ORIGINAL ARTICLE

Exploring the relationship between anaesthesiologists' non-technical and technical skills

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Conflicts of interest
The authors have no conflicts of interest

Funding
Institutional funding.

Submitted 24 June 2015; accepted 8 July 2015; submission 18 March 2015.

Citation
Gjeraa K, Jepsen RMHG, Rewers M, Østergaard D, Dieckmann P. Exploring the relationship between anaesthesiologists' non-technical and technical skills. Acta Anaesthesiologica Scandinavica 2015

doi: 10.1111/aas.12598

Background: A combination of non-technical skills (NTS) and technical skills (TS) is crucial for anaesthetic patient management. However, a deeper understanding of the relationship between these two skills remains to be explored. We investigated the characteristics of trainee anaesthesiologists' NTS and TS in a simulated unexpected difficult airway management scenario.
Methods: A mixed-method approach was used to explore the relationship between NTS and TS in 25 videos of 2nd year trainee anaesthesiologists managing a simulated difficult airway scenario. The videos were assessed using the customised version of the Anaesthetists' Non-Technical Skills System, ANTSdk, and an adapted TS checklist for calculating the correlation between NTS and TS. Written descriptions of the observed NTS were analysed using directed content analysis.
Results: The correlation between the NTS and the TS ratings was 0.106 (two-tailed significance of 0.613). Inter-rater reliability was substantial. Themes characterising good NTS included a systematic approach, planning and communicating decisions as well as responding to the evolving situation. A list of desirable, concrete NTS for the specific airway management situation was generated.
Conclusion: This study illustrates that anaesthesiologist trainees' NTS and TS were not correlated in this setting, but rather intertwined and how the interplay of NTS and TS can impact patient management. Themes describing the characteristics of NTS and a list of desirable, concrete NTS were developed to aid the understanding, training and use of NTS.

Editorial comment: what this article tells us
This study assessed if there was a relationship between non-technical and technical skills in a convenience sample of second year anaesthesiologist trainees. No significant correlation was found, but the participants had a limited amount of clinical experience and that might influence the results.

A combination of good non-technical skills (NTS) and technical skills (TS) is important in preventing and managing adverse events in healthcare.[1–3] NTS encompass the cognitive and social skills that support the TS, i.e. use of medical expertise, drugs and equipment.[4,5] NTS and TS can be trained to improve patient safety.[6–10] Training both these skills through simulation has been recommended and practised for more than a decade.[2,11] Danish trainee

Acta Anaesthesiologica Scandinavica
AN INTERNATIONAL JOURNAL OF ANAESTHESIOLOGY AND INTENSIVE CARE, PAIN AND EMERGENCY MEDICINE

anaesthesiologists participate in simulation-based training of NTS and TS during mandatory courses in their specialist training programme.

The correlation between NTS and TS has been studied. Some studies have indicated a positive correlation between the skills for anaesthesiologists[2,12] and surgeons.[13,14] Others have found low,[15–17] no[18] or negative[19] correlation between NTS and TS. A study of trauma teams found that some NTS correlated positively to the trauma teams' technical performance, whereas other NTS correlated negatively.[20] As there is not yet a clear picture of the relationship between NTS and TS, a deeper understanding of this is needed.[2,21]

Training and implementing NTS in clinical anaesthesiology and surgery is still a challenge.[7,22,23] One of the challenges for the clinician is that instruments for assessing NTS are often developed through interviews with clinicians.[24–26] The instruments therefore represent what the interviewees have recalled from situations of good and poor non-technical behaviour, i.e. 'Work-As-Imagined'.[27] Applying Hollnagel's concept of 'Work-As-Imagined and Work-As-Done', it might be more useful to the clinician if they are provided with a description of actual performance, concretising which NTS are useful in a clinical setting. Therefore, we wanted to explore the variation of NTS among anaesthesiologists in managing a specific situation.

One of the most challenging anaesthetic emergencies is the unexpected difficult airway.[28,29] Although this emergency is rare, it is highly critical, and thus very important for every anaesthesiologist to master. The simulation setting offers the best feasible possibility to collect data systematically as observation of this emergency cannot be planned.

The aim of this study was to explore the characteristics of trainee anaesthesiologists' NTS and TS in a simulated unexpected difficult airway management scenario. The research questions were:

1. Are the ratings of trainee anaesthesiologists' NTS and TS correlated?
2. What characterises the trainee anaesthesiologists' use of good NTS or poor NTS, respectively?
3. What concrete NTS characterise the good management of the unexpected difficult airway?

Methods

An explorative, mixed-method approach was chosen.[30] The study was reported in accordance with Standards for Reporting Qualitative Research (SRQR).[31]

Ethics

An exemption letter from the Regional Ethical Committee of the Capital Region, Denmark was obtained prior to the investigation (H-4-2014-045). The participants signed a consent form after receiving oral and written information, including the continuous option of retracting their consent. All personal data were treated confidentially according to the Danish Data Protection Law.

Setting and participants

A convenience sample of 2nd year trainee anaesthesiologists attending a 3-day national mandatory course were invited to participate. Of 27 possible participants 25 volunteered. The course consisted of a mix of didactic lessons, workshops and simulations on TS and NTS in airway management. The course concluded with a formative Objective Structured Clinical Examination (OSCE) where NTS and TS were assessed. The OSCE consisted of 12 8-min testing stations. One station was selected for the current analysis, where the participants were informed prior to the simulation that they would be assessed on both their TS and NTS in the context of an unexpected difficult airway management situation. An anaesthesiologist teaching advanced airway management skills at this mandatory national specialist training course assessed the participants at an unexpected difficult airway management simulation. These simulations were video-recorded and saved for later analysis. Participants' demographic data were collected.

Non-technical skills assessment instrument, Anaesthesiologists' Non-Technical Skills in Denmark (ANTSdk)

The Anaesthesiologists' Non-Technical Skills in Denmark (ANTSdk) is an observation instru-

ment which was customised from the Scottish Anaesthetists' Non-Technical Skills System, ANTS, to fit the Danish healthcare system's culture and organisation.[23,24] ANTSdk assessment provides structured feedback on NTS and can aid identification of needs for further training. ANTSdk consists of four categories (situation awareness, decision making, team working, and leadership) and 16 underpinning elements; described further by examples of good and poor behaviour. Elements and categories are rated using a 5-point Likert scale, ranging from 1 for the lowest rating to 5 for the highest rating. In all, ANTSdk ratings can range from 16 to 80. Narrative feedback notes supplement each numeric element rating.

Technical skills rating instrument

The 11-item OSCE checklist for rating of trainee anaesthesiologists' TS and NTS had been developed previously in a Delphi-like manner by the course faculty, consisting of five consultant anaesthesiologists with airway management and simulation expertise. Each item was rated on a 3-point scale. To avoid rating NTS in both the TS rating and ANTSdk, as other previous studies have found problematic,[2] three NTS items from the OSCE checklist were removed and a new summed score was generated, hereafter named TS ratings, with possible range from 8 to 24 (Appendix 1).

Video analysis and rater training

Beyond the TS ratings conducted at the OSCE, a second TS rater assessed the video-recorded simulations. Additionally, two NTS raters assessed the NTS displayed in the study videos. A consultant anaesthesiologist (MR) with expertise in airway management and NTS performed the second TS rating. MR was blinded to the first TS rating and the NTS ratings. The two primary investigators (KG and RMHGJ) performed the NTS ratings. The NTS ratings comprised two types: a numerical rating and written description of observed NTS. The latter often contained both good and poor behaviour relating to each element, whereas the numerical ratings reflected the poorest of the different NTS observed by the raters; as this is what potentially could harm the patient the most. The NTS raters used the space provided for narrative feedback notes in the ANTSdk rating form to register the observed NTS for each element. All observed NTS were registered and rated in the order of appearance in the scenario. The two NTS raters trained NTS rating before the study by independently rating 10 previously video-recorded anaesthesia simulation scenarios using ANTSdk. The ratings were discussed with a consultant anaesthesiologist with extensive NTS expertise (DØ). The NTS raters rated five study videos. They then calibrated their ratings and reached consensus by discussion. The remaining study videos were rated independently. The NTS raters were blinded to the TS ratings.

Data analysis

We calculated inter-rater reliability (IRR) for both NTS and TS ratings using intraclass correlation (ICC). The ICC was determined with a consistency definition using a two-way random model for single measures (individual rater) and average measures (Cronbach's alpha, averaging all raters' scores). ICC was used to analyse reliability categorised according to Landis and Koch.[32] ICC levels above 0.61 were considered sufficient for formative assessment.[33]

The correlations between participants' summed scores for NTS and TS ratings were measured using Spearman's correlation coefficient (rho), two-tailed, because data were non-parametrically distributed. Statistical analyses were performed using a statistical software package (SPSS, version 19.0; SPSS Inc., Chicago, IL, USA).

To characterise the good or poor use of NTS, we analysed the written descriptions of observed NTS using directed content analysis.[34] Directed content analysis can be used, when 'prior research exists about a phenomenon that is incomplete/would benefit from further description'.[34] The three study videos displaying the best NTS and the poorest NTS, respectively, were chosen to explore the variation in NTS and to elaborate good non-technical behaviour. The written descriptions of observed NTS for these six videos were divided into single meaning sentences. The sentences were deductively sorted under one of the 16 ANTSdk elements.

In case a sentence could fit into more than one element, we decided under which element it fit best. The sentences under the elements were then sorted into topics and given topic headlines. From the topics, we derived overarching themes that characterised observed good and poor NTS for the situation. We exemplify this with two cases of good and poor NTS illustrating how the themes appeared in the simulation. The cases demonstrate how the interplay of NTS and TS actually can unfold, moving beyond the mere listing of influencing factors. A list from the written descriptions of observed NTS was developed to characterise the good management of the unexpected difficult airway. Both good and poor NTS were included; the poor NTS were reversed to reflect desirable NTS.

Results

The participants' demographic data are shown in Table 1. IRR was substantial for NTS ratings (ICC average measures = 0.66, single measures = 0.49) and TS ratings (ICC average measures = 0.73, single measures = 0.58). The correlation between the NTS and the TS measured as the summed ANTSdk ratings and summed TS ratings was 0.106 (two-tailed significance of 0.613), see Fig. 1 (Appendix 2 provides additional correlation calculations).

Themes characterising good and poor NTS observed in the six study videos chosen to explore the variation in NTS and elaborate good non-technical behaviour (the three best and the three poorest) are shown in Table 2.

To illustrate how the NTS and TS are intertwined, we present two examples of good and poor NTS, respectively. The first case shows good NTS illustrating the themes 'Thought ahead' and 'Delegated tasks' (video 19):

Table 1 Participant demographics (n = 25).

Gender (M/F)	13/12
Age, median (range)	34.5 years (28–44)
Years since graduation from university, median (range)	6.5 (3–16)
Years of clinical experience in anaesthesiology, median (range)*	2 (1–4)

*One participant did not provide this information.

The trainee anaesthesiologist informs the nurse of immediate and subsequent interventions. Before the first tracheal intubation attempt using conventional laryngoscopic technique, the trainee informs the nurse that this is what he will do now, and that if it fails the next step is to use the video laryngo-

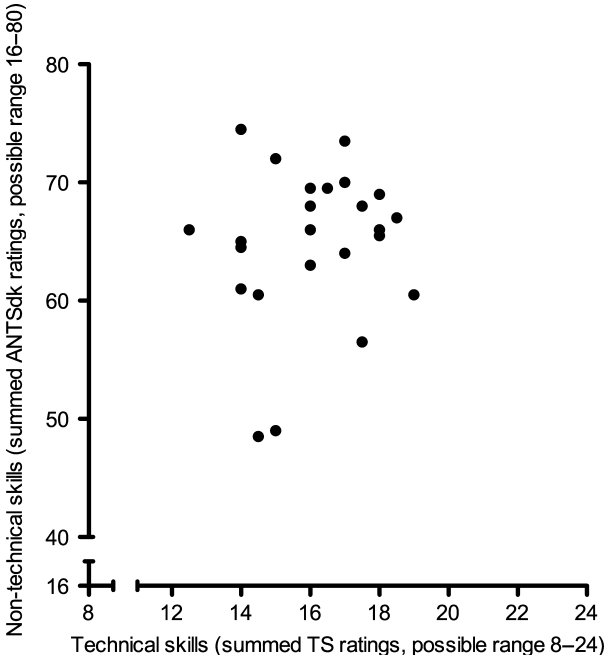

Fig. 1. Correlation between technical skills and non-technical skills. Two participants had identical ratings: TS rating score 18, NTS rating score 66.

Table 2 Themes characterising good and poor non-technical skills observed in the six study videos of a difficult airway management scenario.

Themes characterising good NTS	Themes characterising poor NTS
Systematically collected information	Lacked structured approach
Thought ahead	Lacked articulation of plans and decisions
Communicated and justified decisions	Poor resource and task management
Delegated tasks	Lacked consideration of consequences of treatment
Vigilant response to the evolving situation	Poor response to the evolving situation
	Lacked leadership

> scopic technique [thought ahead]. This enables the nurse to find and prepare the video laryngoscope [delegated tasks] while the trainee makes the first tracheal intubation attempt. When the first attempt fails, the trainee makes a second attempt. At this point the device is already prepared and ready for use.

As the nurse is informed about the plan, the equipment is ready to use as soon as it is required; hence, no time is lost between the tracheal intubation attempts. The actions of the two persons involved become synchronised; thus, the time necessary for briefing the nurse can be seen as an investment, not as a delay. Thinking ahead and delegating tasks optimises the execution of the TS, thereby improving patient management.

The second case shows poor NTS illustrating the themes 'Poor resource and task management' and 'Poor response to the evolving situation' (video 3):

> After two failed tracheal intubation attempts using conventional laryngoscopic technique, the video laryngoscope is chosen as the device for the third attempt. The trainee assembles it himself, instead of handing it to the nurse who stands idle besides him [poor resource and task management]. In the meantime, the oxygen saturation drops to a critical level of 73% before he realises this and starts to ventilate the patient using a facemask [poor response to the evolving situation]. At this point, the trainee does not know if it will be possible to oxygenate the patient.

In the second case, the trainee anaesthesiologist has the medical knowledge of the guideline of difficult airway management and is, seen separately, technically competent at tracheal intubation using the video laryngoscope, but as he is occupied assembling the tube into the video laryngoscope, hence having 'head down', he loses track of time and oxygen saturation. He does not co-ordinate his actions with the nurse; consequently, their actions become desynchronised. Despite saving time not briefing the nurse, he spends time assembling the device while the nurse is idle. The situation evolves to a potentially extremely critical situation. If it was a 'cannot intubate, cannot oxygenate' situation, it would start from a critically low oxygen saturation. Due to poor resource and task management along with poor response to the evolving situation, the overall patient safety is compromised.

Table 3 shows the list of desirable, concrete NTS observed in the six study videos.

Discussion

In this study, we explored the characteristics of trainee anaesthesiologists' NTS and TS in a simulated unexpected difficult airway management scenario. No correlation was found between NTS and TS. Themes characterising good and poor NTS were identified demonstrating how NTS can facilitate or hinder patient safety. We developed a list of desirable, concrete NTS observed in the difficult airway management situation.

The lack of correlation between the NTS and TS is consistent with other studies.[15–17,19] This might be partly explained by the fact that some NTS described in ANTSdk are not present during all anaesthesia situations.[12,35] We found this applicable for the ANTSdk element 'Planning and Preparing' in Table 3. The participants did not have time, e.g. checking the equipment before use, as they were brought into the scenario when the first endotracheal intubation attempt had just failed. Others have found correlation between anaesthesiologists' NTS and TS.[2,12] Reasons for this discrepancy in the correlation found between NTS and TS could be that in one study a technical checklist was used, containing NTS items, e.g. 'Call for help' and 'Look at or verbalises the rhythm'.[2] Another study used a modified and reduced ANTS version for their specific scenario,[12] and thereby did not include all the elements of ANTS/ANTSdk as did our study. For training and research purposes, it might make sense to modify a NTS assessment instrument for the specific situation. However, in the complex, ever-changing clinical environment, different cases might require a different focus of the NTS. Cases that are difficult to diagnose might require more cognitive elements of NTS, whereas cases that require many actions might require more social elements. To capture all of this, a generic assessment instrument seems more feasible.

Consistent with the finding of no correlation between NTS and TS ratings, other researchers have stated that training and rating TS separate

Table 3 List of desirable, concrete NTS observed in the study videos of a difficult airway management scenario.

Non-technical skills in a difficult airway management scenario Observed in a simulated scenario analysed using ANTSdk			
ANTSdk category	ANTSdk element		Concrete NTS observed
Situation awareness	Gathering information	From the nurse anaesthetist on	Relevant patient history and current status of anaesthesia
			Medication administered
			Time from induction of anaesthesia
		From observing the monitor for	Oxygen saturation
			Heart rate
			Blood pressure
		From handling the patient	Assesses airway anatomy and head and neck positioning
			Assesses effect of facemask ventilation
	Recognising and understanding contexts	Recognises severity of the situation; unexpected difficult airway	Repositions the patient (head extension, jaw thrust)
			Requests other devices when experiencing poor view on attempting intubation
			Acknowledges need for oxygenation and ventilation using facemask
			Acknowledges 'cannot intubate but can oxygenate' situation
			Identifies need for suction
			Notices when the patient is waking up
			Plans to wake the patient (avoids further doses of neuromuscular blocking agents)
	Anticipating and thinking ahead	Anticipates need for further interventions	Facemask ventilation
			Plans subsequent intubation attempts
			Plans use of relevant medication
		Anticipates need for help	From colleagues
			Requests alternative equipment/devices
		Is prepared *before* subsequent interventions	Checks blood pressure before giving medication
			Prepares equipment before attempting intubation
			Checks indication for surgery before deciding to wake the patient
	Demonstrating self-awareness	Asks advice from (senior) colleague when in doubt	
Decision making	Identifying options	Creates overview by summarising	
		Establishes several options	Recalls choice of device(s)
			Considers to wake the patient
			Acknowledges when the patient is waking up, understands the need for action
	Choosing, communicating and implementing decisions	Chooses options; communicates, justifies and implements decisions on	Positioning of the patient
			When to start facemask ventilation
			Which devices to use
			Who should intubate

Table 3 (Continued)

Non-technical skills in a difficult airway management scenario Observed in a simulated scenario analysed using ANTSdk				
ANTSdk category	ANTSdk element	Concrete NTS observed		
				What medication to use (sedation, neuromuscular blocking agents)
				Whether to wake the patient
	Reassessing decisions	Systematically re-evaluates		Changes in oxygen saturation
				Effect of facemask ventilation
				Which devices should be used for further intubation attempts
				Need for medication (sedation, neuromuscular blocking agents)
				Airway management; decides to wake the patient when concluding that intubation is not possible
		Changes strategy when relevant		
Team working	Exchanging information	Informs team – to establish 'shared mental model'	Thinks aloud and	Describes the situation
				Describes actions
				Comments on oxygen saturation
				Concludes 'cannot intubate but can oxygenate'
				Ensures ability to oxygenate
				Plans ahead
			Adjusts information to the situation	
			Speaks loud and clear	
			Uses closed loop communication	
		Listens to suggestions from the team		
	Assessing competencies	Identifies levels of competence in the team (nurse, technician or other doctor)		
	Coordinating activities	Delegates relevant tasks to team, without overburdening	Asks for difficult airway tray	
			Asks for preparation of the next device	
			Asks for preparation and administration of medication	
	Supporting others	Responds appropriately to other team members		
		Appears calm		
		Uses polite tone of voice		
		Supports team members	Asks for the assistant's viewpoint	
			Gives positive feedback when appropriate	
			Instructs, helps, and teaches	
			Takes over when team member is not coping	
			Corrects when necessary	
Leadership	Planning and preparing*	Checks equipment before use		
	Prioritising	Prioritises tasks according to algorithm, especially employing facemask ventilation when saturation decreases		
		Considers who should intubate		

Table 3 (Continued)

Non-technical skills in a difficult airway management scenario Observed in a simulated scenario analysed using ANTSdk		
ANTSdk category	ANTSdk element	Concrete NTS observed
	Identifying and utilising resources	Calls for more personnel
		Has the difficult airway tray brought quickly
	Using authority and assertiveness	Takes responsibility for tasks and exercises authority
		Speaks loud and clear
	Providing and maintaining standards	Follows guideline and algorithm for difficult airway management

ANTSdk, anaesthesiologists' non-technical skills in Denmark; NTS, non-technical skills. *Other planning or preparation was not possible to observe due to the nature of the simulation scenario.

from NTS is of limited value, as these skills are integrated in the clinical setting.[18] The two cases described previously exemplify that good or poor NTS do not necessarily result in good or poor TS per se, or vice versa. Both skills contribute to the overall patient management and can thereby contribute to, or be of harm to, patient's safety. Our view is that NTS are intertwined with TS, but not as such correlated. Consider, e.g. the proverbial highly skilled professional with limited social abilities. The combined use of these skills is important for patient safety. This implies that it is important to train and assess both NTS and TS.

The NTS themes in Table 2 and the concrete actions listed in Table 3 are examples of 'Work-As-Done' in the management of an unexpected difficult airway situation.[27] Overall, the themes characterising participants' NTS show that a systematic approach, planning and communicating decisions as well as responding to the evolving situation are essential for good management of this anaesthetic situation. A study examining the coordination patterns during different stages of malignant hyperthermia treatment found that different coordination patterns predicted high clinical performance depending on the phase of the emergency management.[35] Additionally, during non-emergencies, different NTS are used during different phases of anaesthesia.[36] It could be hypothesised that it will depend on the specific context (patient, general health, the specific health problems, actual treatment etc.) which and to what extent NTS are required for 'Work-As-Done'. In other words, not all NTS, as is the case with TS, are relevant to the same extent at any given situation. The key challenge for future research will be to define 'which differences make a difference'.[37]

NTS are considered by many clinicians as difficult to grasp, hence the difficulties in training and implementing NTS.[7,22,23] We find that the list of NTS in Table 3 can be seen as a concretisation and clarification of what NTS can be. This might help both the anaesthesiologist training NTS and the supervisor training anaesthesiologists in NTS by concretising the terms and concepts from behavioural science into everyday clinical actions and situations – a task known to be challenging.[38]

There are strengths and limitations to this study. A limitation to this study is the sample

size, which might lead to Type II errors. However, our main focus was to inform the relationship between NTS and TS further by qualitative analyses, as correlation studies had been conducted previously.[2,12] Other limitations are that only one particular emergency was studied and that the assessments of NTS and TS were performed on a simulation scenario. Simulation has been shown to have ecological validity.[39,40] The strength in the simulated setting is the opportunity to standardise the scenario, patient history, the role-playing nurse and raters. The simulation scenario used was an assessment situation and thus the actions shown might be impacted by the wish to perform well. The OSCE scenarios were short, and therefore it may not have been possible to display or observe all NTS, furthermore the participants were under time pressure. The OSCE checklist, from which our TS ratings were derived, was developed in a Delphi-like manner by the expert faculty for the mandatory course, and has been used for many years. We studied a convenience sample of 2nd year trainees at the end of a 3-day national mandatory course in airway management, as we thought a national sample was important. There could be a risk that their responses were too similar. However, we did not find this, as the participants' NTS were rated in the high end of the possible summed scores, 48.5–74.5 of a maximum of 80 (Fig. 1). A possible explanation could be that the participants' median experience as physicians was 6.5 years. Nevertheless, the results are derived from 2nd-year trainees, and they might differ for anaesthesiologists with different experience levels. The NTS raters made written descriptions of observed NTS during the NTS rating, knowing that these would be the qualitative data analysed afterwards. Occasionally, they changed some ratings and written descriptions, when viewing other participants' perform, to give the fairest assessment.

In the light of these findings, future studies should explore the intertwined relationship between NTS and TS further, e.g. which NTS are most important to use during different situations, e.g. the anaesthetic emergency, the elective surgery, etc. For medical education purposes, it makes sense to assess NTS separately, as they are different from TS.

In conclusion, no correlation was found between anaesthesiologist trainees' NTS and TS. Themes describing the characteristics of NTS were found. The study illustrates how the intertwined relationship between NTS and TS can impact patient management. A list of concrete NTS for this specific anaesthetic situation is provided to aid the understanding, training and use of NTS.

References

1. Brindley PG. Improving teamwork in anaesthesia and critical care: many lessons still to learn. Br J Anaesth 2014; 112: 399–401.
2. Riem N, Boet S, Bould MD, Tavares W, Naik VN. Do technical skills correlate with non-technical skills in crisis resource management: a simulation study. Br J Anaesth 2012; 109: 723–8.
3. Flin RH, O'Connor P, Crichton M. Safety at the sharp end: a guide to non-technical skills. Aldershot; Burlington, VT: Ashgate, 2008.
4. Fletcher GCL, McGeorge P, Flin RH, Glavin RJ, Maran NJ. The role of non-technical skills in anaesthesia: a review of current literature. Br J Anaesth 2002; 88: 418–29.
5. Gaba DM. Assessment of clinical performance during simulated crises using both technical and behavioral ratings. Anesthesiology 1998; 89: 8–18.
6. Draycott T, Sibanda T, Owen L, Akande V, Winter C, Reading S, Whitelaw A. Does training in obstetric emergencies improve neonatal outcome? BJOG Int J Obstet Gynaecol 2006; 113: 177–82.
7. Neily J, Mills PD, Young-Xu Y, Carney BT, West P, Berger DH, Mazzia LM, Paull DE, Bagian JP. Association between implementation of a medical team training program and surgical mortality. J Am Med Assoc 2010; 304: 1693–700.
8. Sevdalis N, Hull L, Birnbach DJ. Improving patient safety in the operating theatre and perioperative care: obstacles, interventions, and priorities for accelerating progress. Br J Anaesth 2012; 109: i3–i16.
9. Bjurström JM, Konge L, Lehnert P, Krogh CL, Hansen HJ, Petersen RH, Ringsted C. Simulation-based training for thoracoscopy. J Soc Simul Healthc 2013; 8: 317–23.
10. Tolsgaard MG, Ringsted C, Dreisler E, Nørgaard LN, Petersen JH, Madsen ME, Freiesleben NLC, Sørensen JL, Tabor A. Sustained effect of simulation-based ultrasound training on clinical performance: a randomized trial. Ultrasound Obstet

Gynecol 2015; doi:10.1002/uog.14780. [Epub ahead of Print].
11. Gaba DM. The future vision of simulation in health care. Qual Saf Health Care 2004; 13: i2–i10.
12. Zausig YA, Grube C, Boeker-Blum T, Busch CJ, Bayer Y, Sinner B, Zink W, Schaper N, Graf BM. Inefficacy of simulator-based training on anaesthesiologists' non-technical skills. Acta Anaesthesiol Scand 2009; 53: 611–9.
13. Catchpole KR, Giddings AEB, Wilkinson M, Hirst G, Dale T, de Leval MR. Improving patient safety by identifying latent failures in successful operations. Surgery 2007; 142: 102–10.
14. Black SA, Nestel DF, Kneebone RL, Wolfe JHN. Assessment of surgical competence at carotid endarterectomy under local anaesthesia in a simulated operating theatre. Br J Surg 2010; 97: 511–6.
15. McCulloch P, Mishra A, Handa A, Dale T, Hirst G, Catchpole K. The effects of aviation-style non-technical skills training on technical performance and outcome in the operating theatre. Qual Saf Health Care 2009; 18: 109–15.
16. Mishra A, Catchpole K, Dale T, McCulloch P. The influence of non-technical performance on technical outcome in laparoscopic cholecystectomy. Surg Endosc 2008; 22: 68–73.
17. Moorthy K, Munz Y, Adams S, Pandey V, Darzi A. A human factors analysis of technical and team skills among surgical trainees during procedural simulations in a simulated operating theatre. Ann Surg 2005; 242: 631–9.
18. LeBlanc VR, Tabak D, Kneebone R, Nestel D, MacRae H, Moulton C-A. Psychometric properties of an integrated assessment of technical and communication skills. Am J Surg 2009; 197: 96–101.
19. Schraagen JM, Schouten T, Smit M, Haas F, van der Beek D, van de Ven J, Barach P. A prospective study of paediatric cardiac surgical microsystems: assessing the relationships between non-routine events, teamwork and patient outcomes. BMJ Qual Saf 2011; 20: 599–603.
20. Westli HK, Johnsen BH, Eid J, Rasten I, Brattebø G. Teamwork skills, shared mental models, and performance in simulated trauma teams: an independent group design. Scand J Trauma Resusc Emerg Med 2010; 18: 47.
21. Hull L, Arora S, Aggarwal R, Darzi A, Vincent C, Sevdalis N. The impact of nontechnical skills on technical performance in surgery: a systematic review. J Am Coll Surg 2012; 214: 214–30.
22. Graham J, Hocking G, Giles E. Anaesthesia Non-Technical Skills: can anaesthetists be trained to reliably use this behavioural marker system in 1 day? Br J Anaesth 2010; 104: 440–5.
23. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. Best Pract Res Clin Anaesthesiol 2011; 25: 215–27.
24. Jepsen RM, Spanager L, Lyk-Jensen HT, Dieckmann P, Østergaard D. Customisation of an instrument to assess anaesthesiologists' non-technical skills. Int J Med Educ 2015; 6: 17–25.
25. Spanager L, Lyk-Jensen HT, Dieckmann P, Wettergren A, Rosenberg J, Ostergaard D. Customization of a tool to assess Danish surgeons' non-technical skills in the operating room. Dan Med J 2012; 59: A4526.
26. Lyk-Jensen HT, Jepsen RMHG, Spanager L, Dieckmann P, Østergaard D. Assessing Nurse Anaesthetists' Non-Technical Skills in the operating room. Acta Anaesthesiol Scand 2014; 58: 794–801.
27. Hollnagel E. Safety-I and safety–II: the past and future of safety management. Surrey, England: Ashgate, 2014.
28. Rosenstock C, Møller J, Hauberg A. Complaints related to respiratory events in anaesthesia and intensive care medicine from 1994 to 1998 in Denmark. Acta Anaesthesiol Scand 2001; 45: 53–8.
29. Cook TM, MacDougall-Davis SR. Complications and failure of airway management. Br J Anaesth 2012; 109(Suppl 1): i68–i85.
30. Shelton CL, Smith AF, Mort M. Opening up the black box: an introduction to qualitative research methods in anaesthesia. Anaesthesia 2014; 69: 270–80.
31. O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. Standards for reporting qualitative research: a synthesis of recommendations. Acad Med 2014; 89: 1245–51.
32. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33: 159–74.
33. Hull L, Arora S, Symons NRA, Jalil R, Darzi A, Vincent C, Sevdalis N. Delphi Expert Consensus Panel. Training faculty in nontechnical skill assessment: national guidelines on program requirements. Ann Surg 2013; 258: 370–5.
34. Hsieh H-F, Shannon SE. Three approaches to qualitative content analysis. Qual Health Res 2005; 15: 1277–88.
35. Manser T, Harrison TK, Gaba DM, Howard SK. Coordination patterns related to high clinical performance in a simulated anesthetic crisis. Anesth Analg 2009; 108: 1606–15.
36. Burtscher MJ, Wacker J, Grote G, Manser T. Managing nonroutine events in anesthesia: the role of adaptive coordination. Hum Factors 2010; 52: 282–94.

37. Bateson G. Steps to an ecology of mind: collected essays in anthropology, psychiatry, evolution, and epistemology. London: University of Chicago Press, 1972.
38. Kneebone R. Total internal reflection: an essay on paradigms. Med Educ 2002; 36: 514–8.
39. Weller J, Henderson R, Webster CS, Shulruf B, Torrie J, Davies E, Henderson K, Frampton C, Merry AF. Building the evidence on simulation validity: comparison of anesthesiologists' communication patterns in real and simulated cases. Anesthesiology 2014; 120: 142–8.
40. Dieckmann P, Manser T, Wehner T, Rall M. Reality and fiction cues in medical patient simulation: an interview study with anesthesiologists. J Cogn Eng Decis Mak 2007; 1: 148–68.

Appendix 1

Technical skills rating instrument

Item	Description
1	Asks nurse anaesthetist about intubation condition
2	Inquires about anaesthetic dosage and time since administering medication
3	Optimises head and neck positioning
4	Applies optimal external larynx manipulation
5	Applies facemask ventilation with caution only as test and when patient desaturates.
6	Prioritises passive oxygenation: holds facemask in place for passive oxygenation
7	Attempts intubation only after optimising each attempt by: - Direct laryngoscopy with new person intubating, possibly with optimal external larynx manipulation. - Alternative device (video laryngoscope or intubating laryngeal mask airway). - Minimises intubation attempts as much as possible.
8	Plans to wake the patient: uses facemask ventilation when waking up the patient

3-point scale, 1 = not/insufficient performed, 2 = sufficient performed, 3 = well performed.

Appendix 2

Spearman's correlations between (a) ANTSdk categories and TS and (b) TS and NTS categories and elements

	Situation awareness	Decision making	Team working	Leadership	ANTSdk ratings (summed score of all elements)
(a)					
Situation awareness					0.596**
Decision making	0.621**				0.696**
Team working	0.563**	0.431*			0.647**
Leadership	0.650**	0.559**	0.414*		0.780**
TS ratings (summed)	0.053	−0.103	0.178	−0.013	0.106

ANTSdk category	ANTSdk element	Correlation coefficient (Spearman's)	Significance (two-tailed)
(b)			
Situation awareness		0.053	0.801
	Gathering information	0.272	0.188
	Recognising and understanding contexts	0.321	0.117

Appendix 2 (Continued)

ANTSdk category	ANTSdk element	Correlation coefficient (Spearman's)	Significance (two-tailed)
	Anticipating and thinking ahead	0.168	0.423
	Demonstrating self-awareness	−0.078	0.71
Decision making		−0.103	0.624
	Identifying options	−0.024	0.91
	Choosing, communicating and implementing decisions	0.158	0.449
	Reassessing decisions	−0.060	0.776
Team working		0.178	0.396
	Exchanging information	0.129	0.540
	Assessing competencies	−0.111	0.598
	Coordinating activities	0.074	0.725
	Supporting others	−0.102	0.628
Leadership		−0.013	0.949
	Planning and preparing	−0.125	0.551
	Prioritising	−0.026	0.900
	Identifying and utilising resources	0.036	0.864
	Using authority and assertiveness	0.214	0.305
	Providing and maintaining standards	0.101	0.632

*$P < 0.05$ (two-tailed); **$P < 0.01$ (two-tailed).