Title: Developing and psychometric testing of the Anaesthesia Nursing Competence Scale

Short running title: Anaesthesia Nursing Competence Scale

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ABSTRACT

Rationale, aims, and objectives: The competence of nurses in anaesthesia care is important for the quality of anaesthesia nursing care and patient safety. However, there is a lack of psychometrically tested instruments to measure the competence. Therefore, this study aimed to develop and test the psychometric properties of an Anaesthesia Nursing Competence Scale assessing nurses' competence in anaesthesia care.

Method: The scale development and psychometric testing had three phases: 1) based on literature reviews and the description of experts, competence areas were identified and items were created, 2) the content validity of the scale was tested by a content expert group and the scale was pilot-tested, and 3) psychometric testing of scale were tested by anaesthesia nurses (n=222)' and nursing students (n=205)' self-assessments. The psychometric testing assessed the reliability when using Cronbach's alpha and the construct validity using factor analyses (confirmatory and exploratory) and known-group technique. Nursing students were included for the purpose of construct validity testing.

Results: The Anaesthesia Nursing Competence Scale (AnestComp) has 39 items and consists of seven competence areas: 1) ethics of anaesthesia care, 2) patient's risk care, 3) patient engagement with technology, 4) collaboration within patient care, 5) anaesthesia patient care with medication, 6) peri-anaesthesia nursing intervention, and 7) knowledge of anaesthesia patient care. Cronbach's alpha values were high in all categories (0.83-0.95) and factor analyses and known-group technique supported a seven-factor model.

Conclusion: The initial results supported the reliability and construct validity of the Anaesthesia Nursing Competence Scale. The scale is considered a promising instrument for measuring anaesthesia nursing competence among anaesthesia nurses. Further research with larger and more diverse samples is suggested to refine the current psychometric evaluation.

Keywords:

Anaesthesia, Competence, Nursing assessment, instruments, psychometrics, educational measurement

INTRODUCTION

For surgical and diagnostic procedures, approximately 8 % of the world's population require anaesthesia care every year.[1] Anaesthesia care is a specialty focusing on patients of all age groups undergoing and recovering from anaesthesia (general anaesthesia, local anaesthesia and sedation) in various clinical settings.[2,3] Advances in medicine and technology have enabled anaesthesia care to be provided in more complex cases than before and the specialty of anaesthesia care is also applied to critical care, pain management, and emergency care beyond the borders of perioperative care.[1,4,5] Nursing in anaesthesia care is demanding because the time available for building a nurse-patient relationship is very short, sedated/anaesthetised patient care is highly technically dependent, and multi-professional teamwork is required.[6-8] In such an environment, it is important to ensure that nurses are competent not only in the knowledge and skills of anaesthesia care, but also in the caring dimension of anaesthesia patients.[5,6,9]

Competence is a fundamental attribute in nursing. However, it is difficult to create a common definition, because competence is understood by contextual factors such as organisational culture, care environment, and educational environment.[6,10,11] Competence in anaesthesia nursing care can be described as multiple dimensional based on practical skills embracing ethics, medical technology, and laws for anaesthesia patient care and theoretical knowledge in nursing and medicine.[5,9,12] Because anaesthesia nursing care is an unique nursing specialty when compared to other proficiencies, anaesthesia nurses' competence should be measured by instruments developed specially for anaesthesia nursing care.

To date, the assessment instruments used to measure nurse competence in anaesthesia nursing care have been generic nursing instruments[13-18] or have measured the anaesthesia nurse's competence by dividing it into technical skills[19-24] and non-technical skills[25,26]. Existing generic nursing competence instruments have been used to assess nurses' competence across fields of nursing. The generic nursing competence instruments are considered to be broader scoped assessment tools for measuring the specific-context of anaesthesia nursing competence. For instance, the Perceived Perioperative Competence Scale-Revised (PPCS-R) is a useful instrument to assess and compare anaesthesia nurses' perioperative nursing competence with that of scrub

nurses' and circulating nurses'.[13-15] However, the PPCS-R do not fully address specialised competence areas required for sedated/anaesthetised patient care where patients are not able to make their own decision and are highly dependent on technology and medication during the anaesthesia care process.[5] Thus, using a generic instrument engenders difficulties grasping such special areas of anaesthesia nursing care. Technical-skill assessment such as the Crisis Management Behaviour Tool[20] and the Technical Action Check-List [20-22] were generally used in simulated environment. These instruments are possible tools to assess the skills of anaesthesia nurses and their behaviour as an outcome of their competence when acute adverse events happen. However, they have been criticised as a nurse's behaviour in simulated settings might not be same as in a real situation.[27] They also may not have the ability to capture anaesthesia nurse competence integrated into various other aspects such as knowledge, skills, and teamwork which represent the non-technical skills.[5,27] Non-technical skill assessment is still in the early stages of instrument development, and for instance, the Nurse Anaesthetist Non-Technical Skills (N-ANTS) adapted from Anaesthetist Non-Technical Skills (ANTS) needs further validation testing.[26] In nursing practice and education, the technical skills and non-technical skills could not be considered separately as an integrated conceptualisation of competence is favoured.[10,28] Anaesthesia nursing care required the development of an anaesthesia nursing-specific competence assessment scale covering both technical and non-technical aspects. During the development of such an instrument, it was also necessary to ensure that it was psychometrically sound. However, there was a lack of psychometrically tested instruments to measure this competence.

Therefore, the aim of the study was to develop and test the psychometric properties of the Anaesthesia Nursing Competence Scale (hereafter AnestComp). In this study, the AnestComp was designed to measure the level competence of nurses in anaesthesia care based on their self-assessments. The self-assessment method enables nurses to evaluate their competence by seeking a reference such as contextual standards in practice.[13,14] Globally, anaesthesia nursing care has been generally provided by two types of nurses based on their educational level: anaesthesia nurses (Registered Nurses, RN) who have undergone additional training at hospitals and nurse anaesthetists (Certified Registered Nurse Anaesthetists, CRNA) who have post-registration education in anaesthesia care.[2,6,9] At present, anaesthesia nursing care is expanding beyond the operating rooms to various clinical settings such as emergency rooms and diagnostic procedures.[1,4,5] Therefore, the AnestComp

focuses on measuring the competence of nurse who are responsible for anaesthesia patient care in various contexts. Consequently, AnestComp can be used not only by anaesthesia nurses and nurse anaesthetists, but also nurses who require competence for anaesthetised patient care in other clinical settings.

A competence scale in anaesthesia nursing care can be used to support many aspects. It can be used for testing the level of competence of new employees in practice (with a pre- and post-testing of orientation programme), for professional development discussions, and for evaluating salary levels. Nurse educators and professional nurse associations can use the scale when developing competence-based educational programmes for nurses.

METHODS

This study had three phases: 1) structuring the content of the scale, 2) content validity testing and pilot testing, and 3) psychometric testing (Table 1).

Table 1. The Anaesthesia Nursing Competence Scale (AnestComp) development and psychometric tests

Phases	Purpose	Method/Data
Phase I	**Structuring the content of the scale**	**Face Validity**
(2014-2016)	To discover competence areas	· Literature reviews / Content analysis
	To confirm the competence areas	· Expert panel, n=7 / Content analysis
	To construct items based on identified competence areas	· Item construction: 40 items
Phase II	**Content validity testing and pilot testing**	**Content Validity/Face Validity**
(2017)	To assess the content validity and clarity of the items	· Expert panel, n=8 / CVI 4 point · Reduction of one item
	To exam the feasibility (format, instruction, and clarity of items)	**Pilot test (39 items)/Face Validity** n=32 anaesthesia nurses n=17 nursing students
Phase III	**Psychometric testing**	**Sample**
(2017-2019)	To investigate the reliability and construct validity of the scale	n=222 anaesthesia nurses n=205 nursing students **Reliability** · Cronbach's alpha estimates **Construct Validity** · CFA and EFA · Known-group technique

Phase I Structuring the content of the scale

The first phase in developing the AnestComp was to determine the competence areas needed to be measured. The content of the scale was based on literature reviews compiled by searching the content areas of competence in anaesthesia nursing education[2] and assessment of instruments used for anaesthesia nursing competence[5]. Twenty-nine relevant articles from the literature searches[2,5] and 10 publications from internet databases (European Commission and International Federation of Nurse Anaesthetists)[2] were included. Thematic analysis[29] was used and all articles and documents were read carefully to code and extract themes. Seven themes were categorised as competence areas: professional/ethical values, crisis/risk management, medical technological skills, collaboration/teamwork, medication, anaesthesia nursing skills/intervention, and knowledge.

In addition to the literature reviews, descriptions by seven experts of the requirements of anaesthesia nursing competence were sought. The experts were anaesthesia nurses and nurse anaesthetists having an average 24 years of working experience (range 5-38) and authors of a clinical nursing book. The experts described competence requirements of anaesthesia nursing care in the form of an essay ("In your opinion, what is nursing competence in anaesthesia nursing care?). The experts' descriptions were analysed deductively to confirm the competence areas found through the literature reviews and then inductively to find any competence areas that had been overlooked or not included. As competence areas, AnestComp was ultimately composed of the following seven categories: ethics of anaesthesia care, patient's risk care, patient engagement with technology, collaboration within patient care, anaesthesia patient care with medication, peri-anaesthesia nursing intervention, and knowledge of anaesthesia patient care. Based on competence areas, preliminary items (40 items) were generated.

Phase II Content validity testing and pilot testing

The preliminary AnestComp was submitted for testing of content validity to another group of experts (n=8) consisting of anaesthesia nurses, nurse anaesthetists, nurse managers in anaesthesia department at university hospitals, and nurse teachers at polytechnics (also called Universities of Applied Sciences); the expert's average age and work experience in health care was 48 years old (range 39-54) and 18 years (range 7-31) respectively. The scale was originally designed to assess nurses' competence in anaesthesia nursing care. For the purpose of the psychometric testing of the scale, the study was designed to collect not only nurses' data but also nursing students'. Therefore, nurse teachers were included as members of the content expert group in order to determine the applicability of the scale for nursing students.

The expert group confirmed the content validity for items of the scale: the relevance of each item to anaesthesia nursing care, the clarity of the item, and the applicability to nursing students. A 4-point scale (e.g. 1=not relevant, 2=somewhat relevant, 3=quite relevant, and 4=highly relevant) was used to compute the Content Validity Index for the Items (I-CVI) in the scale; each I-CVI was calculated based on the number of experts scoring either 3 or 4. The I-CVI is recommended to be over 0.78 in cases where six or more judges are involved.[30,31] Each item I-CVI in the scale was over 0.78 (Mean I-CVI 0.99, range 0.88-1) as regards relevancy and one item concerning clarity was below 0.78 (Mean I-CVI 0.98, range 0.75-1). In terms of the applicability of the scale for nursing students, I-CVI for two items were below 0.78 (Mean I-CVI 0.96, range 0.75-1); it was the consensus of the experts that 95% of the items in the scale could appropriately be asked of nursing students.

In order to test inter-raters' agreement, the Content Validity Index for Scales (S-CVI) was calculated. The S-CVI was defined as ''the proportion of items on an instrument that achieved a rating of 3 or 4 by all the content experts".[30] An S-CVI of 0.80 or higher is recommended.[30] In this study, 39 out of 40 items were judged to be quite relevant or highly relevant (a rating of 3 or 4) by eight experts; therefore, the S-CVI was computed to be 0.98. In terms of clarity, the S-CVI is 0.88 (35 out of 40 items). However, the S-CVI for the applicability to nursing students (S-CVI 0.70, 28 out of 40) did not meet the recommended level. These content expert groups' agreements (S-CVI) as regards the relevance, clarity and applicability determined the face validity, which looks the degree to which an instrument covers the concept it is supposed to measure.[30,32,33]

Based on the I-CVI and S-CVI scores and the experts' comments, the wording of several items was revised, and the 40-item scale was reduced to 39 items. To exam the feasibility of the 39-item scale, AnestComp was pilot-tested with a convenience sample of anaesthesia nurses (n=32) from one university hospital and nursing students (n=17) from a polytechnic located in the same area as the university hospital. The pilot-test was carried out electronically and respondents were asked to comment on the clarity of the items, the format, and the instructions in the instrument. The range of possible responses for each item showed adequate variance in both groups. Based on the pilot test, no changes were made to the instrument. Finally, a 39-item AnestComp in seven categories was used as a model for construct validity testing (Figure 1).

Phase III Psychometric testing

Instrument

The Anaesthesia Nursing Competence Scale (AnestComp) was used to self-assess the level of nurse competence in anaesthesia nursing care. The scale has 39 items and consists of seven categories: ethics of anaesthesia care (items 1-5), patient's risk care (items 6-10), patient engagement with technology (items 11-15), collaboration within patient care (items 16-20), anaesthesia patient care with medication (items 21-25), peri-anaesthesia nursing intervention (items 26-34), and knowledge of anaesthesia patient care (items 35-39). Each item is rated by using a Visual Analogue Scale (VAS) from 0 to 100 (0=not at all, 100=excellent). The higher the score, the better the nurse's competence was considered in anaesthesia nursing care.

Sample

The sample for the psychometric testing of AnestComp was composed of anaesthesia nurses in two University Hospitals in Finland; these hospitals cover the health care of one third of the Finnish population (approximately 120,000 operations annually). The anaesthesia nurses were all registered nurses whose education levels were equivalent to a Bachelor's degree and had been provided with job orientation and training for anaesthesia care at the university hospitals. The anaesthesia nurses prepare, maintain, and monitor patients undergoing and recovering from anaesthesia, but they do not induce general anaesthesia independently. However, those anaesthesia nurses who graduated from nursing school before 1994 had undertaken additional education and

specialty training in anaesthesia care as post-registration education. They had used to independently induce, maintain, and terminate general anaesthesia. Since 1994, specialisation education has not been obligatory in order to become a nurse in anaesthesia care. Currently, there is no nationally regulated post-registration education for anaesthesia nursing care in Finland. Instead, anaesthesia nurses can voluntarily take specialised education in anaesthesia care as supplementary continuing education (1-1.5 years); however, this education does not grant the official title as a nurse anaesthetist.

In this study, the nursing student's data were also included and used as a comparison group with the anaesthesia nurses for the purpose of construct validity testing. The sample of nursing students consisted of nursing students in their 2nd year or above from three polytechnics located in the same areas as the two University Hospitals.

Design and procedure

The data were collected by an electronic/paper and pencil survey with the support of contact nurse managers and nurse teachers. A researcher (YJ) emailed the study information letter with the internet link for the survey (Webropol 2.0) to the contact persons. The contact persons forwarded the email to the anaesthesia nurses and the nursing students during May and June 2017. Despite two reminders, the number of respondents from the anaesthesia nurses was 132 (response rate 30.6%) and nursing students was 78 (response rate 9%). Due to the low response rate of both groups, paper and pencil questionnaires were distributed to the same target sample in October 2017. Those who had already responded through the electronic survey were not allowed to respond again during the paper and pencil survey. The final response rate was 52 % from the anaesthesia nurses (n=222) and 21% from nursing students (n=205).

Ethical considerations

The ethics committee of the university granted ethical approval for the study (Statement 25/2017, 3rd of May 2017) and research permissions were obtained from two University Hospitals (235/2017, 26th of April 2017 and 005/17, 27th of April 2017) and three polytechnics in Finland (3rd of April 2017, 5th of April 2017, 20th of April 2017). Answering the electronic/paper and pencil questionnaires was considered to constitute consent to

participate in the study. Participants were informed about the voluntary nature, anonymity, confidentiality, and purpose of the study in a covering page. In addition, the covering page provided the contact information of the researchers in case the respondents wished to contact researchers later for any reason. The privacy of the respondents was protected by not linking the participant's email address to the data analysis. The information collected from this research was kept confidential according to ethical guidelines.[34]

Data analysis

The statistical data analyses for the psychometric testing were performed with IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY) and Lavaan package in R version 3.5.0. Descriptive statistics (frequencies, percentage, mean, median (MDN), standard deviation (SD), interquartile range (IQR), and range) and inferential statistics were used in the psychometric evaluation.

For the reliability analysis, Cronbach's alpha estimates, a mean of inter-item correlation, and a corrected item-subscale correlation were analysed (recommended $0.3 < r < 0.7$).[35] For construct validity, confirmatory factor analysis (CFA) was used to test the theoretical model fit comprising of seven factors (Figure 1). Because AnestComp was structured based on extensive theoretical analysis, a theoretical structure was tested by a pooled-CFA; this allowed correlations among factors. An acceptable model fit was evaluated including the following estimates: the ratio of chi-squares to the degree of freedom ($\chi 2/DF \leq 3$), the Comparative Fit Index ($CFI \geq 0.90$) and the Standardised Root Mean Residual ($SRMR \leq 0.08$).[36, 37] Standardised loading estimates in CFA should be above 0.5 and ideally recommended above 0.7.[38] Additionally, exploratory factor analysis (EFA) with a fixed-seven number of factors using maximum likelihood estimation and oblique rotation method was tested, and the results of the EFA were compared with the theoretical model of the AnestComp. The Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of Sphericity were used to test the sampling adequacy in EFA.[39] The Known-groups technique was used to estimate the ability of the scale to discriminate between anaesthesia nurses and nursing students based on the groups' mean scores of competences on the Mann-Whitney U test. It was hypothesised that anaesthesia nurses will self-assess a higher level of competence than nursing students.[22, 40]

RESULTS

The anaesthesia nurses were on average 42 years old (range 23-62) and had 18 years of work experience in health care (range 0.6-39.0). It was noted that 42% (n=96) of the sample had speciality education and training in anaesthesia care or perioperative care as post-registration education. The nursing students' average age was 28 years old (range 20-57). The nursing students had completed an average of 159 ECTS (European Credit Transfer and Accumulation System, range 60-215) out of the 210 ECTS required for graduation.

Reliability of the scale

The AnestComp showed good internal consistency based on the Cronbach's alpha values and the item analyses for anaesthesia nurses (Table 2). Cronbach's alpha values in subscales ranged from 0.83-0.95. The mean of the inter-item correlation ranged from 0.52-0.74 and the corrected item-subscale correlation ranged from 0.56-0.89 (recommend $0.3 < r < 0.7$).[35]

Table 2. Reliability of the AnestComp

Subscales & Abbreviated items	Anaesthesia nurses (n=222)		Nursing students (n=205)	
	Corrected item-subscale correlation	Cronbach's alpha	Corrected item-subscale correlation	Cronbach's alpha
Ethics of anaesthesia care	**0.52[a]**	**0.84**	0.58[a]	0.88
1. Supporting the patient's decision-making	0.62		0.58	
2. Providing information to the patient	0.70		0.80	
3. Advocating for the patient's safety	0.63		0.80	
4. Protecting the patient's privacy	0.63		0.67	
5. Empowering the patient	0.67		0.70	
Patient's risk care	**0.74[a]**	**0.94**	0.78 [a]	0.95
6. Anticipating the patient's risk potentiality	0.82		0.75	
7. Identifying an acute adverse event	0.85		0.89	
8. Assessing how severe an acute adverse event is	0.83		0.90	
9. Prioritising actions immediately	0.86		0.88	
10. Following up the patient's condition	0.77		0.85	
Patient engagement with technology	**0.57[a]**	**0.85**	0.53[a]	0.86
11. Checking anaesthesia-machines/technologies	0.69		0.74	
12. Identifying the patient's needs through monitoring	0.79		0.77	
13. Seeing the patient as a human being	0.56		0.41	
14. Using a variety of technical equipment	0.80		0.79	
15. Checking the accuracy of documented patient data	0.57		0.65	
Collaboration within patient care	**0.54[a]**	**0.83**	0.60[a]	0.88
16. Doing a check-list with the patient	0.60		0.65	
17. Seeking assistance from anaesthesia colleagues	0.58		0.60	
18. Communicating professionally with an anaesthesiologist	0.77		0.74	
19. Sharing the patient's information with the OR team	0.77		0.84	
20. Coordinating the patient's care with the PACU team	0.56		0.79	
Anaesthesia patient care with medication	**0.73[a]**	**0.93**	0.64[a]	0.90
21. Planning anaesthesiological medication	0.78		0.62	
22. Assessing the patient's need for medication	0.88		0.77	
23. Administrating anaesthesiological drugs safely	0.84		0.80	
24. Evaluating the anaesthesiological drug's effectiveness	0.83		0.84	
25. Documentation of medication in the correct manner	0.76		0.72	
Peri-anaesthesia nursing intervention	**0.71[a]**	**0.95**	0.70[a]	0.95
26. Relieving the patient's anxiety related to anaesthesia	0.73		0.69	
27. Maintaining the patient's breathing/ventilating	0.87		0.83	
28. Maintaining the patient's blood circulation	0.86		0.90	
29. Maintaining the patient's body temperature	0.71		0.85	
30. Maintaining the patient's position	0.76		0.85	
31. Maintaining the patient's depth of anaesthesia	0.85		0.81	
32. Maintaining the patient's neuromuscular relaxation	0.84		0.82	
33. Relieving the patient's pain	0.89		0.84	
34. Relieving the patient's nausea and vomiting	0.85		0.74	
Knowledge of anaesthesia patient care	**0.65[a]**	**0.88**	0.65[a]	0.90
35. Knowledge of different types of anaesthesia techniques	0.66		0.77	
36. Knowledge of anatomy	0.80		0.78	
37. Knowledge of difficult airway management	0.78		0.76	
38. Knowledge of legislation relevant to anaesthesia	0.78		0.73	
39. Knowledge of economic efficiency in anaesthesia care	0.73		0.74	
Overall competence	**0.53[a]**	**0.97**	0.53[a]	0.98

[a] Mean of inter-item correlation.

Construct validity of the scale

CFA was used to test the theoretical seven-factor model of the AnestComp using data collected by anaesthesia nurses (Table 3). The overall model fit was supported with an SRMR fitness index, as indicated by a value of 0.06 (SRMR ≤ 0.08 indicates a good fitting model) and was not supported with two fitness indexes as such: χ^2/DF=3.28 (≤ 3 indicates a good fitting model) and CFI 0.82 (CFI ≥ 0.90 indicates a good fitting model). On the item level, all factor loadings from CFA were statistically significant and represented a high standardised factor loading range from 0.63 to 0.93 (ideally this should be > 0.7).[38] There were also high positive correlations across seven factors from 0.63 to 0.92 (p<.001).[38]

Table 3. Fitness indexes, factor loadings, and correlation between factors by CFA (n=222 anaesthesia nurses)

Fitness indexes		
Ratio of chi-squares to the degree of freedom ($\chi 2/DF \leq 3$)	3.28	
Comparative Fit Index (CFI ≥ 0.90)	0.82	
Standardised Root Mean Residual (SRMR≤0.08)	0.06	
Factors	**Standardised loading**	**Standard error**
Factor 1. Ethics of anaesthesia care		
Item 1. Supporting the patient's decision-making	0.67***	0.043
Item 2. Providing information to the patient	0.71***	0.040
Item 3. Advocating for the patient's safety	0.73***	0.038
Item 4. Protecting the patient's privacy	0.72***	0.039
Item 5. Empowering the patient	0.75***	0.036
Factor 2. Patient's risk care		
Item 6. Anticipating the patient's risk potentiality	0.87***	0.019
Item 7. Identifying an acute adverse event	0.90***	0.016
Item 8. Assessing how severe an acute adverse event is	0.87***	0.019
Item 9. Prioritising actions immediately	0.86***	0.020
Item 10. Following up the patient's condition	0.79***	0.028
Factor 3. Patient engagement with technology		
Item 11. Checking anaesthesia-machines/technologies	0.77***	0.030
Item 12. Identifying the patient's needs through monitoring	0.90***	0.016
Item 13. Seeing the patient as a human being	0.63***	0.043
Item 14. Using a variety of technical equipment	0.90***	0.016
Item 15. Checking the accuracy of documented patient data	0.60***	0.046
Factor 4. Collaboration within patient care		
Item 16. Doing a check-list with the patient	0.72***	0.036
Item 17. Seeking assistance from anaesthesia colleagues	0.65***	0.042
Item 18. Communicating professionally with an anaesthesiologist	0.87***	0.020
Item 19. Sharing the patient's information with the OR team	0.83***	0.025
Item 20. Coordinating the patient's care with the PACU team	0.63***	0.044
Factor 5. Anaesthesia patient care with medication		
Item 21. Planning anaesthesiological medication	0.83***	0.023
Item 22. Assessing the patient's need for medication	0.91***	0.013
Item 23. Administrating anaesthesiological drugs safely	0.88***	0.017
Item 24. Evaluating the anaesthesiological drug's effectiveness	0.84***	0.021
Item 25. Documentation of medication in the correct manner	0.80***	0.026
Factor 6. Peri-anaesthesia nursing intervention		
Item 26. Relieving the patient's anxiety related to anaesthesia	0.73***	0.033
Item 27. Maintaining the patient's breathing/ventilating	0.93***	0.011
Item 28. Maintaining the patient's blood circulation	0.92***	0.012
Item 29. Maintaining the patient's body temperature	0.68***	0.038
Item 30. Maintaining the patient's position	0.75***	0.031
Item 31. Maintaining the patient's depth of anaesthesia	0.89***	0.015
Item 32. Maintaining the patient's neuromuscular relaxation	0.87***	0.017
Item 33. Relieving the patient's pain	0.90***	0.015
Item 34. Relieving the patient's nausea and vomiting	0.86***	0.019
Factor 7. Knowledge of anaesthesia patient care		
Item 35. Knowledge of different types of anaesthesia techniques	0.80***	0.027
Item 36. Knowledge of anatomy relevant to anaesthesia techniques	0.91***	0.016
Item 37. Knowledge of difficult airway management	0.90***	0.017
Item 38. Knowledge of legislation relevant to anaesthesia	0.74***	0.034
Item 39. Knowledge of economic efficiency in anaesthesia care	0.68***	0.039

Correlation between factors

	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Factor 1	0.73***	0.76***	0.71***	0.76***	0.74***	0.63***
Factor 2		0.77***	0.65***	0.77***	0.76***	0.81***
Factor 3			0.87***	0.92***	0.91***	0.81***
Factor 4				0.90***	0.85***	0.67***
Factor 5					0.93***	0.76***
Factor 6						0.76***

Lavaan package in R version 3.5.0. *** p<.001

Construct validity was further tested with EFA. With a fixed-seven number of factors, the KMO was 0.97 which exceeded the recommended criteria of 0.80, and the Bartlett's Test of Sphericity were statistically significant (P<0.001).[39] This meant that the data for the factor analysis were suitable.[39] Seven factors explained 86.7% of the total variance. The results of the seven-factor solution in EFA showed a slight difference from the theoretical structure of the AnestComp; some items did not load on the corresponding theoretical structure (Table 4).

Table 4. Factor loadings for the seven-factor solution by EFA (n=222 anaesthesia nurses)

	Factor						
Item no. Abbreviated item	1	2	3	4	5	6	7
1. Supporting the patient's decision-making		.35	-.28				
2. Providing information to the patient	.43	.25					
3. Advocating for the patient's safety	.49	.32					
4. Protecting the patient's privacy	.72						
5. Empowering the patient	.68						
6. Anticipating the patient's risk potentiality		.42					
7. Identifying an acute adverse event		.71					
8. Assessing how severe an acute adverse event is		.83					
9. Prioritising actions immediately		.81					
10. Following up the patient's condition		.71					
11. Checking anaesthesia-machines/technologies			-.43				
12. Identifying the patient's needs through monitoring						.45	
13. Seeing the patient as a human	.55						
14. Using a variety of technical equipment			-.22			.31	
15. Checking the accuracy of documented patient data			-.21	.40			
16. Doing a check-list with a patient	.37			.36			
17. Seeking assistance from anaesthesia colleagues				.60			
18. Communicating professionally with an anaesthesiologist				.48			
19. Sharing patient's information with the OR team				.64			
20. Coordinating patient's care with PACU team				.47			
21. Planning anaesthesiological medication			-.30				.26
22. Assessing patient's need for medication					-.36	.25	
23. Administrating anaesthesiological drug safely					-.91		
24. Evaluating anaesthesiological drug's effectiveness					-.82		
25. Documentation of medication in the correct manner					-.72		
26. Relieving patient's anxiety related to anaesthesia				.37			
27. Maintaining patient's breathing/ventilating						.668	
28. Maintaining patient's blood circulation						.577	
29. Maintaining patient's body temperature						.521	
30. Maintaining patient's position						.457	
31. Maintaining patient's depth of anaesthesia			-.65				
32. Maintaining patient's neuromuscular relaxation			-.66				
33. Relieving patient's pain					-.33	.362	
34. Relieving patient's nausea and vomiting					-.25		
35. Knowledge of different types of anaesthesia techniques			-.28				.39
36. Knowledge of anatomy							.46
37. Knowledge of difficult airway management		.26	-.25				.40
38. Knowledge of legislation relevant to anaesthesia							.95
39. Knowledge of economic efficiency in anaesthesia care							.81

The known-groups technique was also carried out.[41] Based on a two-group comparison, the hypothesised differences were supported. The anaesthesia nurse group (MDN 90) self-assessed a significantly higher competence level than the nursing student group (MDN 51) both in all subscales and the overall scale (U=1492.5 p<0.001) (Table 5). Based on the results, the construct validity of AnestComp was supported by the known-group approach.

Table 5. Anaesthesia nursing competence by known-group comparisons (VAS 0-100)

	Anaesthesia nurses (n=222)		Nursing students (n=205)			
Subscales	**Median**	**IQR**	**Median**	**IQR**	Z-value[a]	P-value[a]
Ethics of anaesthesia care	86.0	15.0	56.9	25.2	-14.28	<.001***
Patient's risk care	85.4	16.0	44.5	33.6	-15.87	<.001***
Patient engagement with technology	93.0	11.8	51.4	32.0	-16.19	<.001***
Collaboration within patient care	94.2	10.3	66.5	29.4	-14.22	<.001***
Anaesthesia patient care with medication	93.0	11.8	55.3	31.3	-16.31	<.001***
Peri-anaesthesia nursing intervention	93.3	11.2	50.6	34.8	-16.41	<.001***
Knowledge of anaesthesia patient care	81.8	18.9	36.2	33.2	-15.93	<.001***
Overall competence	89.5	11.28	50.6	25.4	-16.69	<.001***

[a] Mann-Whitney U test, * p<.05, ** p<.01, *** p<.001

DISCUSSION

The aim of the study was to develop and test the psychometric properties of the Anaesthesia Nursing Competence Scale (AnestComp) which assesses nurses' competence in anaesthesia nursing care. The results of the psychometric testing provided initial support for the reliability and validity of the AnestComp.

In the reliability testing, the Cronbach's alpha values (0.83-0.95) from the seven subscales used for the anaesthesia nurse data were good; over the value of the 0.7 is recommended for a new instrument.[41,42] The high values of Cronbach's α across the subscales indicated that each subscale consistently measures one concept.[42] The subscale of peri-anaesthesia nursing intervention particularly showed the highest coefficient alpha (0.95) among the subscales. The high alpha value could be a consequence of the large number of items (nine) in that subscale and might mean that the items measure the same construct repeatedly. This might weaken the content

validity of the scale[43] and item reduction is considered.[42] In a reliability evaluation, single testing is not sufficient to determine the soundness of the scale.[13] It is natural that the reliability is changeable and reacts with the specific group being measured.[42] Therefore, this newly developed scale needs to assess the reliability through repeated testing with other samples.

In terms of validity, AnestComp was examined by using different approaches such as face validity, content validity and construct validity. Since AnestComp intended to measure anaesthesia nursing competence, the validity is considered to be supported if all items in the scale are able to measure concepts related to anaesthesia nursing competence theoretically and structurally. The face validity and content validity conducted in phase I and II focused on identifying the correct constructs for anaesthesia nursing competence and validating that the items were appropriate indicators of the construct. These phases needed time due to the difficulty of highly abstract constructs and the subjectiveness of the assessment.[42]

In Phase III, the construct validity of the theoretical seven factor model of AnestComp was statistically evaluated by a CFA and then compared with an EFA of a seven-factor solution. The statistical validation tests supported the theoretical seven-factor structure of AnestComp and suggested that the scale is worthy of further development. Among the three fitness indexes in CFA, the SRMR index supported a good fit and the other model fitness indexes were out of acceptable values; however, they were close to be acceptable. Most of the high factor loadings indicate that the items converge at a common point of the specific construct. The results provide initial evidence of convergent validity and are in line with the good reliability of this scale; reliability is one of indicators in convergent validity.[38] However, discriminant validity is not clearly supported because the correlations between the factors were high. For instance, factor 6 showed high correlation with factor 3 and factor 5. The high correlation indicates that a construct of the scale is not truly unique from other constructs and measures some phenomena that other constructs also do[38]; this may have affected the overall model fit negatively.

The seven-factor solution by the EFA provides clues to understanding the underlying structure of the AnestComp. Most items were well-loaded for theoretical constructs, but certain items were not or were cross-

loaded to more than one factor. The overlapping tendency seems to have influence the high correlation between factors noticed in the CFA. Four items in factor 6 were loaded/cross-loaded to factor 3 and factor 5. This might cause difficulty when allocating the item to an appropriate factor due to the overlapping characteristics of the competence. The multidimensional aspects of competence have also been discussed in other competence studies [5,10,13] and emphasise the consideration of various perspectives such as theoretical structures, clinical practice, and empirical studies when developing a competence scale.[10] Therefore, the cross-loaded items need modification through further validity testing.

In this study, the known-group technique was used to support the construct validity of AnestComp.[41] The expected score differences were found in each subscale and in the overall scale between anaesthesia nurses and nursing students. The validity of the AnestComp might be questioned if such differences in levels of competence between nurses and students did not occur. In competence studies, the number of years of work experience of nurses was used as a characteristic for the known-group technique.[15,44] However, longer work experience among nurses does not guarantee higher competence and there are associated factors such the level of education.[40,45] Therefore, this study decided to compare the level of competence between anaesthesia nurses who already had registered nurse education and nursing students who were not yet qualified instead of using years of work experience. When validating a measure of competence, the AnestComp has the capability to differentiate between groups that are theoretically known to be high and low[22,40] and is considered a valid scale.

Strengths and limitations

The major strength is that this was the first study measuring the specific-context of anaesthesia nursing competence. The AnestComp focuses intensely on specialised competence areas for anaesthesia patient care. Patient's risk care, patient engagement with technology, anaesthesia medication competence, and peri-anaesthesia nursing intervention are particularly anaesthesia specified competence areas which earlier self-assessment competence instruments do not necessarily deal with. Additionally, the AnestComp showed good reliability, and factor analysis and the known-groups technique provided initial support for construct validity.

There are limitations in this study. First, the result of the factor analysis might be one limitation due to the sample size. No absolute rule on a proper sample size exists, but it is suggested that a sample size should be 5-10 times the number of items in the factor analysis.[46, 47] In this study, the sample size satisfied the minimum requirement for the number of samples (a ratio of 1:5) suggested as 195 for the factor analysis.[46,47] If both anaesthesia nurse data (n=222) and nursing student data (n=205) were included into the factor analysis, the preferable sample size would have been met for the statistic. However, the AnestComp was theoretically developed to measure nurse competence in anaesthesia nursing care, thus, nursing student data were excluded in the factor analysis. Because the statistics could be sensitive to the sample size, additional validation studies concerning re-testing of the theoretical structure with larger samples might be the next step.

Second, the distribution of competence scores of anaesthesia nurses was skewed to the right (ranging from -0.76 to -2.75, toward being more competent). The skewness might create a ceiling effect which should be considered when interpreting the results.

Third, the use of nursing students' data as a comparison group might be a limitation, because the scale was developed for the use of nurses. In order to endorse the use of students' data, the content expert group reviewed the items as being appropriate for the use of students. Also, there was good variation in item responses by students and the Cronbach's alpha values were high in all subscales (0.86-0.95).

Fourth, the levels of competence in this study were based on self-assessment. Self-assessment is considered the least threating and time-efficient approach when assessing competence. However, a self-direction assessment has the disadvantage of having little public accountability and there has been some criticism related to the issue of subjectivity.[10, 27] Therefore, it is recommended that future studies use AnestComp with other assessment methods such as peer and manager assessment, or direct observation.

CONCLUSION

AnestComp was developed to measure nurses' competence in anaesthesia nursing care. The psychometric properties were tested by using empirical data (n=427) consisting of Finnish anaesthesia nurses and nursing students. Estimates of the Cronbach's α and several validation approaches supported the reliability and validity of the scale. The findings indicate that AnestComp is a promising scale for use among anaesthesia nurses. This scale can be used for nurses to identify educational needs in anaesthesia nursing care. It can be a

particularly useful scale for new employees in assessing their competence and evaluating the effectiveness of orientation programmes.

In future studies, some items need to be reconsidered in order to fit the conceptual model better. In addition, it is recommended that the high estimates of Cronbach's α in the subscale be further tested to reduce the length of the instrument. Since the concept of anaesthesia nursing competence is complex and integrated, it would be worthwhile to conduct continuous content analysis and validation tests. Developing an instrument is a continuous process of refining and testing the psychometric properties from various perspectives. AnestComp was psychometrically tested with anaesthesia nurses in Finland; therefore, additional studies using different data, education levels, organizations, and countries would help to improve the construct validity further. The refinement of the instrument might also be enhanced by repeated testing with other samples.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest.

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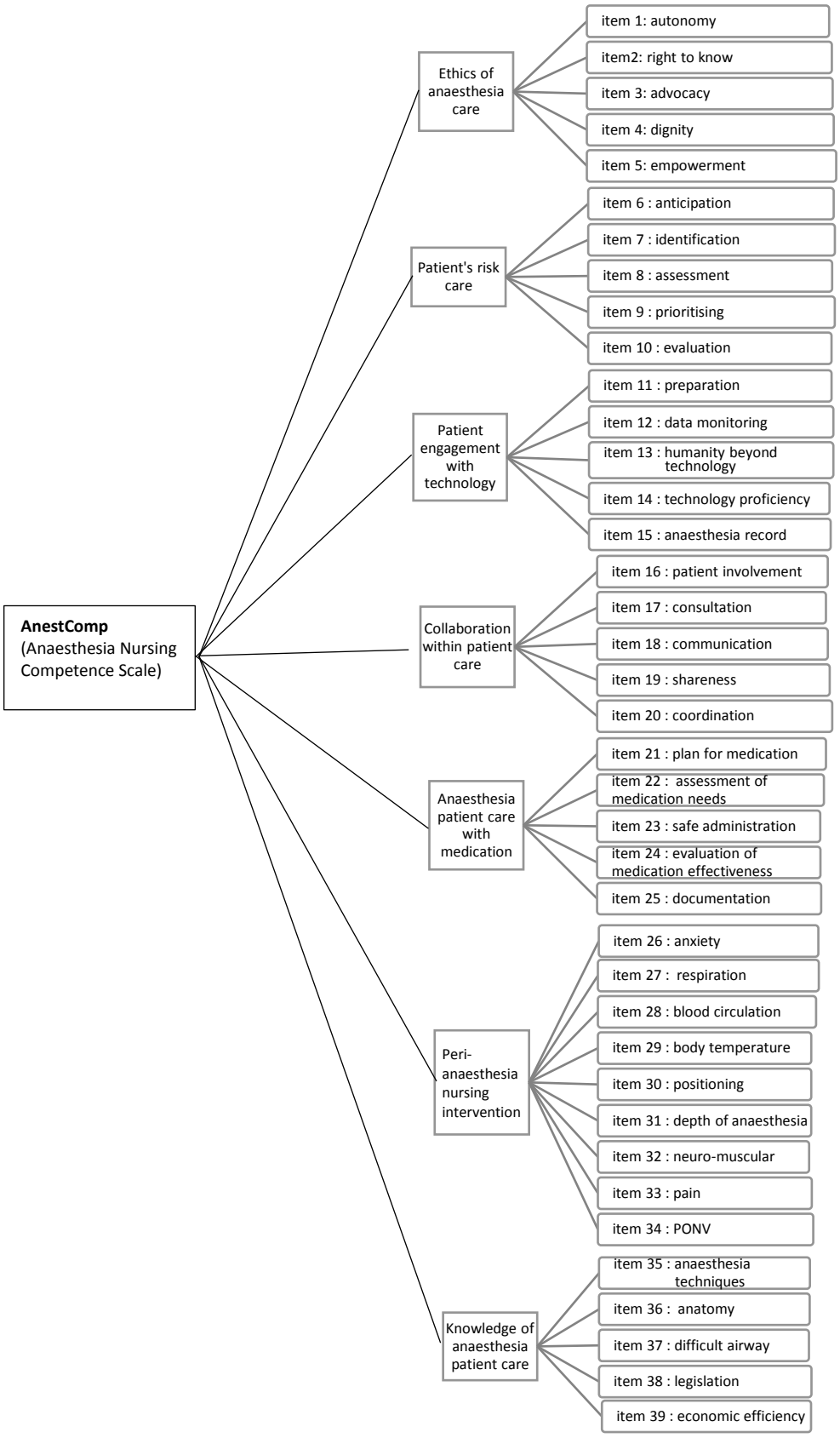

Figure 1. Theoretical framework of the Anaesthesia Nursing Competence Scale and the model for construct validity testing