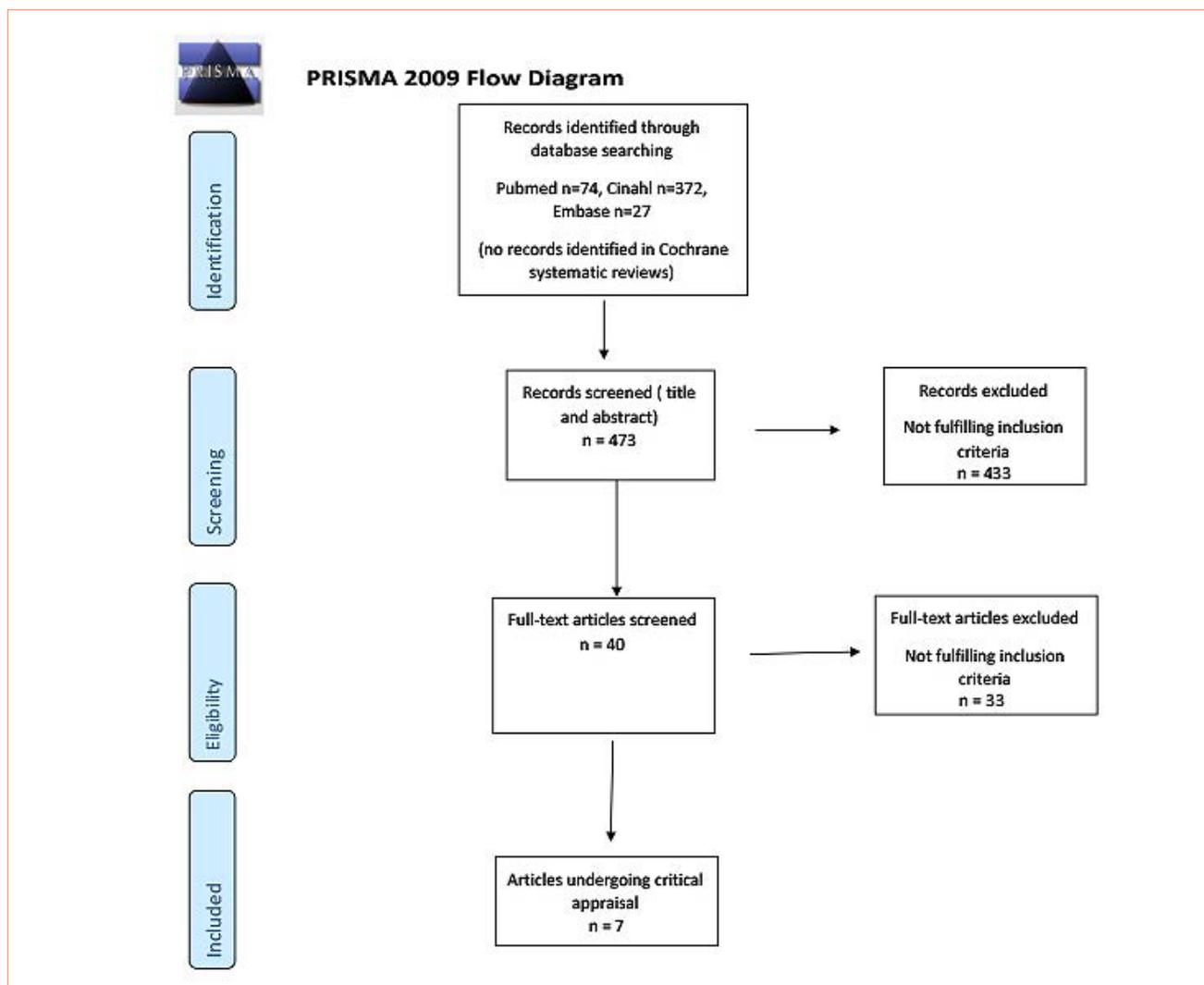


Figure. PRISMA Flow Diagram

placement of the system, paper-based vs electronic data entry, quality of care, and suggestions for improvement.

- **User Satisfaction.** Results show that most anesthesia personnel were satisfied with the digital AIMS.¹⁹⁻²³ Personnel reported that the system made parts of their job easier,^{19,21,23} it was user-friendly and time-efficient (allowing more time to care for patients²³), and it was well integrated into the workflow.^{20,21} Initial training was assumed as important for acceptance of the system.^{21,22} Authors of one study found that most of the anesthesiologists indicated that the system was useful for collecting and evaluating research data.²³

In contrast, the most dissatisfaction was found with the method of manual data entry, time to produce the record, and difficulty learning the system.¹⁹ One study's results found that one third of respondents considered themselves poorly trained.²¹ Moreover, only 35.3% thought that data protection was guaranteed by the system.²¹

In one study, anesthesia providers with previous AIMS experience scored lower on the questionnaire dimension

addressing user satisfaction regarding patient safety, patient outcomes, and increase in costs of healthcare related to computers than anesthesia providers without such experience.²⁴ Authors of another study identified significant differences between nurses and anesthesiologists regarding time savings, in which nurses agreed on its usefulness more often than the attending anesthesiologists ($P=.002$).²³ When asked in relation to the type of surgery, lower acceptance of AIMS was demonstrated for short cases (lasting less than 30 minutes) and simple surgeries compared with lengthy surgeries (lasting more than 30 minutes) and complicated surgeries. Lower preferences were also shown in operations for emergencies, major trauma, or during CPR.²³

- **Technical Aspects.** In one study, software stability and speed were important issues. Visual alarms were deemed useful by two-thirds of the participants, but only 50% wanted acoustic alarms.²¹ Data entry by keyboard or by mouse was preferred over a bar-code scanner. Entry of data relevant to anesthesia, such as catheters, drugs,

or vital parameters, was generally considered easy, but 77.3% found coding of diagnosis and type of surgical procedure difficult. Moreover, data import from monitors, ventilator, syringe pumps, laboratory data, and other data management systems was deemed important.²¹ Another study showed that 29% of respondents preferred a touch screen, 26% chose voice recognition, 16% wanted barcode readers, 16% selected pointing devices such as a mouse or trackball, and 13% preferred a standard keyboard as the method for data entry.²²

- **Physical Placement of the System.** According to one study, only 44% of participants thought the AIMS was conveniently located related to the patient, and 74% believed it “got in their way”.²⁰ In another study, only 59.2% of trainees, 71.5% of attending anesthesiologists, and 76.6% of nurse anesthetists thought the AIMS was conveniently placed in the workplace.²³ A third study found that one-half of the users stated that they had poor visual contact with the patient while working on the personal computer, and many users reported that the position of the workstation caused physical discomfort.²¹

- **Paper-Based vs Electronic Data Entry.** Five of the studies compared anesthesia personnel’s experiences with paper-based and computer-assisted data entry.^{12,20,21,23,24} The electronic data-entry templates were perceived as having more capabilities than paper-based documentation. Paper-based documentation scored lower because the anesthesia providers rated the handwritten system as more difficult and frustrating.¹² In particular, anesthesiologists preferred the AIMS and commented that it was inconvenient to enter vital signs by hand.²⁰ In another study, most did not want to switch back to manual documentation on paper.²¹ A third study found that AIMS was evaluated better regarding malpractice litigations.²³ Fewer attending anesthesiologists than nurses ($P=.003$) considered AIMS superior to handwritten records in lengthy or complicated cases.²³

- **Quality of Care.** The results differed in whether the AIMS resulted in increased quality of care. According to one study, there was significant consensus that the system did not increase the quality of care to the patient, and many expressed concern that the time dedicated to producing the electronic record detracted from patient care.¹⁹ In contrast, another study found that 70.5% of the participants believed that it improved their quality of work and was beneficial for the patient. Most participants thought that the digital AIMS facilitated a more precise documentation (85.3%) and that there were fewer errors (47.1%).²¹ In another study, 85% of the participants thought the procedures and events were accurately documented, and 58% thought that the system resulted in accurate documentation of vital signs.²⁰

- **Suggestions for Improvement.** Only one study provided suggestions for improvement of the system. Suggested improvements were that error correction must

Author, y/country	Purpose	Sample	QAS
Abenstein et al, ¹⁹ 1992/USA	To discuss experiences with AIMS	66 anesthesiologists, residents, nurse anesthetists	1
Beilin et al, ²⁰ 2009/ USA	To describe implementation of and attitudes about AIMS	34 anesthesia practitioners	4
Wilbanks et al, ²⁴ 2013/ USA	To determine accuracy of a recently installed AIMS	80 nurse anesthetists	6
Wilbanks, ¹² 2018/USA	To assess impact and provider and user satisfaction	30 nurse anesthetists	6
Quinzio et al, ²¹ 2003/ Germany	To assess user acceptance of AIMS	44 anesthesiologists, 24 nurse anesthetists	6
DeVos et al, ²² 1991/ USA	To solicit experiences, opinions, and recommendations of users of AIMS	66 anesthesiologists, nurse anesthetists, and student registered nurse anesthetists	4
Jin et al, ²³ 2012/Korea	To evaluate users’ attitudes concerning AIMS and to compare them with manual documentation in operating room	28 anesthesiologists, 27 trainees, 47 nurse anesthetists	4

Table 2. Descriptions of the Included Articles

Abbreviations: QAS, Quality Appraisal Score, Joanna Briggs Critical Appraisal Checklist for Analytical Cross Sectional Studies, 8 possible points, where 0 indicates very low quality and 8 indicates very good quality.

be easily accomplished, both novice and expert users should be able to use the system, results of laboratory and diagnostic studies should be automatically recorded on the record, and the anesthesia record should be completely displayed in the operating room.¹⁹

Discussion

The literature search identified only 7 studies^{12,19-24} fulfilling the inclusion criteria, even with no time limits on the search. Many studies have explored the accuracy and completeness of AIMS (eg, references 24-26). Nevertheless, research on anesthesia personnel’s experiences with AIMS is lacking. Automated capture of physiological parameters was first described in 1934, and early attempts continued into the 1970s. However, a complete transition from paper records has not yet been accomplished.^{27,28} In Norway, several hospitals still use paper-based records. This may explain the knowledge gap in how the use of AIMS is experienced by anesthesia personnel.

The included articles were published from 1991 to 2018. The technological development in this period has been extensive. Nevertheless, experiences with AIMS are

similar in the earlier and recent studies. Technical aspects were only described in the studies from 1991²² and 2003,²¹ indicating a beneficiary development. Nevertheless, the discussion of whether to use paper-based or digitalized data entries has been ongoing until recently.

All the included studies had a quantitative design. Peterson et al⁵ emphasized the critical and urgent need for nurse anesthetists to influence AIMS functionality, adoption, and use. There is limited research with a qualitative approach to the research question.

This review provides both positive and negative experiences with AIMS. Earlier reviews have focused on functionality, installation designs, and benefits and challenges associated with implementing and using AIMS.^{4,6,7} Findings in these reviews align with findings in our review, indicating improved documentation; precise, accurate capture of intraoperative data and patients' hemodynamic responses to anesthesia; and facilitation of risk management and quality assurance activities.^{4,6,7} Disadvantages have been linked to a reluctance to abandon paper records, unacceptable costs of installation and maintenance, distraction of the anesthesia providers, legal concerns, and resistance to changes in clinical workflow patterns.^{21,29,30} This stands in contrast to the findings in our review.

Findings of recent literature reviews suggest that AIMS-based clinical decision support systems can significantly improve some aspects of clinical performance and patient care, particularly if the decision support is smoothly integrated into clinical workflow.^{31,32} Our findings indicate that the AIMS is integrated into daily routines. Nevertheless, findings regarding the effect on quality is not consistent. For example, one study's results showed no difference in the accuracy of practitioners' recall of patient variables when using computerized vs manual-entry record-keeping systems.^{33,34}

Our findings did not indicate a concern in anesthesia personnel about the interface between clinical observation and automatically transferred information. Studies emphasize that monitoring devices cannot replace clinical observation, or vice versa, but should be seen as supplementary to each other.^{8,9} The role of the nurse anesthetist has been described as finessing the human-technology interface, titrating technology to ensure the safe passage of the patient through the operative experience.³⁵ Anesthesia personnel must also maintain situational awareness, being alert and prepared because they are interacting with patients within a short time-frame.^{35,36} Vigilance refers to this ability to sustain attention over long periods.³⁷ Advantages of digital AIMS have been shown to include convenience, accuracy, and improved vigilance, from anesthesia personnel's perspective.³⁸ This sample consisted of only 5 participants, which has its limitations. This small sample indicates a need for further research to explore the interaction

between AIMS and clinical vigilance.

• **Strengths and Limitations.** The literature search was conducted together with a librarian, which strengthened the study. Full-text screening and quality appraisals were conducted individually and blinded, and then compared and discussed until consensus was reached among the 3 authors. This process increased the validity and reliability of the study. We did not limit our search to time or design. This review includes articles with quality appraisal scores ranging from 1 (very low quality) to 6 (good quality). Hence, findings must be interpreted with caution. Still, our findings are supported by those of other systematic reviews.

• **Implications for Future Research.** This review has identified a knowledge gap in the literature on anesthesia personnel's perspectives on AIMS. Hence, we are currently planning to continue the work of this review with a qualitative interview study with anesthesiologists and nurse anesthetists from 3 different hospitals in Norway.

Conclusion

This literature review gives insight into anesthesia personnel's experiences with digital AIMS. Findings indicate both positive and negative effects of such systems. Digital solutions are extensively implemented worldwide. Anesthesia personnel's experiences should be included when healthcare organizations plan, develop, and implement digital data entry systems, because of the impact on workflows, vigilance, and clinical observation.

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AUTHORS

Ann-Chatrin L. Leonardsen, PhD, RN, NA, nurse anesthetist, is an associate professor at Østfold University College and a researcher at Østfold Hospital Trust, Viken, Norway. Email: ann.c.leonardsen@hiof.no.

Anne Marie Gran Bruun, MNSc, RN, NA, nurse anesthetist, is program coordinator for the masters' program in anesthesia and critical care nursing at the University of South-Eastern Norway, Notodden, Norway.

Berit T. Valeberg, PhD, RN, NA, nurse anesthetist, is a professor at Oslo Metropolitan University in Oslo, Norway, and at the University of South-Eastern Norway.

DISCLOSURES

Name: Ann-Chatrin L. Leonardsen, PhD, RN, NA

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Name: Anne Marie Gran Bruun, MNSc, RN, NA

Contribution: This author made significant contributions to the conception, synthesis, writing, and final editing and approval of the manuscript to justify inclusion as an author.

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Name: Berit T. Valeberg, PhD, RN, NA

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