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Impact of a large interprofessional simulation-based training course on communication, teamwork, and safety culture in the operating theatre: a mixed-methods interventional study

Short title: Impact of interprofessional training on communication, teamwork and safety in the operating theatre

Julien PICARD^{1,2*}, Jean-Noël EVAÏN^{1,2}, Charlène DOURON¹, Éloïse MAUSSION¹, Xavier STIHLE¹, Pauline MANHES¹, Pauline ROMEGOUX¹ ; Aline BARON¹, Claire CHAPUIS^{2,3}, Céline VERMOREL^{2,4}, Benjamin GAREL⁵, Jean-Luc FAUCHERON⁶, Pierre BOUZAT¹, Jean-Luc BOSSON^{2,4}, Pierre ALBALADEJO^{1,2}

¹ Department of Anaesthesiology and Critical Care Medicine and Simulation Centre, Grenoble-Alpes University Hospital, Grenoble, France

² ThEMAS, TIMC, UMR, CNRS 5525, Grenoble-Alpes University, Grenoble, France

³ Department of Pharmacy, Grenoble-Alpes University Hospital, Grenoble, France

⁴ Department of Biostatistics, Grenoble-Alpes University Hospital, Grenoble, France

⁵ Hospital administrator, Grenoble-Alpes University Hospital, Grenoble, France

⁶ Department of Surgery, Grenoble-Alpes University Hospital, Grenoble, France

***Corresponding author:**

Julien Picard

Department of Anaesthesiology and Critical Care Medicine

Grenoble-Alpes University Hospital, Grenoble, France.

Email: JPicard@chu-grenoble.fr

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BACKGROUND: Communication and teamwork are critical non-technical skills in the operating theatre. However, prevention of events associated with communication failures by large simulation-based programs remains to be evaluated. The objective was to assess the impact of an interprofessional simulation-based training course on communication, teamwork, checklist adherence, and safety culture.

METHODS: We aimed to assess the impact of an interprofessional simulation-based training course on communication, teamwork, checklist adherence, and safety culture. We conducted a before-and-after interventional study based on a mixed-methods approach combining qualitative and quantitative evaluation criteria. The study was performed in a University Hospital with 39 operating theatres operated by 300 providers before (period 1) and after (period 2) an interprofessional simulation-based training course. Surgical procedures were observed, and the primary outcome measure was the rate of procedures with at least one communication failure associated with adverse event. Additional outcomes measured included the rate of or other communication failures, checklist adherence, while teamwork and safety culture as assessed by questionnaires.

RESULTS: In total, 46 970 communication episodes were analysed during 131 (period 1) and 122 (period 2) surgical procedures. One hundred sixty-four professionals attended 40 simulation-based sessions. The rate of procedures with at least one communication failure associated with adverse events was not significantly different between the 2 periods (38% in period 1 and 43% in period 2; $P = 0.47$). Nevertheless, the rate of communication failures reduced between period 1 and 2 (8117 / 28 303 (29%) vs. 3868 / 18 667 (21%), respectively; $P < 0.01$). Teamwork scores and checklist adherence increased significantly after the intervention (8.1 (7.2 to 8.7) in period 1 vs. 8.6 (8.0 to 9.2) in period 2; $P < 0.01$ and 17% (0-

35%) in period 1 vs. 44% (26-57%) in period 2; $P < 0.01$). Safety culture ratings did not change significantly.

CONCLUSION: This study shows that although the rate of procedures with at least one communication failure associated with adverse event (primary endpoint) was not significantly different, a large interprofessional simulation-based training course has a positive effect on communication failures, teamwork, and checklist adherence.

KEYWORDS: Communication, Interprofessional, Safety Culture, Simulation-based Training, Teamwork

INTRODUCTION

Adverse events in the operating theatre (OT) are frequently associated with failure in non-technical skills (NTS) [1]. Among them, failure in communication and teamwork are leading causes of intraoperative errors [2-4]. More than 30% of communication episodes in the OT can be considered as having failed (ineffective, inducing waste, violation to procedures, adverse events) [5] and composite measures of teamwork are significantly associated with complication or death [6].

Healthcare team training has been shown to be an effective intervention to improve behaviours and learning processes with potential benefits for patients [7]. Simulation-based training programs seem to improve OT performance, NTS and teamwork [8-10]. However, transfer from multidisciplinary simulation training to the OR setting of practice and patient outcomes' improvement is still unclear [11, 12].

Several studies reported that checklists significantly improve information sharing among OT teams and thus safety and outcomes in patients undergoing surgery and other complex procedures [13, 14].

The implementation of large educational programs and adherence to tools to improve patient safety are confronted by several obstacles: multiple surgical specialties, cultural differences between anaesthesia and surgical teams, different backgrounds within OT teams (physicians, nurses, technicians...). In this context, the value of large interprofessional educational programs has rarely been assessed.

We conducted an interventional study based on a mixed-methods approach to assess the impact of an interprofessional simulation-based training course (ITC) on communication, teamwork, checklist adherence, and safety culture at the level of a large university hospital.

METHODS

We conducted a before-and-after interventional study evaluating the impact of simulation-based ITC on communication, teamwork, checklist adherence, and culture of safety in the OT. Study ethics approval was obtained on the 31st of October 2013 (CECIC Rhône-Alpes-Auvergne, Clermont-Ferrand, IRB 5891, Chairperson Dr C. Dualé). Information letter was given to patients before surgical procedure. The study was registered on Clinicaltrials.gov (NCT02152436).

Institutional context

The study was driven in the Grenoble-Alpes University Hospital, a 2100-bed structure, which serves a population of 2 million persons. This study was carried out in 39 OTs operated daily by 300 healthcare professionals (including surgeons, anaesthetists, residents, specialised nurses and other professionals). Annually, 29 000 adult patients are admitted to undergo 11 surgical specialties procedures.

Implementation of the intervention

The study was conducted and supported by the hospital and university and organised jointly with the management of the hospital. The program has thus been announced by institutional electronic mailing to OT healthcare professionals before its beginning. Information sessions specifically addressed surgical teams in their own services, the anaesthesia department, as well as OT professionals. Posters and information flyers were pinned in appropriate places to recruit professionals willing to attend the training sessions. Written informed consent was obtained from the participants.

Establishing a steering committee

A multidisciplinary steering committee was created to develop and validate the assessment grids, the observers' training process and the simulation-based training course.

Study design

We used a mixed-methods approach combining qualitative and quantitative evaluation criteria. Audits and surveys to assess quality of communication, teamwork, checklist adherence, and safety culture were performed during surgical procedures before (period 1) and after (period 2) a simulation-based ITC on healthcare professionals. Period 1 was from January to March 2014 and period 2 from January to June 2015. ITC was conducted from April to December 2014.

Observers' training

Eight observers (4 residents in anaesthesia, 3 nurse anaesthetists and 1 nurse, usually working in these OTs) performed audits and surveys. The observers were not the same at the two periods as the two study periods were 12 months apart. Therefore, a standardised three-step training was proposed to the observers under the supervision of a member of the steering committee. The first step consisted in an individual learning of the assessment grids where each observer learned the criteria for data collection and trained to use the assessment grids at different moments of the surgery. The second step was a two-by-two observers rating work followed by a debriefing discussion to obtain agreement on the ratings. The pairs of observers practiced auditing real surgical interventions together. The assessment grids were then adapted to minimise inter-observer variability. The difference between observers was measured by the reported frequency and characteristics of communication episodes. The third step was a repeated double assessment of teamwork in real situations by two different

observers to ensure the reproducibility was not changing over time. Reproducibility between observers, two-by-two was checked on 33 surgical procedures (23 in period 1 and 10 in period 2). During each period, all professionals in the ORT were informed that audits and surveys were ongoing. The mean difference between 2 observers was measured for the number of communication episodes within the team and the rate of communication failures (**Supplemental data**).

Surgical procedures

The observed surgical procedures were randomly selected to be representative of the actual distribution of surgical procedures in our facility. An observation day was randomly assigned to each of the different OTs resulting in 131 (period 1) and 122 (period 2) audited surgical procedures. The observer was placed in a corner of the OT during the audit. They remained silent and did not intervene at any time during the surgical procedure. To facilitate the analysis of the data and because of different background and training, healthcare providers in the OT were identified as being part of the “surgical team” (surgeon, resident, OT nurses) or the “anaesthesia team” (anaesthetist, resident, nurse anaesthetist). Procedures were divided in three parts: T1 (between patient admission in the OT and the beginning of the procedure), T2 (between the beginning and the end of the procedure) and T3 (between the end of the procedure and transfer to the post-anaesthesia care unit).

Data collection

Data were collected on demographic clinical characteristics of the patients and surgical procedures (ASA score, Lee score, Surgical APGAR score [15]). Communication episodes, teamwork and adherence to surgical safety checklists were recorded and reported on assessment grids.

Audits and surveys

During both periods, one observer was present during the entire procedure to collect characteristics of the procedure and assess communication episodes and checklists adherence. Individual semi-structured interviews were conducted to complete surveys (**Appendix 1**). The same observer interviewed healthcare professionals in charge to assess teamwork and leadership. A French translation of the Hospital Survey on Patient Safety Culture (HSPSC) [17] was sent to all healthcare professionals working in the institution (**Appendix 2**).

Communication assessment

The number of communication episodes between professionals involved in the procedure was recorded. A proper communication was defined as an entire verbal exchange between the right healthcare professionals, at the right moment, about the right patient undergoing the surgical procedure and leading to an adapted response. Communication failures were classified using a standardised evaluation adapted from Lingard's theory-based instrument [5, 18] (**Appendix 1**). Six categories of communication failures were reported: "Not a professional purpose", "Related to another patient", "Wrong timing", "Wrong audience", "Ambiguous" and "Incomplete content". Seven types of consequences of these communication failures were considered: "No consequences", "Adverse event", "Delay", "Impact on the procedure", "Tension", "Resource waste" and "Other". Occurrence of disruptive factors defined as unexpected events or situations that may interfere with the procedure was also collected (technical problems, professionals not usually members of the team).

Teamwork assessment

Teamwork assessment was performed through a semi-structured interview according to a grid adapted from Mazzocco and colleagues [6]. The reported teamwork skills were team preparation including briefing quality, information sharing, free expression, respect, trust in the team. Each skill was scored between 0 and 10 by at least 2 members of the team interviewed at the end of the procedure (0 meaning “disagree” and 10 meaning “totally agree”).

Leadership assessment

After each surgical procedure the healthcare providers were asked to score the “Leader designation” item in the grid adapted from Mazzoco between 0 and 10 (0 for “no leader was designated during the procedure” and 10 for “a leader was formally designated during the procedure”) [6]. Each interviewee was asked to name the leader (surgeon, resident in surgery, anaesthetist, resident in anaesthesia, nurse anaesthetist, nurse). The leadership was considered as effective if the “Leader designation” score was > 5/10 and a leader was formally identified by the healthcare providers.

Surgical Safety checklist adherence

The use of the safety checklist in the OT was recorded by observers [14]. The modalities and completeness of use were reported at three periods of the surgical procedure: before induction, before incision and before patient’s discharge from the OT.

Disruptive factors

During the surgical procedure, some events that could have influenced a given communication episode and/or the consequences of communication failures were recorded as “Disruptive factors”. They were not planned before the procedure but were noticed by the

raters. All disruptive factors were reported by the observers as unpredicted events that could have influenced the communication and/or the consequences of communication failures. They ranged from technical problems to arrival of new providers working in the OR for their first day, or last-minute change in OT planification.

Simulation-based multidisciplinary training course

Half-day sessions included a training on the educational program with posters and audio-guides followed by an interprofessional high-fidelity full-scale simulation session. The educational tools included a series of 17 posters with key messages recorded on audio-guides [19]. Each poster and its thirty to fifty seconds soundtrack contained information about patient safety in the OT related to communication, teamwork, checklist, and safety culture. A facilitator was present to answer any questions (**Appendix 3**). Participants were allowed to read the posters for up to fifty minutes.

The interprofessional simulation sessions were performed in a simulation centre. They included a briefing, a high-fidelity full-scale simulation scenario and a teamwork-oriented debriefing. The participants were told to focus on non-technical skills and not on technical performance. Debriefings were performed by experienced instructors in simulation. Three simulation scenarios based on teamwork were created: “Haemorrhage during surgery with dysfunction of the surgical suction device”, “Identity mismatch in a patient needing an emergent neurosurgical procedure”, “Latex anaphylaxis”. Each participant was subjected to one only scenario. All three scenarios included procedural tasks and specifically designed aspects to trigger communication episodes on an unexpected course of events and forcing the participants to work as a team. The simulations were performed on the Laerdal SimKelly® and SimMan® high-fidelity manikins. A realistic OT environment was reproduced. Only one

scenario was used during each training session. Each scenario involved at least 4 professionals: 2 in the “surgical team” and 2 in the “anaesthesia team”.

Primary and secondary endpoints

The primary endpoint was the frequency of surgical procedures having at least one communication failure with consequences. The secondary endpoints were the rate of communication failures, the teamwork assessment scores, surgical safety checklist adherence, and safety culture surveys.

Power calculation

Data on the number of communication episodes between the different healthcare providers during a surgical procedure is not actually available. According to Lingard, we assumed that 30% of the surgical procedures would include at least one communication failure with consequences [5, 18]. We hypothesised that our intervention would reduce the proportion of surgical procedures with at least one communication failure with consequences to 15% with an alpha risk of 0.05 and a power of 80%. We therefore planned to include 125 surgical procedures in each period.

Statistical Analysis

Data were analysed using Stata 13.0 (Stata Corp, College Station, Texas). Descriptive statistics included frequencies and percentages for categorical variables and median and interquartile range (IQR 25th to 75th percentile) for continuous variables. Comparisons used the Chi-Square test or Fisher’s exact test where appropriate for categorial variables, and Mann-Whitney test for continuous variables. Relative Risk (RR) with 95% Confidence Interval was presented for significant criteria (period 2 compared with period 1). A *P*-value of less than 0.05 was considered to be statistically significant.

RESULTS

Between February 2014 and February 2015, 40 simulation-based training sessions were organised for 164 healthcare professionals (19 surgeons, 22 residents in surgery, 30 nurses, 28 anaesthetists, 33 residents in anaesthesia, 21 nurse anaesthetists, 11 others), representing 32% of the entire workforce employed in these OTs. Several of these professionals performed more than one session to complete teams. Surgical teams included typically one senior surgeon, one resident, and one circulating nurse. Anaesthesia teams included typically one senior anaesthetist and one resident or one nurse anaesthetist. The “Haemorrhage” scenario was performed 14 times, the “Identity mismatch” scenario 14 times, and the “Latex anaphylaxis” scenario 12 times.

Audited surgical procedures (Table 1)

Two hundred fifty-nine surgical procedures were drawn in order to be representative of the actual distribution of surgical procedures in our centre. Six surgical procedures were excluded because they involved patients aged less than 18 years old. Distribution and main characteristics of the surgical procedures, risk factors and severity scores were not significantly different between the 2 periods. General anaesthesia was significantly more frequently used in period 1 compared with period 2.

Communication episodes and disruptive factors (Table 2)

In total, 46 970 communication episodes were analysed during the two periods. The number of communication episodes per procedure and per hour were significantly lower in period 2 than in period 1 within surgical or anaesthesia teams and between teams. Disruptive factors during the surgical procedure were significantly more frequent in period 2 compared to period 1 (53% and 38%, respectively; $P < 0.01$).

Communication failures with consequences (Table 3)

Among the 46 970 communication episodes analysed through the two periods, 232 (0.5%) communication failures with consequences were reported. The rate of communication failures with consequences was significantly higher in period 2 than in period 1. Among the 253 procedures, 102 (40%) with at least one communication failure with consequences were identified. The rate of surgical procedures with at least one communication failure with consequences was not significantly different between the period 1 and the period 2 (primary endpoint) (38% and 43%, respectively; $P = 0.47$). However, among procedures without disruptive factors, the rate of procedures with at least one communication failure associated with consequences was lower in period 2 as compared with period 1. In both periods, the rate of communication failures with consequences was significantly higher when disruptive factors occurred as compared to procedures in which they did not interfere. However, when disruptive factors occurred, the rate of communication failures with consequences was higher in period 2 compared with period 1. When no disruptive factors were reported, there was no significant difference. The type of consequences related with communication failures are reported in **Appendix 4**.

Communication failures (Table 4)

During both periods, 11 985 communication failures were identified, representing 26% of communication episodes. The communication failures were 7192 "Communication episodes related to another patient", 3274 "Communication episodes on a non-professional topic", 734 "Ambiguous communication episodes", 422 "Incomplete communication episodes", 249 "Communication episodes in a wrong timing", and 114 "Communication episodes with the wrong audience". The rate of communication failures was higher in period 1 than in period 2. The median rate of communication failures per hour of surgical procedure also decreased

between period 1 and period 2. The proportion of procedures with reported disruptive factors was significantly higher in period 2 than in period 1.

Teamwork assessment and leadership (Table 5)

Median teamwork scores significantly improved between periods 1 and 2. This improvement was mainly supported by the 'Respect' item. A leader was clearly identified by the team in a higher proportion of procedures in period 2 than in period 1. Importantly, the median teamwork score was higher in teams with a clearly identified leader than in others but not significantly different between periods 1 and 2.

Checklist

The French patient safety checklist includes 23 items (9 for T1, 9 for T2 and 5 for T3). Aloud reading was observed in 17.4% of cases during period 1 and 43.5% of cases during period 2 ($P < 0.01$). Adherence to checklist improved significantly for all OTs and for T1, T2 and T3 ($P < 0.01$; $P = 0.02$; $P = 0.03$).

Safety Culture

A French translation of the Hospital Survey on Patient Safety Culture was sent to all healthcare professionals working in the OT during period 1 ($n = 516$) and period 2 ($n = 549$). The proportion of audited professionals was 38.3% of the whole workforce. The response rates were 62% and 56% respectively. The rate of positive response ("agree" and "strongly agree" for positive questions, disagree" and "strongly disagree" for negative questions) ranged from 17% to 59% for the 12 dimensions explored. The rate of positive response did not improve between periods 1 and 2. The rate of positive response was significantly higher for physicians than for other healthcare professionals. Among the 305 professionals audited during the

period 2, 117 were involved in the simulation-based program. Rates of positive response were not significantly different.

DISCUSSION

The hypothesis of this study was that a large program, managed over several months and including an interprofessional training course would improve various aspects of safety culture in the OT. The impact of our program appears to be real but relatively modest, as we failed to show an effect of our intervention in the primary outcome (rate of procedures with at least one communication failure associated with consequences). Nevertheless, this study shows that a program on safety culture including a simulation-based curriculum applied to large teams has a positive impact: reduction of communication failures, improved teamwork scores, better leadership designation and safety checklist adherence.

Consequences of communication failure in the OT

An extensive literature reports on the importance of communication, teamwork, and leadership to prevent adverse events in complex procedures [6]. Team interactions are persistently disrupted by several issues: lack of communication, role confusion, tension, ineffective teamwork, lack or confusion in leadership, differences in values, hierarchical structure [18].

A recent study showed that failures in communication in the OR contribute to patient harm emphasising that multidisciplinary training should be part of the continuous professional development [19, 20]. The authors describe different types of communication failure and propose several techniques to improve communication in the OT [20]. An important point

they emphasise is that any tool will not work until it is actually used and used correctly. Culture and engagement of all members of the team are essential.

Methodology and assessment of quality improvement initiatives

Assessing quality improvement initiatives in the workplace is not easy and the choice of our primary endpoint can be discussed. Furthermore, a 50% reduction in the occurrence of such a negative outcome as “Communication failures with consequences” was very optimistic and difficult to reach. The purpose of using a mixed methods approach combining qualitative and quantitative evaluation criteria was to try to assess a clinically meaningful impact on daily practice.

We also considered a selective view of leadership, as unique and clear, that is quite reductive and probably not the best for complex multidisciplinary care, where leadership is often shared and dynamic depending on the task at hand. Nevertheless, this restrictive definition is the easiest and most objective to evaluate often reported in the literature [22].

Simulation-based programs demonstrated positive feedback and some evidence related to transfer of NTS to the workplace or patients benefit [9, 24]. Other studies have shown improvement in the perception of team efficiency and actual clinical performance [23]. The feasibility of these methods has been validated in the OT [25, 26]. However, there is limited evidence showing the efficacy of such programs in improving professional behaviour [27, 28].

Limitations

Professional interactions in the OT are likely to be a complex system in which several factors such as unexpected events and disruptions also impact the communication process and the way to measure it. The proportion of disruptive factors reported during the surgical

procedures was significantly greater during the second period. This may have negatively affected the communication failures rates during the second period. Other factors may then have contributed to the observed changes such as the Hawthorne effect [29].

Alternatively, we can postulate that training of one or more healthcare professionals is sufficient to improve the safety culture of the entire team. The whole study was performed in the same theatres, with the same distribution of surgical specialties representative of the usual activity. However, the entire study lasted 18 months. During this period, significant changes in management and organisation of the OTs might have modified not only the environment but also the working rules and confidence of the teams. Among these changes, it must be noted that a significant turnover in healthcare professionals occurred, resulting in integration of younger professionals. This might have diluted the effect of the program. Professional turnover can be considered as a confounding factor. It represents an intrinsic part of the normal functioning of an operating theatre that contributes to the difficulties of demonstrating the impact of an educational program on a whole team. Since 32% of the entire workforce employed in the OTs participated in the simulation-based training sessions, this suggests that statistically at least one member of each team observed had been involved in the educational program. When it comes to disseminating a cultural change within a team, it is likely that new arriving members gradually integrate the safety culture.

The program was prepared with multiple sessions of information among teams with flyers and face to face discussions. However, despite its magnitude, each participant and team participated to the simulation sessions only during half a day. This may not be sufficient to really change their behaviour and safety culture. Indeed, the effectiveness of an interprofessional education program may also not be efficient in changing behaviour and outcomes. A Cochrane review evaluated the effectiveness of interprofessional education

programs [30]. Seven studies reported positive outcomes for healthcare processes or patient outcomes, four studies reported mixed outcomes (positive and neutral) and four reported no effects of interprofessional education programs.

Concerning data collection, eight observers were specially trained for this purpose. Reproducibility tests at the beginning and later on were satisfactory, but a trend toward more severe interpretation may have flawed the results. Indeed, observers gaining experience could have modified their assessment as they experienced the implications of communication issues. However, data collected are multifaceted, not exclusively provided by the observers and are consistent with the general figure of a positive but modest impact of the intervention.

The anaesthetic procedures were significantly different between the two periods and the proportion of general anaesthesia was significantly higher during period 1. This could have impacted behaviours of healthcare professionals.

We also used the same generic tools for surgical specialties although each might have a specific safety culture. Indeed, communication failures can differ across surgical specialties and surgical procedures depending on their sensitivity to communication and teamwork issues [31].

Finally, the results of the French version of the HSPSC survey showed low scores as compared with the initial survey [16]. These results may be explained by differences in education and perception with foreign standards. This can also be explained by an insufficiently powerful intervention. A program reaching a larger number of professionals could have produced a measurable change in safety culture.

CONCLUSION

This study showed that a large simulation based interprofessional program focused on NTS was associated with a positive effect on communication failure, teamwork, leadership, checklist adherence and culture of safety despite it failed in significantly reduce the rate of consequences related to communication failures. This reflects the difficulty in highlighting the impact of training programs on patient's outcome and the relevance of trying to achieve evidence of behavioural impact for an educational program. The originality of this study was the use of multiple mixed-methods approach to evaluate the intervention. Improving safety culture cannot only rely on an educational program, since several of these components are related to management, organisation, history, and past professional experience. Changing the safety culture needs an institutional support integrating organisational and managerial considerations.

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Table 1: Audited surgical procedures

Total procedures n	Period 1	Period 2	P-value
Surgical procedures n (%)			
Surgical teams and operating theatres			1.000
Ophthalmology	23 (18%)	17 (14%)	
Hand surgery	18 (14%)	18 (15%)	
Plastic surgery	14 (11%)	13 (11%)	
Urgent surgery	11 (8%)	11 (9%)	
Orthopaedic surgery	11 (8%)	10 (8%)	
Vascular/Thoracic	10 (8%)	10 (8%)	
Urology	10 (8%)	10 (8%)	
ENT	10 (8%)	9 (7%)	
GI surgery	9 (7%)	9 (7%)	
Cardiac	9 (7%)	9 (7%)	
Neurovascular procedures	6 (5%)	6 (5%)	
Duration	128 [90 to 183]	115 [80 to 165]	0.216
< 1 hour	13 (10%)	16 (13%)	0.435
1-2 hours	51 (39%)	53 (43%)	
> 2 hours	67 (51%)	53 (43%)	
Anaesthesia			
General	112 (85%)	86 (70%)	0.002
Sedation	11 (9%)	19 (16%)	0.077
Regional	6 (5%)	31 (26%)	< 0.01
Patients			
ASA 1-2	98 (75%)	84 (69%)	0.292
ASA 3-4	33 (25%)	38 (31%)	
Lee score 0-1-2	129 (99%)	117 (96%)	0.110
Lee score 3	1 (1%)	5 (4%)	
Surgical Apgar 7-10	104 (80%)	92 (77%)	0.522
Surgical Apgar 0-6	26 (20%)	28 (23%)	
Low-risk situations*	83 (64%)	73 (60%)	0.512
High-risk situations	47 (36%)	49 (40%)	

Data are presented as absolute number (percentage), or as median [interquartile range]. *P* values refer to comparative analyses between periods 1 and 2.

ASA: American Society of Anesthesiologists physical status score; Lee* At least one high risk score (ASA, Lee score, Surgical APGAR).

Table 2: Communications and disruptive factors

	Period 1	Period 2	P-value
Communications	28 303	18 667	
Within the surgical team	15 113 (53%)	9932 (53%)	< 0.01
Within the anaesthesia team	6954 (25%)	4202 (23%)	< 0.01
Between teams	6236 (22%)	4533 (24%)	< 0.01
T1	10 729 (38%)	3934 (21%)	< 0.01
T2	11 714 (41%)	11 477 (62%)	< 0.01
T3	5860 (21%)	3256 (17%)	< 0.01
Communications/procedure	185 [117 to 303]	107 [77 to 173]	< 0.01
Within the surgical team	93 [64 to 160]	54 [39 to 98]	< 0.01
Within the anaesthesia team	40 [25 to 73]	27 [14 to 43]	< 0.01
Between teams	33 [21 to 60]	23 [17 to 40]	< 0.01
T1	71 [42 to 110]	26 [17 to 37]	< 0.01
T2	73 [33 to 131]	65 [42 to 101]	0.917
T3	37 [23 to 59]	20 [12 to 32]	< 0.01
< 1 hour	82 [64 to 112]	67 [46 to 84]	0.069
1 – 2 hours	134 [92 to 168]	97 [70 to 125]	< 0.01
> 2 hours	284 [197 to 381]	173 [120 to 296]	< 0.01
Communications/hour	91 [72 to 115]	62 [49 to 85]	< 0.01
Disruptive factors during procedure	10631 (38%)	9812 (53%)	< 0.01

Data are presented as absolute number (percentage), or as median [interquartile range]. P values refer to comparison between Period 1 vs. Period 2.

T1: Before induction of anaesthesia

T2: Before skin incision

T3: Before patient lives operating theatre

Table 3: Communication failures with consequences

	Period 1 (n = 28 303)	Period 2 (n = 18 667)	P-value
Communication failures with consequences n (%)	106 (0.37%)	126 (0.68%)	< 0.01
Within surgical team n (%)	57 (0.38%)	69 (0.69%)	< 0.01
Within anaesthesia team n (%)	20 (0.29%)	15 (0.36%)	0.527
Between teams n (%)	29 (0.47%)	42 (0.93%)	< 0.01
T1 n (%)	55 (0.51%)	33 (1.06%)	< 0.01
T2 n (%)	36 (0.31%)	73 (0.64%)	< 0.01
T3 n (%)	15 (0.26%)	20 (0.61%)	< 0.01
Procedure with disruptive factors	58 (0.21%)	90 (0.48%)	< 0.01
< 1 hour	23 [18 to 28]	19 [13 to 26]	0.245
1 – 2 hours	36 [25 to 53]	23 [16 to 31]	< 0.01
> 2 hours	81 [52 to 107]	35 [24 to 58]	< 0.01
	Period 1 (n = 131)	Period 2 (n = 122)	
Procedures with at least 1 communication failure with consequences	50 (38%)	52 (43%)	0.470
Within surgical team	31 (24%)	37 (30%)	0.232
Within anaesthesia team	14 (11%)	11 (9%)	0.656
Between teams	20 (15%)	23 (19%)	0.448
T1	29 (22%)	21 (17%)	0.326
T2	21 (16%)	36 (30%)	0.010
T3	13 (10%)	15 (12%)	0.548
Procedure with disruptive factors	24 (55%)	37 (64%)	0.345
< 1 hour	2 (15%)	3 (19%)	0.811
1 – 2 hours	13 (26%)	17 (32%)	0.459
> 2 hours	35 (52%)	32 (60%)	0.373

Data are presented as absolute number (percentage), or as median [interquartile range]. P values refer to comparison between Period 1 vs. Period 2.

T1: Before induction of anaesthesia

T2: Before skin incision

T3: Before patient lives operating theatre

Table 4: Communication failures

	Period 1	Period 2	<i>P</i> -value
All communications n	28 303	18 667	
Communication failures n (% all communications)	8117 (29%)	3868 (21%)	< 0.01
Within surgical team	4002 (14%)	1962 (11%)	< 0.01
Within anaesthesia team	2221 (8%)	879 (5%)	< 0.01
Between teams	1894 (7%)	122 (1%)	< 0.01
T1	2907 (10%)	797 (4%)	< 0.01
T2	3176 (11%)	2207 (12%)	0.045
T3	2034 (7%)	864 (5%)	< 0.01
Surgical procedures (n)	Period 1 (131)	Period 2 (122)	
Rate of communication failures			
Per procedure			
n	50 [31 to 85]	27 [18 to 39]	< 0.01
%	29% [23 to 35]	22% [17 to 28]	< 0.01
Per hour of procedure			
n	26 [18 to 35]	14 [9 to 21]	< 0.01
Procedures with at least 1 communication failure			
Within surgical team	131 (100%)	122 (100%)	-
Within anaesthesia team	126 (96%)	118 (97%)	1.000
Between teams	129 (99%)	116 (95%)	0.160
T1	130 (99%)	118 (97%)	0.199
T2	128 (98%)	122 (100%)	0.248
T3	127 (97.0%)	116 (95%)	0.529
Procedures with disruptive factors	44 (34%)	58 (48%)	0.024
< 1 hour	13 (10%)	16 (13%)	0.426
1 – 2 hours	51 (39%)	53 (43%)	0.466
> 2 hours	67 (51%)	53 (43%)	0.220

Data are presented as absolute number (percentage), or as median [interquartile range]. *P* values refer to comparison between Period 1 vs. Period 2.

T1: Before induction of anaesthesia

T2: Before skin incision

T3: Before patient lives operating theatre

Table 5: Teamwork assessment and leadership

	Period 1 (n = 131)	Period 2 (n = 122)	P-value
Global teamwork scores	8.1 [7.2 to 8.7]	8.6 [8 to 9.2]	< 0.01
Team preparation	7.7 [6.3 to 9]	8 [6.5 to 9]	0.29
Information sharing	8.7 [7.5 to 9.3]	8.8 [7.7 to 9.3]	0.34
Free expression	9 [8 to 9.5]	9.3 [8.3 to 9.8]	0.02
Respect	6.8 [5 to 8.3]	8.3 [7.5 to 9.3]	< 0.01
Trust in the team	9.3 [8.5 to 10]	9.6 [9.3 to 10]	0.02
	Period 1 (n = 131)	Period 2 (n = 122)	P-value
Leadership score > 5 n (%)	104 (79.4%)	112 (91.8%)	0.01
Distribution of the designated leader n (%)			
Surgeon	186 (79%)	246 (85%)	
Resident in surgery	140 (4.2%)	4 (1.3%)	
Anaesthetist	30 (13%)	21 (7%)	
Resident in anaesthesia	2 (0.8%)	2 (0.7%)	
Nurse anaesthetist	1 (0.5%)	6 (2%)	
OT nurse	6 (2.5%)	12 (4%)	

Data are presented as median [interquartile range], or as absolute number (percentage). P values refer to comparison between Period 1 vs. Period 2.