Speaking up is related to better team performance in simulated anesthesia inductions: an observational study

Kolbe, Michaela ; Burtscher, Michael J ; Wacker, Johannes ; Grande, Bastian ; Nohynkova, Renata ; Manser, Tanja ; Spahn, Donat R ; Grote, Gudela

Abstract: BACKGROUND: Our goal in this study was to test the relationship between speaking up-i.e., questioning, correcting, or clarifying a current procedure-and technical team performance in anesthesia. Hypothesis 1: team members' higher levels of speaking up are related to higher levels of technical team performance. Hypothesis 2: team members will react to speaking up by either clarifying their procedure or initiating a procedural change. Hypothesis 3: higher levels of speaking up during an earlier phase of teamwork will be related to higher levels of speaking up during a later phase. METHODS: This prospective observational study involved 2-person ad hoc anesthesia teams performing simulated inductions of general anesthesia with minor nonroutine events (e.g., bradycardia) in a large teaching hospital. Subjects were registered anesthesia nurses and residents. Each team consisted of 1 nurse and 1 resident. Synchronized video and vital parameter recordings were obtained. Two trained observers blinded to the hypotheses coded speaking up and further team communication and coordination behavior on the basis of 12 distinct categories. All teamwork measures were quantified as percentage of total time spent on the respective teamwork category. Two experienced staff anesthesiologists blinded to the hypotheses evaluated technical team performance using a Delphi-validated rating checklist. Hypotheses 1 and 3 were tested using linear regression with residents' and nurses' levels of speaking up as 2 separate predictor variables. Hypothesis 2 was analyzed using lag sequential analysis, resulting in Z values representing the extent to which the observed value for a conditional transition significantly differs from its unconditional value. RESULTS: Thirty-one nurses and 31 residents participated. Technical team performance could be predicted by the level of speaking up from nurses ($R(2) = 0.18$, $P = 0.017$) but not from residents ($R(2) = 0.19$, $P = 0.053$); this result supports Hypothesis 1 for nurses. Supporting Hypothesis 2, residents reacted to speaking up with clarifying the procedure by providing information ($Z = 18.08$, $P < 0.001$), initiating procedural change by giving instructions ($Z = 4.74$, $P < 0.001$) and team member monitoring ($Z = 3$, $P = 0.0013$). Likewise, nurses reacted with clarifying the procedure by providing or evaluating information ($Z = 16.09$, $P < 0.001$; $Z = 3.72$, $P < 0.001$) and initiating procedural change by providing assistance ($Z = 0.57$, $P < 0.001$). Indicating a trend for Hypothesis 3, nurses' level of speaking up before intubation predicted their level of speaking up during intubation ($R(2) = 0.15$, $P = 0.034$), although this did not reach the Bonferroni-corrected significance level of $P = 0.025$. No respective relationship was found for residents ($R(2) = 0.15$, $P = 0.096$). CONCLUSIONS: This study provides empirical evidence and shows mechanisms for the positive relationship between speaking-up behavior and technical team performance.

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Speaking Up Is Related to Better Team Performance in Simulated Anesthesia Inductions: An Observational Study

Michaela Kolbe, PhD,* Michael J. Burtscher, PhD,* Johannes Wacker, MD,† Bastian Grande, MD,† Renata Nohynkova, MD,† Tanja Manser, PhD,* Donat R. Spahn, MD, FRCA,† and Gudela Grote, PhD*

BACKGROUND: Our goal in this study was to test the relationship between speaking up—i.e., questioning, correcting, or clarifying a current procedure—and technical team performance in anesthesia. Hypothesis 1: team members' higher levels of speaking up are related to higher levels of technical team performance. Hypothesis 2: team members will react to speaking up by either clarifying their procedure or initiating a procedural change. Hypothesis 3: higher levels of speaking up during an earlier phase of teamwork will be related to higher levels of speaking up during a later phase.

METHODS: This prospective observational study involved 2-person ad hoc anesthesia teams performing simulated inductions of general anesthesia with minor nonroutine events (e.g., bradycardia) in a large teaching hospital. Subjects were registered anesthesia nurses and residents. Each team consisted of 1 nurse and 1 resident. Synchronized video and vital parameter recordings were obtained. Two trained observers blinded to the hypotheses coded speaking up and further team communication and coordination behavior on the basis of 12 distinct categories. All teamwork measures were quantified as percentage of total time spent on the respective teamwork category. Two experienced staff anesthesiologists blinded to the hypotheses evaluated technical team performance using a Delphi-validated rating checklist. Hypotheses 1 and 3 were tested using linear regression with residents' and nurses' levels of speaking up as 2 separate predictor variables. Hypothesis 2 was analyzed using lag sequential analysis, resulting in Z values representing the extent to which the observed value for a conditional transition significantly differs from its unconditional value.

RESULTS: Thirty-one nurses and 31 residents participated. Technical team performance could be predicted by the level of speaking up from nurses ($R^2 = 0.18$, $P = 0.017$) but not from residents ($R^2 = 0.19$, $P = 0.053$); this result supports Hypothesis 1 for nurses. Supporting Hypothesis 2, residents reacted to speaking up with clarifying the procedure by providing information ($Z = 18.08$, $P < 0.001$), initiating procedural change by giving instructions ($Z = 4.74$, $P < 0.001$) and team member monitoring ($Z = 3$, $P = 0.0013$). Likewise, nurses reacted with clarifying the procedure by providing or evaluating information ($Z = 16.09$, $P < 0.001$; $Z = 3.72$, $P < 0.001$) and initiating procedural change by providing assistance ($Z = 0.57$, $P < 0.001$). Indicating a trend for Hypothesis 3, nurses' level of speaking up before intubation predicted their level of speaking up during intubation ($R^2 = 0.15$, $P = 0.034$), although this did not reach the Bonferroni-corrected significance level of $P = 0.025$. No respective relationship was found for residents ($R^2 = 0.15$, $P = 0.096$).

CONCLUSIONS: This study provides empirical evidence and shows mechanisms for the positive relationship between speaking-up behavior and technical team performance. (Anesth Analg 2012;115:1099–108)

A growing body of research aims at understanding how medical harm can be prevented.[1–8] This is particularly relevant for highly dynamic medical settings such as anesthesia in which health care professionals work together in varying compositions for short time periods in so-called action teams.[9–11] A remarkable finding of research

From *ETH Zurich, Zurich, Switzerland; †Institute of Anesthesiology, University Hospital Zurich, Zurich, Switzerland.

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Address correspondence to Michaela Kolbe, PhD, ETH Zurich, Kreuzplatz 5, CH-8032 Zurich, Switzerland. Address e-mail to mkolbe@ethz.ch.

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on medical action teams is that something seemingly trivial such as communication is a major factor contributing to medical errors.[12–20] In surgery, for example, it is even the second major source of error after lack of competence.[12] Even if these teams have excellent preconditions, such as highly skilled and motivated team members, they may suffer from breakdowns in teamwork, e.g., due to miscommunication and a resulting lack of mutual "sense-making."[10,21–24]

One prominent communication error is the failure to speak up. In a tragic example of unsuccessful speaking up resulting in the death of a patient, a nurse observed very experienced senior anesthesiologists during the induction of general anesthesia unsuccessfully attempting to intubate a patient scheduled for a routine operation. After the patient's lungs had not been ventilated for several minutes, the nurse fetched a tracheotomy set but did not attract sufficient attention to this promising problem solution from the doctors to change their course of action.[25] That is, junior doctors or nurses may communicate an important observation only implicitly, leading to a lack of effect on the procedure.[25] This communication problem is well known in many work environments, particularly in aviation.[26–30] In medicine, the potential risks of not speaking up are increasingly acknowledged; speaking up is increasingly considered essential for error prevention and quality of care.[25,26,31,32]

In accordance with the literature, we define speaking up as explicitly communicating task-relevant observations, requesting clarification, or explicitly challenging or correcting a task-relevant decision or a procedure.[30] We assume that speaking up is particularly crucial in intense, dynamic health care contexts such as anesthesia in which nonroutine events require rapid information processing and decision making.[33] However, this assumption has not yet been formally tested. Medical research has investigated the perceived barriers to speaking up (e.g., repercussion, social rejection) and the training of how to speak up (e.g., using the 2-challenge rule) using surveys and evaluating training interventions.[34–36] An interview study found that the perceived ease of speaking up was correlated with the success of implementing a new technology for minimally invasive cardiac surgery.[21] Yet, empirical evidence for positive effects of speaking-up behavior on technical team performance has yet to be established. Addressing this research gap was the main goal of our study, i.e., we investigated the empirical relationship between observed speaking up and technical team performance. As secondary aims, we also explored the effects of speaking-up behavior on immediate team interaction and its development during different phases of teamwork.

First, on the basis of the literature suggesting that speaking up is crucial for high quality of care, we assumed that team members' (i.e., resident physicians' and nurses') higher levels of speaking up are related to higher technical team performance (hypothesis 1). Second, we were interested in the effects of speaking up on team interaction. By investigating teammates' immediate reactions to speaking up, we aimed to reveal the mechanism of why speaking up may be beneficial for performance. In line with the definition of speaking up, we assumed that team members would most likely react to it by either clarifying their procedure or initiating a procedural change (hypothesis 2). Third, we investigated the development of speaking up over the course of 2 distinct induction phases.[37,38] Previous research has shown that expressing opinions, similar to remaining silent, can become self-reinforcing.[39] Thus, we assumed that higher levels of speaking up during an earlier phase of teamwork (i.e., before intubation) would lead to higher levels of speaking up during a later phase (i.e., during intubation; hypothesis 3).

Testing our hypotheses implied 2 methodological requirements: (a) observing the actual level of speaking up and (b) using reliable markers for technical team performance. We incorporated both requirements in this observation study.

METHODS

The study was approved by the Ethics Committee of the Canton Zurich, Switzerland. Written consent was obtained from study participants. The study was registered at ClinicalTrial.gov (NCT00706108).

Study Design

The prospective observational study involved 2-person ad hoc anesthesia teams performing simulated inductions of general anesthesia with minor nonroutine events (e.g., bradycardia) in a large teaching hospital in Switzerland. We chose the simulator setting to ensure standardization of the case. An advanced cardiac life support training mannequin (MegaCode®, Laerdal, Stavanger, Norway) allowing cardiac arrhythmia simulation was extended by a noninvasive blood pressure (NIBP) and a pulse oximetry (Spo_2) simulator to be used for simulation of induction of general anesthesia. Video and vital variable recordings were obtained using a setup allowing synchronized recording and playback of video, monitor, and ventilator data. The simulation scenario was standardized and designed as a straightforward induction of anesthesia according to local standards and took place in an actual operating room (OR). To design the simulated scenario as realistically as possible, we simulated 8 nonroutine events, which are typical for inductions, within each scenario in the following order[40]: (1) Cefazolin, a cephalosporin, planned as prophylactic antibiotic on OR schedule for a patient allergic to cephalosporin (noted in the patient chart), (2) handwriting on anesthesia preoperative chart partly illegible, (3) patient moans during induction, (4) hypotension, (NIBP decreases to 60/30 mm Hg), (5) bradycardia (40 per minute), (6) airway obstruction (high airway pressure and decreased breath sounds over left chest after intubation), (7) desaturation (Spo_2 decreases to 88%), and (8) hypertension (NIBP increases to 200/150 mm Hg).

Participants

The required sample size was estimated by a priori power analysis using G*Power.[41] Because all participants were volunteers, our possible sample size was limited. Assuming a large effect size ($f^2 = 0.35$) for linear multiple regression with 2 predictors ($\alpha = 0.05$, power = 0.80), the total required sample size was 31 teams.[41] Participants were 64 staff members (32 registered anesthesia nurses, 32 resident physicians) organized in 32 teams performing a simulated induction of general anesthesia with the resident performing intubation while being assisted by

Table 1. Mean Frequency and Standard Deviations of Study Variables for Nurses and Residents

	Behavior	Example	Nurse		Resident	
			M	SD	*M*	SD
1	Instruction	"Give him the fentanyl."	0.96	0.97	6.45	2.02
2	Speaking up	"Are you sure you want to intubate right now?"	2.36	0.89	1.94	1.11
3	Planning	"When we've finished intubation we'll call for an OR nurse."	0.24	0.38	0.78	0.49
4	Monitoring	Team member watches what another team member is doing.	1.96	1.37	3.29	2.15
5	Talking to the room (action)	"I'm turning the alarm down."	2.22	1.66	4.24	1.84
6	Provide assistance	After the physician announces he/she is going to intubate, the nurse holds out the laryngoscope.	3.89	1.62	0.57	0.42
7	Information request	"Where's the defibrillator?"	1.80	1.04	4.91	1.98
8	Information evaluation	"Are you sure he has no allergies?"	2.79	1.39	2.38	1.35
9	Information upon request	Includes answering direct questions. Information is given only in response to direct questions, e.g., "the defibrillator is right behind you."	1.17	0.55	1.82	1.09
10	Gather information	Reading indicators on a monitor or patient's chart.	25.76	10.33	28.42	5.67
11	Talking to the room (information)	"He seems to feel better now."	0.70	0.67	1.67	1.05
12	Information without request	Providing information without being asked to do so, e.g., "blood pressure is okay."	3.25	1.57	4.87	2.67
	Work experience	"How many years have you been working in anesthesia?"	3.61	5.12	2.10	1.28
			M		SD	
	Technical team performance	Laryngoscopy <60 seconds; inspiratory oxygen concentration >30%; systolic blood pressure 80–140 mm Hg; heart rate 60–100 per minute; SaO_2 >95% (Appendix 1 includes complete item list).	66		10	

N = 31 teams. Teamwork and coordination behaviors (1–12) were defined as the time spent on the respective category in relation to induction duration. Technical team performance measured on a rating scale ranging from 1 to 100.

the nurse. Each team consisted of 1 nurse and 1 resident (the resident at the intubating position, nurse assisting). A consultant anesthesiologist was immediately available, if requested. Participants were only included if they had at least 3 months' clinical experience to assure sufficient familiarity with the anesthesia procedures and equipment. Participants were explicitly informed that they could withdraw from the simulation at any time. One team made use of this opportunity after the simulation, thereby reducing the final sample to 31 teams.

Team Communication and Coordination Behavior Coding

Testing hypotheses 1 and 3 required the coding of team members' speaking up. Additionally, testing hypothesis 2 required coding of further team communication and coordination behaviors to investigate how team members reacted to speaking up. We used a coding scheme capturing verbal and nonverbal interactions with 12 distinct categories (Table 1).[42] Applying an event sampling procedure, we classified each behavior according to its code (e.g., speaking up), its timing (i.e., beginning, end, duration), and the team member role (e.g., anesthesia nurse). Specifically, speaking up was coded when a team member questioned a current decision or procedure, corrected the task-relevant behavior of the other team member, or asked for a task-relevant clarification.

Coding was performed by 2 observers with a background in psychology and training in use of the coding instrument, both blinded to our hypotheses, using specialized software for behavioral observation (Interact, Mangold International, Arnstorf, Germany). Watching the videotape, the observers marked the beginning (e.g., defining the onset time when a nurse asked for task-relevant clarification) and ending of a code (e.g., when the nurse was finished asking for task-relevant clarification). For determining interrater reliability, 10% of the data were independently coded by both coders. Cohen's kappa for speaking up was 0.80; the overall Cohen's kappa was 0.77. Both values represent substantial agreement.[43]

Technical Team Performance Assessment

Because a simulated setting precludes assessment of real patient outcomes, we assessed the practical result of the anesthesia team's efforts during anesthesia induction in terms of technical team performance. Acknowledging that standards reflect an institution's accepted best practice implementing both current scientific evidence and institutional experience, we quantified technical team performance using a measure that assessed the level of agreement of team actions with the respective institutional standards for induction of general anesthesia. For this purpose, a checklist was Delphi-validated[37] by repeated assessment by experienced staff anesthesiologists. The resulting checklist included items representing (a) steps of an ideal standard anesthesia induction and for preventing errors (e.g., checking correct position of tube by auscultation), as well as (b) monitoring and reacting to adequate target values (e.g., SaO_2 > 95%). The complete performance checklist can be found in Appendix 1. Very similar checklists have already

Table 2. Intercorrelations Among Technical Team Performance and Speaking Up

Variable	*M*	SD	Technical team performance	Speaking up during complete induction (R)	Speaking up during complete induction (N)	Speaking up before intubation (R)	Speaking up before intubation (N)	Speaking up during intubation (R)	Speaking up during intubation (N)
Technical team performance	66	10	—						
Speaking up during complete induction (R)	1.94	1.11	.16	—					
Speaking up during complete induction (N)	2.36	0.89	.43*	.18	—				
Speaking up before intubation (R)	1.94	1.25	.22	.64**	.16	—			
Speaking up before intubation (N)	2.29	1.12	.18	.25	.63**	.18	—		
Speaking up during intubation (R)	1.59	1.01	.34†	.54**	.29	.30†	.26	—	
Speaking up during intubation (N)	2.65	1.43	.47**	−.022	.69**	−.02	.38*	.26	—

N = 31 teams. (R) = residents. (N) = nurses.
†*P* < 0.10. **P* < 0.05. ***P* < 0.01, 2-tailed.

been used to assess technical team performance in anesthesia.[44–47] The performance measure was applied by 2 experienced staff anesthesiologists, blinded to our hypotheses, who reviewed video, monitor, and ventilator data. Each score was compared to the respective maximum score to obtain an adjusted measure of team performance ranging between 1 and 100. A score of 100 would indicate that the team conducted the induction perfectly according to the standard and dealt optimally with the simulated nonroutine events. To establish interrater reliability, we evaluated 3 randomly selected videotapes by both raters. Interrater reliability was subsequently calculated using the ICC coefficient, which was 0.98, indicating high reliability.[48]

Statistical Analyses

In accordance with comparable studies, teamwork measures were defined as the time spent on the respective teamwork category in relation to induction duration.[20,23,37,38] For example, if an anesthesia nurse spent 1 minute of a 20-minute induction on speaking up, the speaking-up score was 5%. These relative durations allowed for controlling for variation in duration of the induction. The percentage of team communication and coordination behavior was arcsine-transformed, as recommended for proportional data.[49]

All hypotheses were tested separately for residents and nurses, that is, residents' and nurses' speaking-up behavior was not aggregated. After visually inspecting the data by means of data scatter plots revealed no indications for nonlinear relationships, hypotheses 1 and 3 were tested using linear regression analysis (PASW Statistics 18, SPSS Inc., Chicago, IL). Specifically, hypothesis 1 was tested with speaking up as predictor and technical team performance as criterion. Testing hypothesis 3 included speaking up before intubation as predictor and speaking up during intubation as criterion. Hypothesis 2—proposing that team members would most likely react to speaking up by either clarifying their procedure or initiating a procedural change—was analyzed via lag sequential analysis to determine whether speaking up was significantly more or less often than expected followed by one of the other 11 categories.[50] Of those 11 categories, "information request," "information evaluation," and "providing information upon request" are *clarifying the procedure*, whereas "instruction," "planning," and "provide assistance" are *initiating procedural change*. The lag sequential analysis is explained in Appendix 2. Its results are *Z* scores: significant positive *Z* scores indicate that a specific behavior of one team member is followed significantly more often by a specific behavior of the other team member. By contrast, negative *Z* scores indicate that a specific behavior of one team member is followed significantly less often by a specific behavior of the other team member.

RESULTS

Duration of the 31 simulations ranged from 18 to 33 minutes (M = 21, SD = 4). In total, 28,883 distinct team communication and coordination behaviors were coded. Table 1 shows the descriptive statistics of the study variables; Table 2 shows the intercorrelations among technical team performance and speaking up. Residents' and nurses' levels of speaking up were not significantly correlated (r = 0.18; P = 0.17), and nurses showed higher levels of speaking up than residents.

Speaking Up and Technical Team Performance

Hypothesis 1, which stated that team members' (i.e., resident physicians' and nurses') higher levels of speaking up are related to higher technical team performance, was tested with a hierarchical linear regression. This regression model[a] is shown in Table 3 (n = 31 teams). In step 1, we entered nurses' levels of speaking up as predictor of technical team performance in the regression term because they had the highest levels of speaking up. Nurses' levels of speaking up significantly predicted technical team performance (R^2 = 0.18, P = 0.017). The value of 0.43 indicates that as speaking up from nurses increased by one standard deviation ($SD_{arcsine}$ = 0.009), technical team performance (SD = 9.99) increased by 0.43 standard deviations, i.e., by 4.229. Table 4 shows respective examples of nurses' levels of speaking up in the highest-, medium-, and lowest-performing teams.

In step 2, we entered residents' levels of speaking up as predictors of technical team performance in the regression term to determine the additional predictive value of the residents' levels of speaking up. Although this regression model yielded a trend for the proposed assumption, it was not statistically significant (R^2 = 0.19, P = 0.053).

That is, technical team performance could be predicted by the level of speaking up from nurses but not from residents.

[a]There was no multicollinearity within our data (VIF values ranging from 1.00 to 1.032; tolerance statistics ranging from 0.969 to 1.00). The assumption of independent errors was met (value of Durbin–Watson statistic = 2.3).[51]

Table 3. Linear Regression of Speaking Up on Technical Team Performance

	B	SE B	Beta	P	97.5% CI of B* Lower limit	97.5% CI of B* Upper limit	R^2	F
Step 1				0.017			0.18	6.44
Intercept	54.99	4.78		0.000	43.71	66.28		
Nurses' level of speaking up	481.48	189.80	0.43	0.017	32.83	930.14		
Step 2				0.053			0.19	3.27
Intercept	53.85	5.32		0.000	41.26	66.43		
Nurses' level of speaking up	463.66	195.24	0.41	0.025	1.25	926.08		
Residents' level of speaking up	80.92	155.18	0.09	0.606	–286.61	448.45		

N = 31 teams. CI = confidence interval.
*Bonferroni-corrected for 2 comparisons.

Table 4. Examples of Technical Team Performance and Nurses' Level of Speaking Up in the Highest, Medium, and Lowest Performing Team

	Technical team performance	Nurses' level of speaking up
Highest-performing team (case 23)	93	3.37
Medium-performing* team (case 12)	65	2.10
Lowest-performing team (case 8)	48	1.71

Level of speaking up was defined as the time spent on speaking up in relation to induction duration. Technical team performance measured on a rating scale ranging from 1 to 100.
*Median of technical team performance = 0.658

Immediate Effects of Speaking Up on Team Interaction

Hypothesis 2 proposed that team members would react to speaking up with either clarifying the procedure or initiating a procedural change. Applying lag sequential analysis (Appendix 2), we explored the team members' immediate reactions to speaking up. Residents reacted to speaking up with clarifying the procedure by providing information ($Z = 18.08$, $P < 0.001$), with initiating procedural change by giving instructions ($Z = 4.74$, $P < 0.001$), and also with team member monitoring ($Z = 3$, $P = 0.0013$). Likewise, nurses reacted with clarifying the procedure by providing information ($Z = 16.09$, $P < 0.001$) and information evaluation ($Z = 3.72$, $P < 0.001$) and with initiating procedural change by providing assistance ($Z = 0.57$, $P < 0.001$) but not by giving instructions (Table 5). These results support hypothesis 2.

Development of Speaking Up

Hypothesis 3, which stated that higher levels of speaking up in an earlier phase of the induction (before intubation) are related to higher levels of speaking up in a later phase (intubation), was tested with 2 linear regressions. Both regression models are shown in Table 6.

In the first regression we predicted nurses' speaking up during intubation. In step 1 we entered nurses' levels of speaking up before intubation. This model yielded a trend for the proposed assumption, but was not statistically significant when applying the Bonferroni correction for 2 comparisons ($R^2 = 0.15$, $P = 0.034$). In step 2 we entered residents' levels of speaking up before intubation. This model was not statistically significant ($R^2 = 0.15$, $P = 0.096$).

In the second regression we predicted residents' speaking up during intubation. In step 1 we entered residents' levels of speaking up before intubation. This model was not statistically significant ($R^2 = 0.09$, $P = 0.099$). In step 2 we entered nurses' levels of speaking up before intubation. This model was not significant ($R^2 = 0.13$, $P = 0.13$) either.

In summary, we found a trend indicating that nurses' previous level of speaking up, not the level of their respective colleague, predicted later occurrence of speaking up.

DISCUSSION

Three significant findings resulted from our simulation-based observational study. The first and main finding was a significant positive association between nurses' overall level of speaking up and technical team performance. Second, further analyses of team interaction by means of lag sequential analysis showed that speaking up by nurses as well as by residents resulted in clarifications of the procedure (e.g., providing and evaluating information) and initiated procedural change (e.g., residents gave instructions, nurses provided assistance). Third, because there was a tendency for the nurses' level of speaking up before intubation to be associated with their level of speaking up during subsequent intubation, our results also point to the potential value of early speaking up.

Empirical Evidence for Positive Effects of Speaking Up on Team Performance

Our findings are a meaningful contribution to research on improving communication and preventing medical harm in anesthesia because they provide the first empirical evidence for the positive relationship between actual speaking-up behavior and technical team performance. Moreover, they also show how speaking up affects immediate team interaction and how it develops over the course of anesthesia induction. Previous literature has focused on (a) explaining why speaking up is essential for preventing medical harm and ensuring good quality of care,[25,31,32,52] (b) investigating the perceived barriers of speaking up,[34,35,53–55] (c) the impact of the perceived ease of speaking up on performance,[21] and (d) the training of how to speak up,[36] but not on the effects of training on patient outcomes. The positive effects of the actual speaking-up behavior on performance had been suggested but not been formally studied. Through observing the level of naturally occurring speaking up and using quantifiable markers for technical team performance, our study provides empirical evidence for an association of speaking

Table 5. *Z* Values for the Criteria Speaking up for Lag 1

	Target behavior by respective other team member											
Criterion behavior	Instruction	Speaking up	Planning	Monitoring	Talking to the room (action)	Provide assistance	Info request	Info evaluation	Info upon request	Talking to the room (info)	Gather info	Info without request
Following behavior by nurse												
Speaking up as previous act by resident	–1.19	–1.69	0	1.67	–1.69	3.57**	–1.19	3.72**	16.9**	–1.67	–0.92	–1.69
Following behavior by resident												
Speaking up as previous act by nurse	4.74**	–0.99	0	3*	–1.79	0	–1.74	0.16	18.08**	–2.32*	1.53	–1.48

N = 31 teams. Info = information.
**P* < 0.01. ***P* < 0.001 (one-sided).

Table 6. Linear Regression of Speaking Up Before Intubation on Speaking Up During Intubation

					97.5% CI of *B**			
	B	SE B	Beta	*P*	Lower limit	Upper limit	R^2	*F*
Predicting nurses' speaking up during intubation								
Step 1				0.034			0.15	4.93
Intercept	0.02	0.01		0.011	0.00	0.03		
Nurses' level of speaking up before intubation	0.49	0.22	0.38	0.034	–0.03	1.01		
Step 2				0.096			0.15	2.55
Intercept	0.02	0.01		0.013	0.00	0.03		
Nurses' level of speaking up before intubation	0.51	0.23	0.40	0.032	–0.03	1.05		
Residents' level of speaking up before intubation	–0.11	0.20	–0.10	0.596	–0.58	0.37		
Predicting residents' speaking up during intubation								
Step 1				0.099			0.09	2.91
Intercept	0.01	0.00		0.002	0.00	0.02		
Residents' level of speaking up before intubation	0.24	0.14	0.30	0.099	–0.09	0.58		
Step 2				0.133			0.13	2.17
Intercept	0.01	0.01		0.110	–0.00	0.02		
Residents' level of speaking up before intubation	0.21	0.14	0.26	0.154	–0.13	0.55		
Nurses' level of speaking up before intubation	0.19	0.16	0.21	0.249	–0.19	0.57		

N = 31 teams. CI = confidence interval.
*Bonferroni-corrected for 2 comparisons

up with better technical team performance and suggests possible explanations for its effects on, and development during, teamwork. Specifically, our data suggest that it is the level of speaking up by the assisting nurses that matters for team performance.

The particular importance of nurses' speaking up might not only reflect their more extensive work experience in our study population (Table 1) but also their functional role-behavior adapted to the specific conditions of a teaching hospital OR setting. In the investigated setting, resident physicians were performing simulated clinical procedures while being assisted by nurses. That allowed the assisting person to monitor the overall situation, which was a precondition for speaking up.[56] Possibly, if a nurse had performed the intubation while being assisted by a resident, the speaking up levels of the resident would have been similarly relevant for performance. Alternatively, in case of a more complex scenario (e.g., cannot intubate, cannot ventilate), which mostly requires an attending physician to monitor or assist the team, his or her levels of speaking up would probably have also been relevant to performance.

The results of the lag sequential analyses enhance our understanding of the mechanism through which speaking up has an impact on technical team performance, i.e., it results in clarifications of the procedure and initiates procedural change. Residents also reacted with monitoring, indicating that speaking up can result in observing the other team member. Some responses to speaking up were identical for residents and nurses; others were different. Residents reacted with monitoring and giving instructions, whereas nurses reacted with providing assistance. The latter result again reflects the functional work roles in anesthesia teams. Residents held the responsibility for the intubation and were manually involved and thus very concentrated on performing the laryngoscopy. This may have narrowed their range of possible responses to nurses' speaking up. Whereas providing assistance may not have been possible for residents, monitoring and giving instructions were. Nurses, on the other hand, monitored the resident during intubation and were thus able to respond to residents' speaking up with providing assistance.

With respect to the development of speaking up, the trends resulting from regression analysis suggest that it can be important for nurses to start speaking up early because speaking up before intubation was associated with speaking up during intubation. This result could indicate that

speaking up early may set the stage for being more at ease and likely to apply this technique later on. With regard to training, these results could indicate that anesthesia teams should be encouraged to get comfortable with speaking up early instead of waiting until the first attempt to speak up until a potentially critical situation occurs. In the clinical work environment, speaking up could already be initiated explicitly during the World Health Organization (WHO) Surgical Safety Checklist–based "time out" during which the OR team has the chance to assemble and to discuss anticipated critical patient issues before skin incision.[57] However, because our study only found a trend for the importance of earlier speaking up by conservative interpretation, further research is needed to draw a more robust conclusion.

Strengths and Limitations of the Study

This is a prospective observational study that directly assessed dynamic team processes instead of relying on team members' self-reports, which provide only static snapshots.[52] Through observing the actual level of speaking up and by using quantifiable markers for technical team performance, our study provides empirical results on the association between speaking up and performance. The sequential analysis of team interaction provided insights in the immediate effects of speaking up.

Our study has several limitations. First, our findings on speaking up during a simulated induction cannot be generalized to speaking-up behavior in real clinical settings. Although observations of simulated cases are a good opportunity to assess the nature of people's behavior in environments similar to their work and to provide a certain degree of standardization, we cannot exclude that our study participants may have behaved differently if the simulated nonroutine situations had happened during real clinical intubations. For example, knowing that no real patient was potentially at risk may have influenced the participants' motivation to speak up. Second, the correlational design does neither allow for conclusions about causal relationships between speaking up and team performance nor allow for conclusions about the preconditions for speaking up. Given that nurses were more experienced than residents and only nurses' levels of speaking up were positively related to performance, the role of work experience as a potential precondition for effective speaking up should be explored in further studies. Third, to perform the statistical analysis reported here, we quantified speaking up as the time spent with questioning a current decision or procedure, correcting task-relevant behavior, or asking for a task-relevant clarification in relation to induction duration. Although only task-relevant behaviors were coded, some of them may have been more important than others, and some shorter speaking-up behaviors may have been more important than longer ones. Finally, the limited sample size in combination with resident participants (instead of senior anesthesiologists to whom the nurses may have been more reluctant to speak up to) may have further reduced the generalizability of our findings and prevented us from analyzing the potential causal link among speaking up, team interaction, and team performance by means of statistical mediation analysis.

Implications for Future Research

Our study offers directions for future research on speaking up. First, as we tested our hypotheses in a simulated setting, further research should investigate whether our findings can be replicated in the clinical setting, ideally including larger sample sizes from several hospitals. This would allow for relating interaction patterns to further organizational variables such as psychological safety, that is, the shared belief held by team members that they are safe for interpersonal risk taking.[58] This would increase our understanding of what organizations must provide to anesthesia team members to feel at ease with speaking up. Second, interventional studies should test the effects of "trainable" speaking up on performance—also with respect to optimal amount, timing, and quality—in a simulated setting using a randomized control group design. This would allow us to draw causal conclusions on the impact of speaking up on performance. Third, the aforementioned interventional studies should be followed by comparable studies in clinical settings to examine the transferability of the respective findings into clinical practice and the impact on real patient outcomes.

CONCLUSION

We think that by providing empirical evidence for the positive association of speaking up with team performance and by showing some of the mechanisms that might explain this association, the current research contributes to the understanding of the impact of speaking up in anesthesia. We hope that our work will inspire additional research and application of speaking up to help expand its utility for patient safety.

Appendix 1. Technical Team Performance Measure for Anesthesia Induction (Adapted for Simulated Inductions)

No.	Item
	Check circuit/ventilator:
1	Composition
2	Reservoir bag and exhalation check valve
3	Leak tests
4	Verify ventilator function
	Check anesthesia equipment:
5	Verify suction device
6	Check laryngoscope
7	Verify anesthesia equipment: Endotracheal tube in appropriate size
8	Mask attached to circuit
9	Size of mask fits patient
10	Guedel airways available
11	Ambu bag available
12	Stylet available (in case of rapid sequence induction)
13	Infusion pump available and programmed
	Drugs drawn up before induction:
14	Opioid
15	Intravenous anesthetic
16	Neuromuscular blocker
	At arrival / before anesthesia induction:
17	Talk to patient
18	Anesthesia staff introduce themselves to patient
19	Verify patient identity
20	Ask about preoperative fasting
21	Announce manipulation on awake patient
22	Verify whether operating table can be tilted (mechanics OK)
23	Optimizing head position
24	Visual inspection of mouth, teeth, airway
25	Verify protocol and informed consent for the procedure
26	Intubating anesthesiologist wears gloves
27	All team members wear gloves if contact with blood / body fluids is possible
28	Intubating anesthesiologist wears face mask
	Monitoring prior to induction:
29	Electrocardiogram
30	Pulse oximetry
31	FiO_2 sensor
32	Noninvasive arterial blood pressure measurement
33	Nerve stimulator (neuromuscular monitoring)
	Induction of anesthesia:
34	Intravenous line in situ, running
35	Infusion running well
36	Suction at hand
37	Noninvasive blood pressure measurement set to 2-minute intervals during anesthesia induction
38	Oxygen administration: mask sufficiently tight
39	Oxygen administration: sufficient amount of time
40	Oxygen administration: FiO_2 80%–100%
41	Oxygen administration: flow > 8l per minute
42	Adequate dosage: opioid (fentanyl 1–3 μg/kg)
43	Adequate dosage: intravenous anesthetic
44	Lidocaine before propofol
45	Check eyelid closure reflex before mask ventilation
46	Mask ventilation possible before administration of neuromuscular blocker
47	Adequate dosage of neuromuscular blocker
48	Adequate mask ventilation
49	Verify neuromuscular block before intubation
50	Adequate anesthesia depth before intubation
51	Laryngoscopy <60 seconds
52	Apnea <90 seconds
53	No tolerance of SaO_2 decrease below 92%
54	Take off contaminated gloves after intubation before anything else is touched
55	Check endotracheal tube position: depth from teeth
56	Check endotracheal tube position: auscultation
57	Check endotracheal tube position: capnography
58	Check endotracheal tube position: verify cuff pressure
59	Tape endotracheal tube
60	Ventilator settings adequate (general rule: tidal volume 8 mL/kg, respiratory rate 8–12 per minute, positive end-expiratory pressure 0–5 cmH_2O)
61	Ventilator: alarm thresholds set
62	If additional neuromuscular block indicated: adequate subsequent dose
63	Gastric tube (if indicated)
64	Adequate analgesia before skin incision
	Inspection of patient after induction:
65	Check pulse
66	Give nonanesthesiologists permission for manipulation on patient
67	Check potential pressure marks, check position of patient
68	Eye protection (with ointment or tape)
	Adequate target values:
69	Inspiratory O_2-concentration >30%
70	Systolic blood pressure 80–140 mm Hg or mean arterial blood pressure (MAP) >50 mm Hg (ASA 1 patients)
71	Heart rate 60–100 per minute
72	SaO_2 >95%
73	$EtCO_2$ 30–40 mm Hg (4–5.4 kPa)

Appendix 2. Performing the Lag Sequential Analysis

Step	Procedure
1. Determining number of required event sequences	The minimum number of event sequences required for meaningful interpretation of lag sequential analysis results can be determined using the following formula: $N_s = 9m^2/(m-1)$, where $m = k(k-1)L - 1$.[50] N_s refers to the minimum number of coded event sequences that are necessary for meaningful interpretation. L indicates the length of the sequence (the lag), and k the number of the codes used. Applying this formula to the lag1 analysis (L = 1) and the 12 categories for each resident and nurse (k = 24), performing the lag 1 analysis required 226 event sequences. Given the available 28,883 coded event sequences, performing this analysis was justified.
2. Generating interaction matrix	Using Interact, an interaction sequence matrix of team communication and coordination behaviors was generated. Because 12 categories were included for both resident and nurse, this resulted in a 24 × 24 behavior matrix.
3. Testing transitions for significance	Transition frequencies were determined for each pair of codes and Z statistics were applied to test whether the transitional probabilities differed significantly from the unconditional probability for the following code. Significant positive Z scores indicate that a specific behavior of one team member is followed significantly more often by a specific behavior of the other team member. Negative Z scores indicate that a specific behavior of one team member is followed significantly less often by a specific behavior of the other team member.
4. Alpha correction	Because Interact does not allow for alpha corrections in multiple comparisons, we applied the Bonferroni correction and divided Alpha by the number of comparisons (i.e., 24 comparisons—speaking up by each resident and nurse followed by all 12 coded behaviors), which resulted in 0.00208 as the criterion for significance.[51]

DISCLOSURES

Name: Michaela Kolbe, PhD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: Michaela Kolbe has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
Name: Michael J. Burtscher, PhD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: Michael J. Burtscher has seen the original study data, partly reviewed the analysis of the data, and approved the final manuscript.
Name: Johannes Wacker, MD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: Johannes Wacker has seen the original study data and approved the final manuscript.
Name: Bastian Grande, MD.
Contribution: This author helped conduct the study.
Attestation: Bastian Grande approved the final manuscript.
Name: Renata Nohynkova, MD.
Contribution: This author helped conduct the study.
Attestation: Renata Nohynkova approved the final manuscript.
Name: Tanja Manser, PhD.
Contribution: This author helped design the study and write the manuscript.
Attestation: Tanja Manser approved the final manuscript.
Name: Donat R Spahn, MD, FRCA.
Contribution: This author helped write the manuscript.
Attestation: Donat R. Spahn approved the final manuscript.
Name: Gudela Grote, PhD.
Contribution: This author helped design the study and write the manuscript.
Attestation: Gudela Grote approved the final manuscript.
This manuscript was handled by: Sorin J. Brull, MD, FCARCSI (Hon).

CURRENT AFFILIATIONS

Michael J. Burtscher is currently affiliated with Institute of Psychology, University of Zurich, Zurich, Switzerland. Johannes Wacker is currently affiliated with Institute of Physicians for Anaesthesia and Intensive Care, Klinik Hirslanden Zurich, Zurich, Switzerland. Tanja Manser is currently affiliated with Département de Psychologie, Industrial Psychology and Human Factors, University Fribourg, Fribourg, Switzerland.

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